CONFLICT AND RECONCILIATION BETWEEN ARCHITECTURAL HERITAGE VALUES AND ENERGY SUSTAINABILITY

A Case Study of Xidi Village, Anhui Province

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Abstract. Energy consumption in buildings has increased dramatically over the last decade due to population growth, increased demands for indoor environmental quality, and global climate change, resulting in a growing awareness of the importance of sustainable development. Amongst many cases, architectural heritage faces a unique challenge in striking the delicate balance between its value and energy sustainability. The key aim of this paper is to reconcile the impact of sustainable design interventions with the values of architectural heritage by proposing a pragmatic and site-sensitive design approach. This article uses the case of the village of Xidi to simulate the energy consumption of traditional South-eastern Chinese residential buildings using the Designer’s Simulation Toolkit (DeST) considering different design options. The material selections and simulation results are further analysed by considering essential heritage building conservation documents and charters to accommodate the need for reducing energy consumption without compromising the value of heritage buildings.

Keywords. Architectural Heritage; Energy Consumption; Designer’s Simulation Toolkit; DeST; Xidi Village; Huizhou; SDG 11.

1. Introduction

Huizhou, an ancient region of China, is located near the Xin’an riverbank at the base of the Huangshan Mountains in southern Anhui Province, and its characteristic buildings represent one of the pivotal styles in traditional Chinese architecture. Their recognisability relies in the use of such characteristic elements as grey and black tiles and white walls, as well as in having four dwellings enclosed in a courtyard forming a patio (Figure 1). Within this context, this article focuses on the village of Xidi due to its recognition by United Nations Educational, Scientific and Cultural Organization.
and listing in the World Heritage List in 2000.

In recent years, most research on Huizhou architecture has focused on the sustainability of energy consumption, aesthetic features, and culture of traditional Huizhou architecture (Sun & Guan 2012; Lu 2016). What emerges from this research is the focus on experimental testing, preferring to quantitatively analyse the impact of building energy sustainability, without however connecting the sustainability of energy consumption with the sustainability of historical values. In this paper, the issue of sustainability is considered based on its twofold context: on the one hand, it refers to the issue of energy consumption, and on the other hand, it evaluates the sustainability of heritage as a resource to be preserved for the future generations. How to reconcile these two aspects is the core argument of this paper. Firstly, the paper discusses architectural heritage values and energy sustainability in the context of the village Xidi, and it proposes a theoretical framework for interventions through the analysis of key literature, legislation, and charters related to both fields. Based on this discussion, existing problems related to the value and the meaning of the buildings, to the environmental sustainability, and to the needs of the present users have been discussed through a series of online interviews. Possible interventions, identified as possible solutions to these problems, have been thus simulated and discussed against their feasibility both in relation to their efficiency and respect of the material and cultural values of the buildings. The aim of this approach is to use digital simulations to plan heritage renovation without harming the buildings’ value and to provide a reference for similar sustainable renovation projects.

2. Research Framework

This research establishes a theoretical framework by investigating key academic literature, charters, and legislation documents, suggesting a series of principles that a sustainable renovation project should practise. Secondly, through site investigation, the problems of Xidi residential buildings are identified and proposed renovation strategies are tested and verified through digital simulation (Figure 2). This research is based on a design-oriented simulation system, Designer’s Simulation Toolkit 2.0 (abbreviated as “DeST”) with the latest updates (9th of July 2021 release). DeST can be used to simulate and analyse building energy consumption and HVAC (heating, ventilation and air conditioning) systems, as it aims to improve the reliability of system design, to ensure the quality of system performance, and to reduce the energy
consumption of buildings (Yan et al., 2008). This paper uses DeST to simulate the year-round energy consumption of a typical building in Xidi village to optimise passive strategies and provide support for subsequent construction.

3. Theoretical Framework

3.1. SUSTAINABILITY OF ARCHITECTURAL HERITAGE

The core issue of this paper is how to reconcile sustainability in terms of energy consumption in buildings with sustainability in terms of architectural heritage. It is difficult to discuss architectural heritage without reference to one word: authenticity. This is one of the key criteria for eligibility for listing as a World Heritage Site, and this article discusses the conflict and reconciliation between the authenticity of buildings and the sustainability of buildings’ energy consumption. As one of the key concepts of the Venice Charter (1964, p. 1) for the conservation of architectural heritage, authenticity appears for the first time in a dignified way in the first paragraph of the text. “People are becoming more and more conscious of the unity of human values and regard ancient monuments as a common heritage. The common responsibility to safeguard them for future generations is recognized. It is our duty to hand them on in the full richness of their authenticity”. Based on the Venice Charter, the World Heritage Committee developed subsequently the Nara Document on Authenticity (1994) which declares for the first time the sources of information for authenticity, which include: form and design, materials and substance, use and function, traditions and techniques, location and setting, spirit and feeling, and other internal and external factors. These can be clearly related to the values recognised in the document nominating Xidi as a World Heritage Site, stating “Xidi and Hongcun have faithfully preserved the typical elements of a former traditional village, including the surroundings, the man-made waterways, the layout of the village, the architectural style, the decorative arts, the building methods and materials, the traditional techniques and the overall appearance of the village” (2000, p. 10). In this sense, the value of this village lies not only in the style and historical aspects, but also as a testimony of the use of materials and craftsmanship, pointing to potential problems when dealing with new interventions.

3.2. SUSTAINABILITY OF ARCHITECTURAL ENERGY

In the report of the World Commission on the Environment and Development, United Nations Brundtland Commission (1987) defined “sustainability” as meeting the needs
of the present without compromising the ability of the future generations to meet their own needs. Similarly, Charles Kebert stated in 1994 that sustainable building is the creation and responsible management of a healthy built environment based on resource efficient and ecological principles. Emerging from these definitions, one understands clearly that sustainable architecture intends to minimise the negative impact of buildings on the environment through the efficient and proportionate use of materials, energy and the ecosystem as a whole, and to adopt a conscious approach to energy and ecological conservation in the design of the built environment. An approach, which is a different field could be compared to the concept of “preservation for future generations” mentioned in the Venice Charter.

4. Conflict and Reconciliation

That said, heritage protection and sustainable architecture, as different focuses in the field of architecture, would require finding the right balance between reaping the benefits of a sustainable building and altering architectural heritage. Consequences of energy efficiency interventions, when applied inappropriately and with no understanding of heritage, can easily damage not only meaning, value, and stability of the buildings, but also users’ health, and eventually, they could fail to achieve the desired savings or reduction of the environmental impact (Historic England, 2018). Achieving the balance and avoiding unintended consequences requires a multitude of considerations, but it would be important to focus here on two key aspects of the context of the village of Xidi: the needs of the present-day residents and the use of specific materials.

4.1. RESPECTING THE RIGHTS OF RESIDENTS

When regenerating heritage buildings, which are still in use, the comfort of the original inhabitants and the “vitality” of the heritage building need to be respected. Already in 1931, the Athens Charter states that the conservation of heritage buildings should not compromise the inhabitants’ rights to a healthy living environment. In any case, the value of heritage must not override the interests of the living environment, which is directly related to the welfare and physical and mental health of the individual. The treaties mentioned above indicate that the habitability of buildings is also part of the conservation of architectural heritage. The Washington Charter (1987) also emphasises the inseparable relationship between historic cities or regions and those who inhabit them, suggesting that new functions and activities should be adapted to the characteristics of historic towns and urban areas. It has been also claimed that the living environment of their inhabitants is a priority in the conservation of historic cities or regions, while many existing and potential uses of the World Heritage sites can contribute to the quality of life of the communities (International Council on Monuments and Sites, 1964). Similarly, the Machu Picchu Charter (1977) states that conservation, renovation, and reuse of existing heritage sites and architecture should be integrated into the urban development process in order to ensure the economic significance and continued viability of these objects. Keeping these buildings vibrant means to optimise the living environment for the residents. As a result, in contrast to uninhabited buildings, heritage-protected dwellings and villages are concerned both
with the cultural values and the importance of the living environment for the inhabitants. In addition, new interventions would need to consider not only conservation-based approaches, but also regeneration and development: the primary function of a building is to be used and inhabited.

4.2. USE OF IDENTICAL, LOW-IMPACT, REMOVABLE MATERIALS

Regeneration with the same materials as the original building is also a way of reducing damage to the heritage value of the building. Alterations must impact the existing forms and materials as little as possible, whether dealing with regeneration of an isolated building or of an entire village. Choosing those technical measures that do not compromise the authenticity of heritage or are demountable, low-impact, and easily recognisable (as suggested by the Venice Charter) could be therefore a possible solution. For example, in the Hoi An Declaration (2003), it is suggested that new materials with the same or lower strength and hardness than the original ones should be used in the renovation and conservation of old buildings. However, whereas the very ideas of removability and different characteristics of materials are appealing when dealing with the importance of heritage, such solutions need to be assessed also from the point of view of sustainability.

5. Present-day Issues in Xidi

The current research on building energy consumption in Xidi is aligned with the general research in Huizhou buildings. It focuses mainly on summer insulation, patio lighting, window lighting, and winter weather resistance. These issues are also aligned with the problems pointed by the present-day inhabitants. A series of six online interviews about the satisfaction of the living environment in Xidi were conducted with local residents. The interviews include the candidates’ personal information, average time spent indoors per day, available room area, frequency of window ventilation per day, satisfaction with indoor temperature, satisfaction with indoor humidity, satisfaction with lighting, satisfaction with air quality and satisfaction with noise. The results indicated that all of the candidates indicated that the room temperature was too low in winter. Since the area is not in the far north of China, only few contemporary buildings in Anhui Province are equipped with heating devices, and the very layout of the dwellings in Xidi favours flow of cool air in the winter, mainly due to the additional airflow from the patio. In addition, four of the residents indicated that the indoor temperature of the building was also too high in summer, and that cooling equipment was used to achieve a more comfortable indoor environment, making effective insulation an important issue to be solved, which is discussed later.

Furthermore, half of the residents indicated that rooms were insufficiently illuminated, and this problem is also taken into account in the renovation measures. This issue is related to the patio-centred layout of the dwellings in Xidi, most of which are very similar, even though buildings have some minor differences. Amongst these, some typical layouts became prototypes for others, as a number of studies already summarise (Lv, 2005; Zhang et al., 2013; Che, 2015). According to them, most of dwellings in Xidi can be formed from two basic architectural layouts through a number of combinations, which has led to modelling the two combinations in DeST (Figure 3).
These models follow a similar pattern, where the patio remains the central part of a house. Based on the above, a renovation method is proposed for the Xidi residence, in order to meet the needs of local residents: the installation of a shading structure on the patio that can be opened or closed (Figure 4).

Figure 3. Left: Typical layout 1; Right: Typical layout 2

Figure 4. A possible renovation measure: the addition of removable shelters on the patio to keep the room warm in winter

6. Simulation Result and Discussion

This modelling process included adding the following data to the simulation: geographical location, building materials, opening sizes in order to evaluate the effects of ventilation, and heat generated by human activity in each room (which, accordingly with the sixth census of China in Anhui Province, has been set to the heat generated by 1-2 inhabitants). Furthermore, based on interviews with local residents, it has been assumed that the buildings’ users would turn on cooling or heating equipment when the room temperature makes them uncomfortable in order to save the electricity bill. Taking into account Anhui Province’s monsoon and subtropical monsoon climate, with the summer season from June to August and the winter season from November to January, it has been assumed that with the present-day situation, heating would be necessary on ninety days (2 hours per day) and cooling on ninety days (2 hours per day) throughout the year. For example, outdoor temperatures in Xidi range from -5°C to 16°C in the coldest months, with an average temperature of around 5°C (Figure 5), which is below the World Health Organisation’s standards for human habitable temperatures.
Within this context, the simulation process proceeded taking into account the concept of “vitality”, i.e. “the rights of residents with less damage to residential heritage buildings”, which have been previously mentioned. However, at the same time, it is worth noting that common measures, such as adding thermal insulation to walls or patios, cannot be considered due to the heritage value of the buildings and their typical “white-walled, black-tiled” character. Given that, the only insulation possibility could be adding such a layer to the roof.

During the interviews, the residents also mentioned adding glazing to the patio, which was in fact considered in the DeST. It would have increased the internal temperature control without impairing the already difficult natural sunlight access to the inhabitable areas of the dwellings. Indeed, based on the existing research, one of the more significant effects on thermal insulation is insulating glass, particularly low-e film insulating glass. Glass, insulated glass, and low-e film insulating glass were finally selected for testing and the data from the simulations are shown in Figure 6 to left of Figure 7. Besides, since the patios in Xidi are mostly wooden, based on the idea of using similar materials expressed before, it has been considered to install removable timber structures in the patio, using the same spruce timber as in the traditional local constructions (right of Figure 7) (1-N-2 is the patio room and 1-N-1, 1-N-3, 1-N-4 and 1-N-5 are the normal rooms).
According to these four comparison experiments, it can be demonstrated that the percentage of extreme temperatures (less than 16°C and more than 29°C) is the smallest of the three types of glass when using low-e film insulating glass. This situation is particularly noticeable in summer. Therefore, the installation of low-e film insulating glass is more effective than ordinary glass and insulated glass. Moreover, as shown in the right of Figure 8, the installation of timber is more effective than plain glass, insulated glass and low-e film insulating glass in summer. However, timber shading is the least effective in winter insulation, and one of the issues raised by the residents of Xidi is the lack of light and timber interferes with the lighting. As mentioned, one of the principles of reconciling architectural heritage values with energy sustainability is to respect the rights of the inhabitants, thus low-e film insulating glass considered to be more suitable for the dwellings. In order to manage the potential negative effects of low-e film insulating glass in summer, an additional removable shading could be provided (such as locally available dry bamboo canes), as well as regular ventilation by opening the windows could be advisable.

As the last part of this analysis, this paper simulates the thermal and cooling loads of a building with a typical Xidi layout equipped with low-e film insulating glass and without low-e film insulating glass (fifty times ventilation per hour) in order to demonstrate the positive impact of adding patio glass on building energy consumption (Figure 8 and Figure 9). By comparing these diagrams, it is clear that the installation of the low emissivity coating glass results in significant energy savings in the winter months in both typical layouts. This last piece of information is important as it suggests that such an intervention can have a broader application in a number of cases of dwellings, which – as stated before – follow a similar layout pattern or are modifications of these two basic plans.
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Figure 9. Typical layout 1 & 2, heat and cold loads in buildings after installation of low-e film insulating glass during one year

7. Conclusion

While this paper concentrates on Xidi as a case study for analysing how to effectively reduce energy consumption in heritage buildings, some of the conclusions here have broader implications. The basic theoretical framework discussed throughout the article stands as a valid common ground for a number of interventions, which engage in both fields – sustainability and heritage conservation. The issue of authenticity in relation to the present-day users and inhabitants stands as a core problem in all the buildings that are constantly and continuously used. The simulation results indicate that, albeit the timber is the most suitable option for this project in the summer, its insulation effect in winter is worse than the other three types of materials, and the principle of respecting the residents’ rights would be unattended due to the interfered lighting. Therefore, the low radiation coating glass option is suggested to be the most suitable solution for the patios renovation in houses in Xidi. It is important to note that the change of buildings’ layout had a relatively small impact on the overall simulation, while the change of materials was crucial. It leads to the important assumptions that the above simulation would remain valid in a number of other cases and that further research in sustainability would certainly benefit from the historical and cultural background, which would point to the typical and traditional solutions, which would help to draw the common ground for the possible interventions. Future work will require other cases to explore the relationship between other aspects of building energy efficiency and architectural heritage and develop rulemaking in procedural, systematic, and more in-depth simulations.

References


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