Research on the Design Methods for Green Renovation of Existing Buildings in Lingnan Region

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Abstract. China's urbanization has entered a new stage with the promotion of "Carbon Peaking and Carbon Neutrality Goals" and "Urban Renewal Strategy". Problems such as poor comfort, high energy consumption and unreasonable functions of existing buildings have attracted extensive attention from society. The climate-adapted human environment created by traditional buildings in the Lingnan region offers insights for the green transformation of buildings in this area. This paper summarizes the wisdom from the climate-adaptive construction of traditional buildings in Lingnan region, and proposes a green transformation design scheme that meets the requirements of energy efficiency and comfort, which provides a reference for the green renovation design of existing buildings.

1 Introduction

Since the reform and opening up for more than 40 years, China's urban development has gone through a transition from incremental development to stock renewal [1]. Urban planning research has also gone through the stages of "three old" renovation, shantytown renovation, old city improvement, old city renovation, and environmental improvement, and further into urban renewal, urban revitalization, urban redevelopment, and urban recovery [2-3].

The Second Session of China's 14th National People's Congress in 2024 emphasized the vigorous development of green and low-carbon economy, actively and steadily promoting Carbon Peaking and Carbon Neutrality Goals, and identified green and low-carbon development as one of the key tasks for the government work in 2024 [4]. The construction and operation of buildings account for a significant proportion of total energy consumption [5]. Currently, existing building area in China has exceeded 58 billion square meters, with new construction only account for 1% to 3% of all buildings each year. However, the area of green buildings in existing buildings is less than 1.5 billion square meters, accounting for less than 3% [6]. Existing buildings are mostly characterized by high energy consumption, high environmental burdens, and poor indoor environmental comfort due to technological limitations [7]. Green retrofitting of existing buildings is not only an important part of implementing the concept of sustainable development and achieving the "Carbon Peaking and Carbon Neutrality Goals", but also a practical measure to create livable cities and eco-friendly society [8].

China has a vast territory with diverse climatic types. The climate-adapted spaces created by traditional architecture in Lingnan region provide relatively comfortable and low-energy consumption environment for traditional societies. Drawing on experiences from traditional construction wisdom, this article reconstructs the relationship between space and climate based on the climatic characteristics of the Lingnan region, thereby achieving energy conservation and meeting people's needs for comfortable environment. Finally, using a renovation scheme for an existing building as an example, this article provides references for the green transformation design of existing buildings.

2 Distillation of traditional building wisdom

2.1 Traditional architectural forms

The Lingnan region refers to the area south of the Five Ridges in southern China, characterized by warm and humid climate with intense solar radiation. The traditional wisdom developed over a long history has effectively addressed the relationship between architecture and climate. From traditional villages to urban buildings and then to modern architecture, there is a complete development context and mature architectural forms, leaving behind valuable spatial design experiences including narrow alleys, arcades, and courtyards. By categorizing the spatial forms of traditional Lingnan architecture, three typical types of spaces can be identified: the "street lanes + inner courtyards" space in traditional villages, the "corridor + courtyard" space of bamboo tube houses in towns, and the "outer corridor" and "arcade" spaces in modern urban buildings (Table 1) [9]. By incorporating thermal buffer spaces in buildings and

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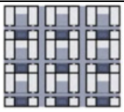
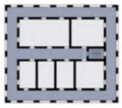
creating a symbiotic system with external spaces, this spatial approach not only improves indoor thermal environments but also reduces the use of air conditioning in hot climates, thus achieving low-carbon and energy-saving effects [10].

Table 1. Architectural forms in Lingnan in different periods [11].

Phase	Space forms	Primary function	Plan
Traditional villages	street lanes + inner courtyards	Ventilation, Shading, Control of heat radiation	
Bamboo House	corridor + courtyard	Control of indoor heat, ventilation organization and lighting	
Modern urban architecture	outer corridor arcade	Thermal buffer space creates indoor environmental comfort	

2.2 Renovation strategies

This study combines the traditional construction wisdom with modern architectural research and summarizes suitable design strategies for modern building renovations. The process of interaction between the artificial climate environment within buildings and the natural environment outside is essentially energy exchange. There are primarily three modes of heat transfer: conduction, convection, and radiation. The construction techniques employed in traditional Lingnan architecture essentially control heat transfer through spatial means, focusing on convection and radiation. On one hand, natural ventilation is organized to facilitate heat dissipation through convection, while on the other hand, measures are taken to minimize solar radiation, especially direct radiation. Therefore, for humid and hot regions like Lingnan, building renovations can start with the balance of heat prevention and ventilation, forming mutually coordinated spatial relationships (Table 2) [12].

Table 2. Main types and characteristics of traditional buildings in Lingnan region.

Main purpose	Space forms	Interface highlights	Position
Ventilation /energy guidance	courtyard inner corridor cold alley	Top or side interface penetration	Mostly located inside buildings
Sunshade / energy barrier	verandah arcade eavesdrop impregnated floor	Interface occlusion	Mostly on the periphery of the building

3 Case study

This paper takes a case study of the renovation of a certain building in the East Residential District of South China University of Technology (SCUT) as an example to explore green renovation techniques of existing buildings in the Lingnan region.

3.1 Overview

The building to be renovated in this paper is located in South China University of Technology (SCUT) East Residential District, which is a typical college unit compound-type old neighbourhood with a long history, and the buildings in the district were constructed from the 1950s to the 1990s, and the district is tree-lined, and the facilities are outdated. The district has an excellent location, being 300 meters away from the subway station, adjacent to universities to the north, and with a sports field to the west (Fig. 1). The building to be renovated is currently used as office space, with 2 floors above ground and a height of 6.69 meters. It occupies a total area of about 700 square meters, with a building area of 240 square meters. Due to its old design and lack of proper maintenance, the building has problems in ventilation, heat insulation, and shading, which urgently need to be improved.

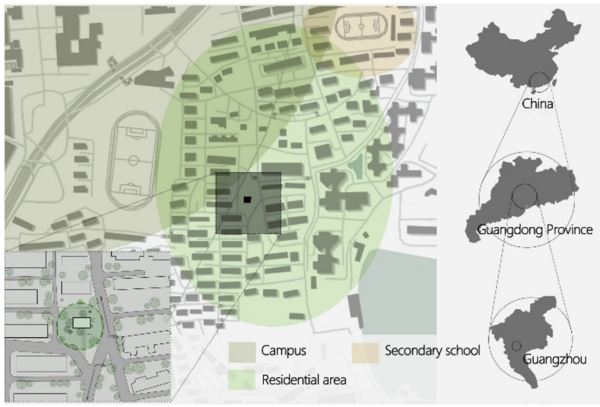


Fig. 1. Architectural forms in Lingnan in different periods.

3.2 Existing issues

There are many problems in the old building. In terms of ventilation, the main ventilation method of the building is through side windows, which are sliding windows with small opening area. The internal space is not interconnected, making it difficult to achieve comfortable indoor air circulation through a single horizontal ventilation direction. In terms of thermal insulation, the building's external windows lack insulation devices, and no curtains are installed indoors. In summer, strong solar radiation increases the energy consumption. Additionally, the building is located in the centre of the community, which results in high pedestrian traffic and poor privacy. Furthermore, there are leakage issues on the roof that urgently need maintenance and renovation. In terms of traffic organization, the vertical traffic within the building relies entirely on a narrow 0.9-meter-wide straight staircase in the centre, with solid walls on both sides, which is narrow and inconvenient (Fig. 2).

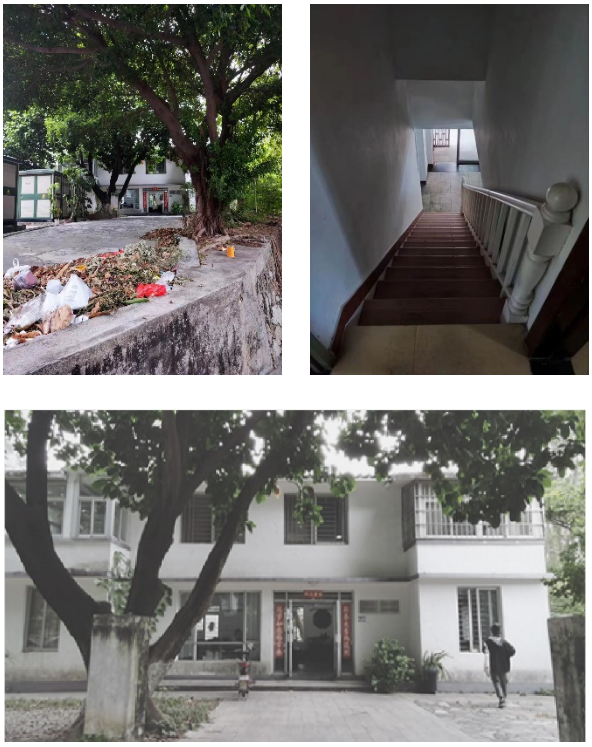


Fig. 2. Photos of the current state of the building.

3.3 Green Renovation

3.3.1Overview

The renovation of the building combines the original architectural style, the climatic conditions of the Lingnan region, and the design requirements for energy conservation. On one hand, the layout of site is optimized by setting up corridors and pool facing the dominant wind direction, so that the wind enters the building after being cooled through the water surface and shaded area, effectively regulating the microclimate. On the other hand, through the use of green walls, wide corridors, sun shields, and other techniques, a “thermal buffer zone” is created between the interior and exterior thermal environments, reducing direct solar heat and saving cooling energy consumption (Fig. 3).

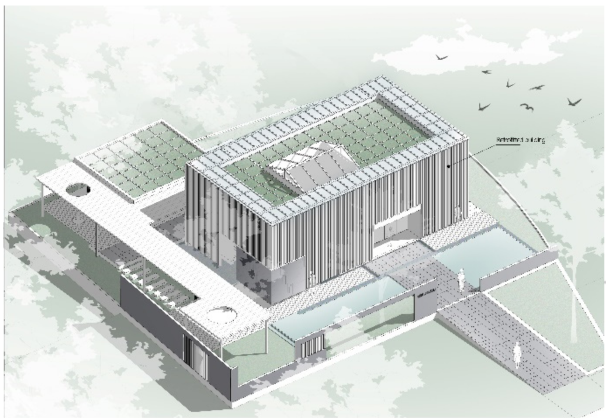
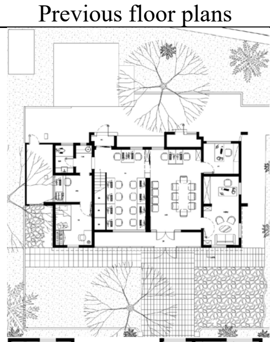
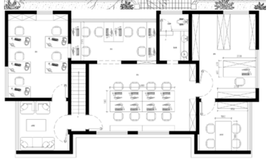
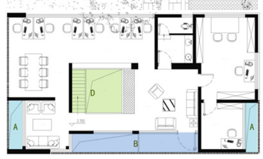


Fig. 3. Architectural bird's-eye view.

3.3.2 Architectural plans design

Due to low utilization of internal space and inconvenient vertical transportation inside the original building, it is necessary to redivide part of the indoor spaces. The first floor space removes the non-bearing walls to form a large indoor space that is open from north to south, and the centre of the space forms the Lingnan space type of "patio + inner courtyard" around the staircase. The entrance area of the building is recessed to create a "arcade" entrance space with self-shading properties, and the recessed area is utilized as a buffer zone, which serves as a rain shield and forms a good transition and connection with the outside environment (Table 3). The main functions of the first floor are open office, meeting room and management area, which is connected to the outdoor meeting room through the corridor. The second floor is for management office and data storage.

Table 3. Floor plan.

	Previous floor plans	New floor plan
1 F		
2 F		

Cold alleys and verandas
Driftboards and arcades
Outer corridors and open halls
Patio and inner courtyard

3.3.3 Optimization and utilization of light

Based on the existing windows of the original building, sunshade louvers are installed on the south side of the building to ensure daylighting needs and privacy while reducing solar radiation. The sunshade louvers can be adjusted according to the angle of the sun, achieving nearly complete shading when fully closed, blocking 60% to 80% of solar radiation, thus avoiding cooling energy consumption due to overheating. It optimizes the intensity of natural light transmission, reducing the energy consumption required for lighting. Additionally, modular solar power units are installed along the edges of the building roof to directly convert solar radiation into electricity. These modules can adjust angles with the changing sunlight, and are equipped with power conversion and storage devices at their base, which can enhance the thermal insulation efficiency while supplementing the required electricity and reducing the overall energy consumption of the building (Fig. 4).

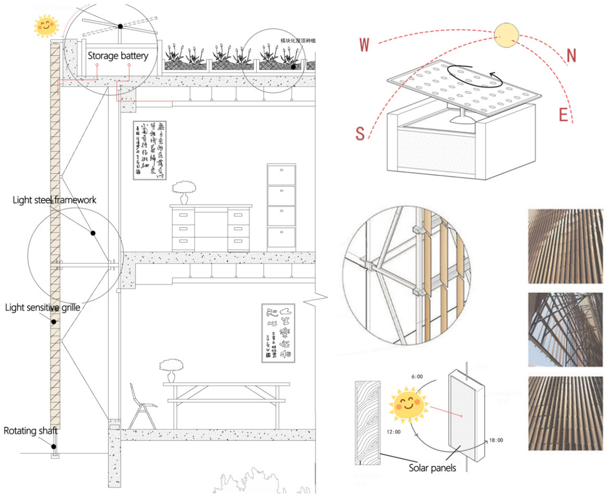


Fig. 4. Solar photovoltaic panels.

3.3.4 Optimization of wind

Drawing inspiration from the traditional arcade architecture in Lingnan region, the central part of the ground floor office area is open, allowing the southern breeze to enter from the outdoor water feature at the entrance. It flows through the arcade and lobby into the courtyard, creating a draught. In order to prevent heat buildup at the exterior doors, the entrance adopts the sacrifice of building area to form a setback area, which makes the building form self-shading. The setback area also forms a buffer zone, which serves as a rain shelter, while seamlessly connecting with the urban space. Interior small offices are divided by vertical wooden partitions to avoid obstructing airflow paths. The skylights creates a chimney effect, improving the indoor environment by utilizing natural ventilation (Fig. 5). This design aims to ensure indoor comfort without relying extensively on air conditioning systems, especially during transitional season.

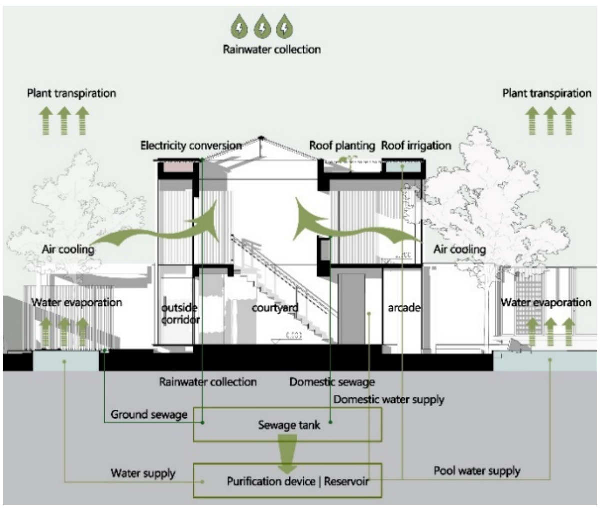


Fig. 5. Comprehensive utilization analysis diagram of wind, light and heat.

3.3.5 Optimization of thermal environment

Considering the issue of roof leakage and the characteristic of the Lingnan region where high temperatures and rainy periods overlap, the roof insulation adopts a water-retaining green roof system. Water tanks are installed at lower levels to collect rainwater from the roof, as well as domestic and air conditioning condensate water, for spraying on the roof. The water-retaining materials evaporate heat, thereby reducing the roof temperature and minimizing heat transfer through the roof. An intelligent control system is also set up for automatic control, so that when the surface temperature of the roof is too high, water spraying will be carried out automatically to reduce the temperature. To meet the demand for convenience, a modular roof system is adopted to facilitate production, installation, and subsequent maintenance.

The microclimate indoors can be regulated through green plants [13]. The scheme incorporates an ecological wall system based on plant walls, fans, and dehumidifying agents to reduce the use of air conditioning systems and regulate the thermal environment. By connecting pipeline equipment to the existing foundation pipeline, water flow circulation is achieved, preventing mosquito breeding. At the bottom of the ecological wall, an aquaponic system is utilized, nurturing ornamental fish and planting aquatic plants to establish a beneficial cycle (Fig. 6). The combination of water and greenery can effectively regulate temperature. Moreover, the introduction of natural elements into the work environment can effectively alleviate stress, oxygenate the air, foster a healthier working and social environment, and enhance work efficiency and sense of happiness.

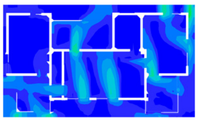
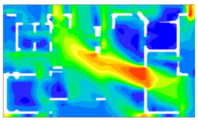
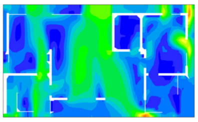
Fig. 6. Indoor green environment.

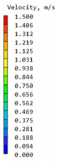
3.3.6 Numerical simulation

Numerical simulation with the software Phoenics can comprehensively, accurately and intuitively simulate the wind flow and heat distribution. Therefore, it becomes an important tool for assessing the wind speed and thermal environment in green building design, which is also the trend of the "digital" concept in information age.

In this study, the optimization effect of wind and thermal environments is further quantified through software simulation. This study sets the average summer temperature and prevailing wind direction in the Lingnan region as simulation parameters, and adopts the standard k-E low-speed turbulent model. The calculation domain is determined as the building area, with a grid spacing of 0.3m for calculations. The simulation is conducted for the building’s wind environment before and after renovation. The results reveal a significant improvement in wind speed inside the building after the renovation (Table 4).

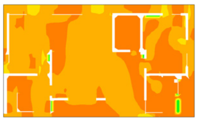
Table 4. Indoor wind speed.

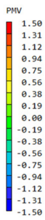
Phase	1F	2F
Before renovation		
After renovation		



The Predicted Mean Vote (PMV) evaluation model is one of the most authoritative methods for assessing thermal comfort in the environment, and PMV value closer to 0 indicates higher thermal comfort. The simulation results by Phoenics software reveal a significant improvement in the thermal environment of the building after renovation (Table 5).

Table 5. Indoor PMV.

Phase	1F	2F
Before renovation		
After renovation		



4 Conclusion

(1) This paper summarizes the wisdom in creating climate-adaptive traditional architecture in Lingnan region ("street lanes + inner courtyards", "corridor + courtyard", "outer corridor", "arcade") and presents design strategies for ventilation regulation and sunshade insulation.

(2) This study combines a case study of building renovation to promote indoor ventilation by means of skylights on the top of the atrium, outdoor water features, and the combination of the building entrance and internal space. The ventilation effect is verified and simulated using Phoenics software.

(3) In this study, the thermal environment of building is effectively improved by adding sunshades, adopting water-retaining green roofs, and implementing measures such as introducing green plants and water indoors, which is verified by simulation using Phoenics software.

(4) Through the design for existing buildings renovation in Lingnan region, this study creates a more beautiful, comfortable and energy-saving architectural space environment by combining the spatial layout and related green technology systematically while meeting the basic functional requirements. It provides references for the design for green renovation of existing buildings in Lingnan area, and effectively guides the practice of building renovation.

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