Study on the Suitability Technology System of Residential Green Building in Hot Summer and Warm Winter Zone

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Abstract. This paper introduces the key technologies of green two-star residential buildings in Hot Summer and Warm Winter Zone, as well as the green means adopted in the green construction stage, and focuses on the economic and social benefits brought by green building technology in the operation stage. The research content has certain reference significance for the technical selection and implementation of green building in this climate area.

1. Introduction
CECEP • Meijing Home is located in Nan'an City, Fujian Province, which the total area is 51,500m² and total construction area is 142,500m². The project obtained the Green Building Design Label certification in November 2013, and obtained the Green Building Label certification in December 2018. The project is residential building, which consists of 22~25 floors high-rise buildings.

2. Major technical measures
The theme of whole project construction is "green energy saving, low carbon and low energy consumption". The project was designed in conjunction with the local climate, reasonable choice of demonstration energy-saving technologies, localization of construction technology, comprehensive and systematic use of human settlements technology.

In the construction stage, the green building technology was implemented from the perspective of "four sections and one environmental protection". In the operation stage, the project achieves the whole life cycle, full cycle green operation. The project truly integrated green technology and ecological technology into residential building design.

2.1. Land saving and outdoor environment

2.1.1. Land use indicators. The total number of households is 708, and total number of people is 2266. Per capita residential land limit is 14.11 m²/person.

2.1.2. Community public service facilities. The project is surrounded by complete supporting service facilities, including kindergarten, Chenggang primary school, leaching middle school, Nan 'a hospital, sports center, post office, bank, etc. The residential area is equipped with business, property management, neighbourhood committee, community guard room, garbage collection point, etc.
2.1.3. Entrances and public transport. There are 4 entrances and 3 garage entrances in the project, which can achieve the purpose of human and vehicle diversion. Huanxi station is within walking 500m range around the community, and Xinhua Nan road station is within walking 800m range. There are no. 11, no. 22 and no. 27 buses passing by, which is convenient for residents to travel.

2.1.4. Landscaping. Landscape plants are mainly planted with native plants. The trees mainly include basin shelf, jacaranda, camphor, sheep hoof nail, banyan tree, beauty tree, chongyang wood, and yellow locust tree. The Shrubs mainly include quadrel, elderflower, blue maple chicken claw maple, golden leaf banyan tree column, cuckoo ball, etc. The main groundcover species are star anise golden disk, rhododendron maw and so on. There are 50 species of woody plants and 852 trees, which the average number of trees on the greenbelt area is 4.3/100 m2. Landscaping is shown in Figure 1.

![Figure 1. Photos of landscaping](image)

2.1.5. Underground space utilization. Underground space is reasonably developed and utilized, including generator room, equipment room and parking, etc. Underground construction area is 33896.9 m2, the ground construction area is 89312.27 m2, and the ratio of underground construction area and ground construction area is 37.95%.

2.2. Energy saving and utilization

2.2.1. Building energy saving design. This project is implemented in accordance with ‘Detailed rules for the implementation of energy conservation design standards for residential buildings in Fujian province’ (DBJ13-62-2004). Through the Energy saving design of building envelope such as exterior wall, windows and doors, roof and so on, after the calculation of thermal performance, all buildings in this project meet and exceed the specified energy conservation requirements.

| Building envelop e | 2 ~ 8 # building | 1# Passive building |
|--------------------|------------------|--------------------|
| External wall      | Aerated concrete block(200mm),K=1.54W/(m²•K),D=2.94W/(m²•K) | Aerated concrete block (200.0 mm) + polystyrene (100.0 mm),K=0.39W/(m²•K),D=3.63W/(m²•K) |
| | Extruded polystyrene sheet(25mm)+Reinforced concrete(100mm),K=0.97W/(m²•K),D=2.64W/(m²•K) | Extruded polystyrene board(100 mm) + reinforced concrete(100 mm),K=0.33W/(m²•K),D=2.88W/(m²•K) |
| Window             | Hollow glass(6+19A+6) | low-e insulating glass (5mm+6A+5mm+0.15v+5mm) |
2.2.2. Efficient equipment and systems. 1# passive residential buildings adopt indoor energy-saving air-conditioning unit with fresh air heat pump heat recovery. Outdoor fresh air is mixed with indoor return air after being treated by all-air unit and sent to each room. The energy efficiency ratio of the energy-saving unit is 4.6, which meet the requirement of level 2 energy efficiency ratio in ‘Unit air conditioning function limit and energy efficiency level’. The refrigeration of 2#~8# residential buildings adopts split air conditioning.

2.2.3. Energy-saving and efficient lighting. The lighting source of the project selects three primary colors, high luminous efficiency T8 thin tube diameter straight tube fluorescent lamp and LED indicator lamp respectively according to the plane function. The design reduces the installation height of the lamp as far as possible to save electric energy on the premise of meeting the minimum allowable installation height and aesthetic requirements of the lamp.

2.2.4. Solar hot water. This project is demonstration project of renewable energy building application in Quanzhou. 1# building adopts distributed vacuum tube solar water heating system. The collectors focus placed on the roof, which the area is 102 m². 2#~8# high-rise residential building adopts the balcony wall type flat panel solar energy hot water system. Each household decorate 2.4 m² plate collector in the balcony and arrange 100L water tank. The annual saving is RMB 248,900. Photos of solar panels is shown in Figure 2.

![Figure 2. Photos of solar panels](image1)

![Figure 3. Photos of water saving irrigation](image2)

2.3. Water saving and water resources utilization

2.3.1. Measures to avoid leakage of pipe network. The project adopted the water supply mode of constant pressure and variable frequency pneumatic water supply. The project also controlled the water inlet branch pipe pressure no more than 0.2mpa through reasonable partition and setting branch pipe pressure reducing valve to avoid leakage of pipe network.

2.3.2. Water saving irrigation. This project mainly used micro-sprinkling irrigation, and the water source was recycled rainwater. The sprinkler head adopted the buried rotary -6000 sprinkler head, with an effective range of 6.0m. Photos of water saving irrigation is shown in Figure 3.

2.3.3. Rainwater collection system. This project adopted the rainwater collection and treatment system, which mainly collected roof rainwater. The system set up 150 cubic meters rainwater pool, and the treatment technology of precipitation, quartz sand filtration and over-current ultraviolet disinfection was adopted to ensure the clarity and safety of water. When rainwater is not enough, it is supplied by the municipal water supply. Roof rainwater was collected and used for outdoor greening irrigation and road pouring after treatment. Annual rainwater consumption was 3951.56m³, total annual water consumption of the site was 113,127.45 m³, and unconventional water use ratio reached 3.5%.
2.4. Material saving and resource utilization

2.4.1. The use of high strength steel. The amount of HRB400 grade steel bars as the main reinforcement in the main structure of no.1 ~8# buildings is 9493.36t, and the amount of main reinforcement is 9782t. The proportion of HRB400 grade (or above) steel bars as the main reinforcement is 97.05%≥70%.

2.4.2. The use of recyclable materials. The recyclable materials of the project include steel, aluminium alloy profile, window glass and wood. The total weight of the building materials is 115,212.61t, and the weight of the recyclable materials is 119,799.57t. The proportion of the recyclable materials in the total building materials is 10.4%.

2.4.3. The use of waste materials. Three kinds of blocks are adopted in this project, including autoclaved fly ash brick (fly ash content 90%), autoclaved aerated concrete block (70% is industrial waste residues -- stone powder), and autoclaved porous fly ash brick (fly ash content 90%). They are all building materials produced with waste materials, accounting for 100% of similar building materials.

2.5. Indoor environmental quality

2.5.1. Improve indoor natural lighting. This project set up 12 light guide tubes with a diameter of 900mm around buildings 4, 5 and 6, which can improve the 10.39% indoor natural lighting of underground layer area. Photos of light tubes is shown in Figure 4.

2.5.2. Window ventilators improve natural indoor ventilation. The facade of each house is uniformly set with vents, which can effectively organize the indoor natural ventilation. The window ventilator is installed on the outer window of the living room, which can enhance the indoor natural ventilation and provide a quiet environment for the indoor environment. Photos of Window ventilator is shown in Figure 5.
2.5.3. **Adjustable outer shading.** In order to fully reduce the building energy consumption, the project adopt adjustable outer shading in the east, west and south direction. The ratio of controllable shading reaches 81.42%, which effectively reduces the energy consumption of indoor air conditioning. Photos of adjustable outer shading is shown in Figure 5.

2.5.4. **Indoor air quality testing.** In the operation stage, the indoor air quality of the project was tested, and the concentration of radon, ammonia, formaldehyde, benzene and TVOC all met the requirements.

2.5.5. **Sound insulation quality inspection for buildings.** In the operation stage, the sound insulation performance of the partition wall and floor board of this project is tested, and the sound insulation met the intermediate value requirement.

2.6. **Green construction management**

2.6.1. **Green construction. environmental protection.** In the aspect of noise pollution control, the construction noise is monitored by selecting low-noise equipment and taking measures to reduce vibration and noise. In the light pollution control, avoiding night construction. If night construction is inevitable, paying attention to avoid the light shining into the surrounding residential buildings. The construction waste on site shall be classified, placed, regularly cleared and transported, and effectively recycled. Drainage in the construction process, drainage pollution detection is carried out irregularly, and the ph meets the requirements.

2.6.2. **Green construction. waste management.** Scrap steel, formwork, cement bags, wires and cables are collected and recycled. By the calculation, the recycling of construction waste recovery of 82.36%, per 10000 m2 building area construction solid waste emissions by 35.71 t. Photos of waste collection is shown in Figure 6.

![Figure 6. Photos of waste collection](image6.png)

![Figure 7. Photos of saving electricity and water during construction](image7.png)

2.6.3. **Save construction energy and water.** Energy-saving construction equipment shall be used in the construction. Through regular power consumption calculation and contrast analysis, the project total power consumption of 644411 KWH, unit building area is 4.52 KWH / m2. Collect domestic water and rainwater for toilet flushing in the construction living area, saving 10% of domestic water per month. The whole construction process, engineering water consumption of 40699 tons, unit building area is 0.29 t / m2. Photos of saving electricity and water during construction is shown in Figure 7.

2.6.4. **Reduce construction loss.** In the construction site, reduce the loss of concrete and steel bar through reasonable process arrangement. According to the statistics, the concrete loss rate of premix is 0.93%, and the steel loss rate is 1.12%.
2.7. Operations management

2.7.1. Garbage classification demonstration. At the end of 2017, this project was selected as the only garbage classification demonstration community in Quanzhou by Xiamen Aijia IoT Co., LTD. Aijia IoT company has set up green houses in building 4 and building 8 in the community, with dedicated personnel for maintenance and garbage classification demonstration. Photos of the green house is shown in Figure 8.

![Figure 8. Photos of the green house](image1)

![Figure 9. Photos of greening maintenance](image2)

2.7.2. Virescence maintenance. In order to protect people's health and protect the ecological environment, professional companies are entrusted with the management and maintenance of greening maintenance and the prevention and control of diseases and insect pests on a regular basis. Photos of greening maintenance is shown in Figure 9.

2.7.3. Intelligent system. The intelligent system of the project includes: automatic fire alarm system, cable TV, and security intercom system, visual intercom system, parking management system, emergency broadcast and background music system.

3. Effects and incremental costs

3.1. Effects

This project reduces the energy consumption of air conditioning by optimizing the design of envelope and shutter shading, and the energy saving rate reaches 55.82%, which is about 20% lower than the requirements of "implementation rules for energy-saving design standards of residential buildings in Fujian province" (DBJ13-62-2004).

The number of households installing solar hot water system was 708, covering 100% of the total, which reduced the energy consumption of hot water and saved 248,900 yuan per year.

12 light guide tubes were installed to improve the lighting area of the underground space by 10.39% and reduce the lighting energy consumption of the underground garage. Each section coal is about 2.8 kgce/m², reduce carbon dioxide emissions, to protect the environment has a certain economic benefits. After installing the light guide tube, the annual lighting energy consumption can be saved up to 7106 kWh and the cost can be saved up to 3197 yuan.

According to the water consumption data (from November 2016 to October 2017), the total annual water consumption of households is 42,839 tons, and the per capita water consumption is 59.6 L/person•d, which is lower than the low limit of "standard for water-saving design of civil buildings "GB 50555.

The rainwater collection system saves the consumption of tap water. The annual rainwater consumption is 2,402 m³ and the utilization rate of non-traditional water sources is 5.23% and save water 57, 64.8 yuan.

Indoor pollutants were detected and the results were as follows.
Table 2. Air quality test results

| Type          | Ammonia(mg/m³) | Radon(Bq/m³) | Formaldehyde(mg/m³) | Benzene(mg/m³) | TVOC(mg/m³) |
|---------------|----------------|--------------|---------------------|----------------|-------------|
| Sitting room  | 0.10           | 300          | 0.09                | 0.09           | 0.50        |
| Standard requirement | 0.20     | 400          | 0.10                | 0.11           | 0.60        |
| result        | √              | √            | √                   | √              | √           |

3.2. Incremental costs
The total investment in green building technology is 6.96 million yuan, and the incremental cost per unit area is 48.84 yuan /m².

Table 3. Incremental cost

| Technical measures                  | The unit price(¥) | Standard construction | The unit price(¥) | Amount   | Incremental cost (¥ ten thousand) |
|-------------------------------------|-------------------|-----------------------|-------------------|----------|-----------------------------------|
| Detection of soil radon concentration | 50                | /                     | /                 | 852      | 4.26                              |
| The rate of greening increased      | 10                | 10110                | 8                 | 12064.6  | 3.98                              |
| Adjustable outer shading            | 300               | /                     | /                 | 13222.2  | 396.67                            |
| Solar hot water system              | 2500              | Electric water heater | /                 | 1699.2   | 247.80                            |
| Light tube                          | 6000              | /                     | /                 | 12       | 7.20                              |
| Rainwater collection system         | 0.3 million       | /                     | /                 | 1        | 30.00                             |
| Water saving irrigation             | 5                 | /                     | /                 | 12064.6  | 6.03                              |
| **Total**                           |                   |                       |                   | **695.94**|                                    |

4. Conclusion
The project adopts the design concept of "green energy saving, low carbon and low energy consumption" according to local conditions, and is listed as the provincial key project in 2012 by Fujian provincial people's government. High-rise residential buildings shall be designed with two-star green building standards to improve the comfort level of products and create a healthy, safe and convenient living space.

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