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The Analysis of Energy Consumption and Pollution of Shenzhen's Buildings

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ABSTRACT
As one of the four major economic development centers in China, Shenzhen is the first city to reform and open to the outside world in China. It is faced with serious ecological damage resulting from intense development and environmental pressure. According to the data, in China, building energy consumption alone accounts for a quarter of China's total energy consumption. Shenzhen's development intensity has reached 47%, which is 19% higher than its neighbor Hong Kong, and much higher than many other Chinese cities.
As the development center of the economy, transportation and industry, Shenzhen's building energy consumption is one of the main sources of energy consumption and pollution. Therefore, this paper studies and elaborates on a reasonable analysis of the energy consumption and pollution problems of local buildings in Shenzhen. The paper also discusses how to address these problems under the premise of ensuring the normal quality of life, meanwhile keeping the development of industry and economy. By reading and studying research papers with a comprehensive analysis method, this paper concludes that the alleviation of environmental pressure via reconstructing the microscopic environment, increasing vegetation coverage, and making laws and regulations feasible.

Keywords: *Shenzhen, Energy Consumption, Environmental Pollution, Solutions*

1. INTRODUCTION

In 2012, China Urban Development Report was released. It clearly stated that nearly two-thirds of cities in China were polluted. Shenzhen, also known as "Pengcheng", is located on the east bank of the Pearl River Estuary, with Daya Bay and Mirs Bay to the east, Pearl River Estuary and Lingdingyang Bay to the west, and Shenzhen River to the south near Hong Kong. The city covers nine regions with a total area of 1997.47 square kilometers; the sum area is 927.96 square kilometers. The resident population was 1,756,0061 as of November 1, 2020.

Since the reform and opening up, Shenzhen's economy has surged and become an important hub for international transactions. In China, the output value of the construction industry has increased by 20 times since 1978. Shenzhen, which has made significant contributions to rapid economic growth and industrial development, is inevitably confronted with pollution issues caused by a large number of abandoned raw materials and ongoing construction operations.

A large number of utilized raw materials in the early stages of construction flow into rivers and pollute the water resources[1]. Even if the construction of a building is completed, the building's further needs in lighting, heating, and air conditioning make the constant release of the pollutants unavoidable. As a result, if Shenzhen is to maintain its fast-paced and sustainable development, relevant resolutions must be made to address the issue of over-emitting and generating toxic gases and raw materials. Aside from the pollution problem, Shenzhen also faced insufficient land. According to the data, the available area of Shenzhen is only about 700 square kilometers, which is inadequate to cope with further excavation and exploitation when comparing to past data. If the development mode is maintained in the future, according to scientific calculations, there will be no available land in Shenzhen in 20 years. Therefore, this paper will introduce several measurements aiming to achieve the long lasting co-existence relationship between human's needs and the environment's capacity.

In 1969, Ian Lennox McHarg, an American environmental designer, proposed the inseparable relationship between man and the natural environment in his book ‘Integrating Nature with Design’ [7]. In China, Qiu Baoxing, vice-minister of construction, published an article in 2005 pointing out six differences between green and ordinary buildings. In 2011, Gao Yunting and Wang Gang carried out a SWOT analysis on green building in China. Based on the analysis results, they proposed a dual promotion operation mechanism with the government as the core and user participation and design.

This paper introduces the current situation of shenzhen's environmental pollution and the sources of most of the pollutants. From three perspectives: architecture, law and ecology, this paper proposes solutions. This thesis adopts case analysis method. The environmental pollution situation at Shenzhen Bay Park was analyzed. At the same time, comparative analysis is also used to demonstrate the effect of building structure and ecological structure on energy saving by comparing the difference between urban and rural building structures. Through this paper, it is expected to draw attention to green building and solve more environmental problems caused by building.

2. THE CASE ANALYSIS OF THE STATUS OF ENERGY CONSUMPTION AND POLLUTION OF SHENZHEN’S BUILDINGS

2.1. Shenzhen Bay Park

Shenzhen Bay Park is a representative example of the severe environmental pollution in Shenzhen. Shenzhen Bay Park covers a total area of 128.74 hectares with a coastline of around 13 kilometers. Located in Nanshan District, it is one of the regions with the fastest economic development. It is surrounded by the headquarters of high-tech companies such as Tencent, Alibaba and so on.

As a national key protected wetland, Shenzhen Bay Park is still facing serious pollution, such as water, noise, air pollution. It is mainly affected by six major categories of problems: water pollution, sediment deposition, light /noise exhaust pollution, human disturbance, ecological invasion and pest diseases. Each of these factors is related to what has been built and is being built nearby, as shown in Figure 1.

Figure 1: A tributary of Shenzhen Bay

Nevertheless, the main sources of pollution in Shenzhen Bay are domestic chemical sewage, commercial&industrial wastewater and solid waste. Domestic sewage and wastewater are mainly produced by adjacent high-tech companies due to business demand and population mobility. Furthermore, some sewages are also resulted from the tributary connected to Shenzhen bay. Light pollution, exhaust pollution and noise pollution generated from the nearby office building have greatly damaged the birds’ habitats. Light can affect birds’ biological cycle rhythm thus affecting their inner timing cycle. At last, large-scale land reclamation projects have covered a large area of wetlands with silt, which has affected water resources, biodiversity and local habitats.

2.2. Dormitory energy consumption of Shenzhen University

From the perspective of physical buildings, some experts have constructed a simulation model of energy consumption in the student dormitories of Shenzhen University by using anylogic simulation software, Java programming technology and ABM subject modeling method[9]. The sample size is 400 undergraduate dormitories.

According to the survey, the student behavior that contributes the most to the energy consumption of the dormitory is the probability of students in the dormitory, and the smallest behavior is the standby time of the computer. The total energy consumption of the actual 400 dormitories in a year is 721297.12 kwh, while the total energy consumption through simulation is 685380.51 kwh.

When students stay in the dormitory, the use of electrical appliances is the main way to increase energy consumption. When the maximum probability of students in the dormitory is reduced to 0.8, the total energy consumption can be reduced by 1.73%. When the probability is reduced to 0.5, the total energy consumption can be reduced by 2.78%. The electrical appliances used more in the dormitory are air conditioners, which are mainly used from May to

October. The use of air conditioners by students accounts for 70% of the annual energy consumption. If the sample dormitory could increase the set temperature of the air conditioner by one degree, the energy consumption could be saved by 3.34%. In addition, in the male dormitory, the energy consumption contributed by the use of computers is 381,359.20 kWh, while the energy consumption of computers in the female dormitory is 304,021.31 kWh.

3. SOLUTIONS TO ENVIRONMENTAL POLLUTION PROBLEMS

3.1. Micro-transformation for water resources, noise and light pollution

For the pollution of natural water resources and sediment deposition, people can implement a corresponding transformation plan and strengthen local management power[3]. For example, the government issues mandatory regulations to restrict the construction of surrounding buildings and prohibit commercial construction in the nature reserve. Second, one of the reasons for sediment deposition is upstream soil erosion, which can be addressed by redesigning the upstream environment, such as planting trees along the river. Furthermore, for light and noise pollution, we can set up sound insulation walls along the coastal road. In order to effectively reduce the noise and weaken the light source, sound insulation equipment can be placed in the triangle area of the nature protection area.

3.2. Using vegetation cover to change the ecological environment

According to the data simulation, when it rains heavily in a densely populated area, a large amount of rainfall would wash pollutants collected from farmland and surrounding buildings into the river, which eventually results in a considerable degree of water pollution. Because the majority of buildings in cities and towns are converted from the forest and shrubby areas, large-scale transformation reduces ecological environment capacity and degradation capacity in Shenzhen.[3] In Shenzhen, the safety level of the ecological environment in coastal areas, roads along major traffic lines, urban and township areas is almost 80%-90% lower than in forest and shrub-grass areas of Shenzhen. Therefore, increasing the coverage of green vegetation in urban(shown in Figure 1) and residential areas is conducive to improving the above-mentioned problems.

Figure 2: sound insulation3.3. Reduce air pollution by optimizing related rules

According to the spatial distribution data of nitrogen dioxide, the annual average concentration in the Guangdong-Hong Kong-Macao Greater Bay Area from 2006 to 2016, the annual average concentration of NO2 in Shenzhen is relatively high[4]. Firstly, we can take effective corrective actions based on the Air Pollution Prevention and Control Law. For special or challenging problems, people need to make concrete analyses for appropriate solutions. For instance, for some local factories, whose profits are greater than the standard fines in related law. As a result, it can not effectively prevent such kinds of factories from reducing air pollution, which means people need to study the whole picture and set up a feasible solution to stop such behavior and guide them to do the right things.

Secondly, the ownership of air pollution in each area should be clearly clarified and they should be required to take on corresponding social responsibilities. Air pollution source is mainly factories and enterprises, but they generate negative externalities which means they affect the whole community people. The Environmental Protection Law specifies the punishment for pollution but does not specify the legal responsibility for environmental damage. Therefore, it can be effectively improved by optimizing the law.

Thirdly, the Pearl River Delta area can develop an effective plan to alleviate air pollution by improving management systems, adjusting industry structures, regulating industrial pollution sources, requiring pollution treatment devices and developing clean energy.

4. EFFECTIVE MEASURES TO REDUCE PUBLIC BUILDINGS ENERGY CONSUMPTION IN SHENZHEN

According to the report "Energy Consumption and Energy Conservation Analysis of Public Buildings in Shenzhen", the thickness of public buildings walls in Shenzhen is mostly between 200 mm and 240 mm. The materials used to construct the wall are generally brick

or stone without heat insulation measures. In Shenzhen, only about 35% of the buildings have insulation measures. Most buildings use inner shading, louvers and drapes for shading.

Data also shows that the total load of the building is proportional to the thermal performance of the building's envelope. Now, most of the envelope structures in Shenzhen have certain limits on energy saving. Through improving envelope structure, it can reduce both the air conditioning load and energy consumption of air conditioning running through improving envelope structure. Approaches like utilizing external shading, replacing energy-saving lamps, increasing indoor natural light through adjusting the position of natural light can all help to reduce the loss of light energy. According to the survey, [6] current lighting consumes approximately 17% of the electricity. If we can combine the use of natural light, then the exterior area space lighting energy consumption can be reduced by about 60%. Energy consumption can also be reduced by adjusting the air conditioning's temperature.[5]For example, if the indoor setting temperature is 23 degrees Celsius, the annual air conditioning load ratio is 1. If adjusted to 27 degrees Celsius, the annual air conditioning load ratio is down to 0.78. With changing the air conditioning temperature, the energy-saving rate can reach 14%[8]. The Bullitt Center in Seattle , USA is a perfect example of green building. The building has six floors and faces the northwest. It is a commercial building. Because Seattle has a temperate marine climate and the annual temperature difference is small, the first task to save energy is to reduce the energy consumption of air conditioning. The designer improves the building thermal insulation effect by changing the enclosure structure. The outermost layer of the building is a rain screen system composed of metal plate, air interlayer and 10cm thick minerals. There is a 1.6cm thick glass fiber gypsum board on the inner side of the envelope. At the same time, the building also combines the wind direction and wind frequency to transform the building to achieve the purpose of energy conservation.The windows and shading systems of the building correspond to the lighting and ventilation tasks of the building. One can achieve maximum daylighting through automatic shutters and manual windows for even light. The stainless steel louver on the outer layer of the envelope is about 0.3m away from the window. This design reduces the cooling load caused by solar radiation.

5. CONCLUSION

As a rapidly developing city, while maintaining sustainable and stable growth, Shenzhen must also recognize the problems arising from the development and actively confront and resolve them. For building energy consumption and pollution, we can make strict regulations and laws to effectively reduce water and air pollution, increase the area of green plants, and make efforts to recover the degradation ability of the natural environment through effectively dissolving the sewage. We can reduce the total building energy consumption by changing or upgrading the public building's materials, design and usage. In this paper, if there are actual examples of physical simulation of energy saving, it may make the architectural principle more intuitive and effective. In the future, people can devote more energy to research in the field of developable architecture. Future research needs to discuss how to guarantee the living and working quality of life without putting too much pressure on nature. At the same time, in a market-oriented economy, builders should also take economic conditions into consideration[10].

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