International High-Performance Built Environment Conference – A Sustainable Built Environment Conference 2016 Series (SBE16), iHBE 2016

Green Darning City, Taking the Tenth China (Wuhan) International Garden EXPO Design as Examples

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Abstract

The paper takes design of the tenth China (Wuhan) International Garden EXPO as an example, concludes the development direction of low-carbon parks in China, and highlights the use of sponge city and green architecture design. Firstly, the paper introduces overview and design cases of the EXPO. Then, the paper elaborates the goals of low-carbon design. It describes the low-carbon technical application of the EXPO park, i.e. comprehensive design based on overall coordination and avoidance of conflicts, intelligent city planning, processing technology of existing landfill, conducting onsite balance work for earthwork, water recycling system planning, building ecological low-carbon architecture, building and repairing of ecological darning bridge, etc. Besides, the park also adopts design principle of sponge city. As an urban oasis, Wuhan International Garden EXPO dars the divided city; as a public space, it provides an ecological space for more citizens to visit and enjoy. Its example is a reference for design of low-carbon parks in China in the future.

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Peer-review under responsibility of the organizing committee iHBE 2016.

Keywords: Low Carbon; Expo Garden; Water Treatment; Ecology Suturing; Garbage Disposal;

1. Introduction

Along with the development of economy, population explosion and burning of the coal and petroleum, carbon dioxide emission has risen extensively and the concentration of carbon dioxide in the atmosphere has increased

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Peer-review under responsibility of the organizing committee iHBE 2016.
dramatically, which leads to abnormal global climate change mainly characterized by climate warming and threatens human living environment and physical & psychological health. Nowadays, the global warming and global greenhouse effect have become the most concerned environmental issues in this century. On January 14, 2016, the World Economic Forum, with headquarters in Geneva, released the Global Risk Report of 2016 which claimed that the ineffective measures of dealing with and solving the problems of climate change have been the greatest global risk of 2016. The climate change of the ecological environment has already become the hottest topic in the world. Garden plants and green land are the important part of ecological environment and is playing crucial roles in city carbon cycle. Increasing the number and area of garden and green land absorbs the man-made emissions of carbon dioxide and release oxygen, which improves the living conditions of urban residents directly [1]. Therefore, the development of low-carbon city garden is a crucial part of the future urban development.

British is the first country that came up with the low-carbon concept and advocates actively low-carbon economy. In 2003, British first put forward the "low-carbon concept" in the Energy White Paper Our Future Energy - Creating a Low-carbon Economy, which aroused wide concern of the society at that time. V. Whitford, from the University of Manchester in UK, published the "Natural Process Form of the City - Indicator Research of Regional Ecological Operation" in 2001, of which the research on city trees’ carbon sink and carbon respiration was conducted and simply calculation method was proposed [2]. The zero energy consumption community in British Aberdeen, completed in 2002, verified the feasibility of the low-carbon community through more than 10 years of practical operation experience with the concept of sustainable development and green building. With constant deepening consciousness of carbon dioxide reductions in order to deal with the global warming in the world, apart from "low-carbon economy", "low-carbon technology", "low-carbon energy", "carbon footprint", "low-carbon city", "low-carbon community" and a series of new concepts and new policies arise at the historic moment, which opens up a new road towards low-carbon civilization in the world [3].

Starting with the basic requirements of the "low-carbon" concept, blending the low-carbon concept into the urban park design is the future development direction. On the basis of social, ecological and economic benefits regarded as the fundamental functions of normal urban parks, and with emphasis on early-stage management, planning plan, construction and maintenance management during the whole life cycle, low-carbon urban park aims to improve the energy efficiency, reduce energy consumption, increase carbon sink and reduce carbon emission, and form good climate environment urban park with "low emission, low cost, low energy consumption, low pollution and high efficiency" [4]. Low-carbon urban park is equipped with the features of low carbon footprint, low carbon emission, low carbon cost, high carbon sink ability and so on, which adjusts microclimate and provides visitors with a suitable climate for feeling the nature [5]. In recent years, as low carbon pilot cities, Beijing, Shanghai and Baoding successively have Nanhaizi Park, Chongming Forest Park, Expo Houtan Park, etc., and win pretty good social effects.

Low-carbon urban park not only provides solutions to low-carbon urban development, but also brings new development opportunities. To explore low-carbon urban park is the only way to develop low-carbon city. Low-carbon urban park has played an important role in dealing with climate warming and reducing energy consumption [6]. The low-carbon design concept of urban park mainly reflects in four elements: mountain, water, plants and buildings which are the four basic elements of landscape [7]. The construction of mountain, water, plants and buildings are the main work or main methods of building landscape [8]. The practice of low-carbon parks in China also starts from these four elements. Low carbon concept is found here and there from design to construction. Low–carbon park conforms to the needs of development of the era more easily than ordinary urban park and must have extensive and profound significance.

2. Research Object - Wuhan Expo Garden

The 10th China International Garden Expo was held in Wuhan, Hubei. The Garden covers an area of 213.77 hectares, including 176 hectares public green area, 6.1 km long greenway, 48,000 arbors, 60.8 hectare shrubs, 36.5 hectares lawn and more than 410 kinds of plants. The Garden is located in the combining area of urban center and suburb city, which is separated by ring road into south and north parts sutured by the Garden. The northwest area is close to Jinyin Lake, a natural lake in downtown thus it is easy to create garden waterscape by obtaining water from the nature lake. Jinke refuse landfill, the biggest domestic waste landfill site in Asia, make the ecological
restoration about the 780 mu Jinkou refuse landfill with the aerobic technique and make the dream of building the expo garden onto the refuse mountain become a reality, the former refuse landfill turning into an ecological low-carbon park (Fig. 1).

Fig. 1. (a) The Site of Wuhan Expo Garden; (b) The Original State of the Site; (c) Jinkou Refuse Landfill.

The Garden is divided into two landscape areas: the north area is artificial mountain-Jingshan and the south scenic spots are developed around the artificial lake Chushui. Ecological low-carbon park garden expo applies the ecological technology to the whole garden and the close link with ecological technology is easily found everywhere. For example, LID low impact development, clean energy application, garden waste recycling, green architecture, wisdom garden and other technologies are widely used in the Expo Garden. At the beginning of the Garden design, facing with the restraining factors of complex waste management, numerous field pipeline, short construction period and diverse construction contents, designers decided to adopt the way of integrated design, speed up the design, avoid the intersection of each part and the repeated work in the process of design and improve the design efficiency, which saved the manpower and resources and is a low-carbon green design process (Fig. 2).

Fig. 2. (a) The design plan is to darn the ecology at the north and south parts and set up a footbridge; (b) Ecological greening on landfills; (c) Set the pavilion north-south axis, the axis of the east-west cultural; (d) The structure of the planning——Jin mountains and Chu lakes.

3. Application of Low-carbon Technologies

3.1. Ecological suturing

The original terrain is lower in the south and higher in the north and the north and the south is split. The terrain in the south slopes gently and the terrain in the north Jinkou refuse landfill is higher, which has great altitude with the
The garden base is passed through by the 3rd Ring Road and divided into south and north part. The south and north traffic accessibility is poor and has become the major obstacle for visitors.

Considering weakening the noise and visual impact of the overlying soil along the 3rd Ring Road, the design plan is to darn the ecology at the north and south parts and set up a footbridge which passes overhead the third circulation line and strengthen the connection of the south and north parts (Fig. 3).

3.2. Refuse disposal

The garden base was originally the largest refuse landfill in Asia-Jinkou refuse landfill whose burying has been started since 1989. The cumulative amount of landfill was nearly 7 million tons; the average depth of the landfill was about 10 meters, and the landfill area covered an area of 40.86 hectares. After the location is determined, by using the principle that “aerobic degradation technology in waste treatment is faster than anaerobic or oxygen degradation”, the air was pressured with certain equipment or facility and then injected into the dump by using the pipes, and the carbon dioxide and other gas were exhausted at the same time. During the process, the temperature, humidity and gas of the reactant were monitored and microorganisms of the waste were activated to regenerate, which changed anaerobic or oxygen degradation into aerobic degradation and speeded up the degradation process of garbage (Fig. 4).
Table 1. Refuse Disposal.

<table>
<thead>
<tr>
<th>Partition</th>
<th>Area(㎡)</th>
<th>Average landfill thickness (m)</th>
<th>Total amount of garbage(㎡)</th>
<th>Treatment program</th>
<th>Construction period</th>
<th>Running period</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>64,000</td>
<td>13</td>
<td>832,000</td>
<td>Aerobic stabilization program</td>
<td>4 months</td>
<td>2 years</td>
</tr>
<tr>
<td>II</td>
<td>149,300</td>
<td>15</td>
<td>2,239,500</td>
<td>Aerobic stabilization program</td>
<td>4 months</td>
<td>2 years</td>
</tr>
<tr>
<td>III</td>
<td>97,700</td>
<td>11</td>
<td>1,074,700</td>
<td>Landfill closure program</td>
<td>3 months</td>
<td>sustained</td>
</tr>
<tr>
<td>IV</td>
<td>97,600</td>
<td>9</td>
<td>878,400</td>
<td>Landfill closure program</td>
<td>3 months</td>
<td>sustained</td>
</tr>
</tbody>
</table>

3.3. Artificial Mountain

After handling Jinkou refuse landfill with 450,000 square meters, it is planned to build about 15-meter high “Jingshan” with the soil which comes from reconstruction of peripheral urban village, subway excavation and southern water treatment. Therefore, an effect from the adaption to local condition and self-balancing are achieved and mountain forest down land and micro topography are formed. In the Expo Garden, it is higher in the north, lower in the south and there is water storage in the center. When dealing with the earth and stone work, the earth volume dug from open channel at the entrance of "Chushui" is used as earth work for shaping the terrain. In the process of the artificial mountain, we basically keep the balance of the earthwork quantity by utilizing waste earth from surrounding construction sites in order to avoid the waste of manpower and financial resources and cut down the cost of the earth.

3.4. Design of sponge city

According to the design principle of sponge city, the Expo Garden uses many kinds of technologies to make the city like a sponge with excellent "elasticity" to adapt to environment changes and respond to natural disasters (Fig. 5). When it rains, the sponge city absorbs water, stores water, generates water seepage and purifies water. And when the water is needed, the storage water is rereleased for use and makes the water flow naturally in the garden [9].

Fig. 5. Sponge EXPO construction.
- Rainwater collection of pervious concrete: The Expo Garden has two squares at the south and the north entrances and the total area reaches 70,000 square meters. The square is paved with pervious concrete and water permeable bricks with 15%-25% pores which make the permeable rate up to 31-52 L/m/hour. When it rains, the rain penetrates into the underground through the pores in the concrete and the bricks, part of the rain going back to underground and part of the rain collected by the crisscrossed permeable blind pipes buried under the ground. Among them, the rain collected from the square in the north entrance flows into wetland scenic area in the north of the garden and is elevated to the peak of "Jingshan", then flows along the slope of "Jingshan" to the southern artificial lake "Chushui" with the capacity of 100,000 cubic meters. The rain collected by permeable blind pipes in the south entrance square directly flows into "Chushui". When flowers and trees need to be watered, the water is achieved from "Chushui" through the pump.

- Rainwater purification by rain garden: The Expo Garden builds 6 discarding flow pools each with a capacity of 200 tons and 12 rain gardens with different capacities. These discarding flow pools and rain gardens are used for collecting and purifying the rainwater. When it rains, part of the surface runoff is collected at the discarding pool through the ecological grassed waterway throughout the garden and reaches Chushui after being precipitated and filtered. Some are collected by the rain gardens to water the flowers and trees after being purified by the wetland plant.

- Rainwater collection on the roof: The roofs of main architectures of the garden are made green by covering with soil. When it rains, some water is absorbed or retained by the flowers and trees on the roof. Some water flows away through the network of drains and some others flow into the PP module which is specially used for collecting rainwater through the pipes buried on the roofs or in the walls. These modules are integrated with rain water filtration, purification and storage function. During the drought period, these modules provide water for nearby flowers and trees.

4. Water Treatment

4.1. Rainwater collection and use system

To restore natural balance evolved over millions of years, a low LID influence urban development system should be established. Through roof greening, rain garden, reuse of recycled water, pervious water and a series of ecological methods, the surface runoff per unit time is reduced, which stops the rainwater by 68%, alleviates peak pressure of fast drain system, purifies storm sewage, reduces carbon emissions and supplements groundwater resources. Therefore, this balances air humidity, increases the biodiversity and builds a livable ecology environment (Fig. 6).

- Diversion from artificial lake and ecological purification: The north side of the Expo Garden is near to the Jinyin Lake with normal water level of 19.15 m, which is the water diversion source of artificial lake "Chushui". The water from the Jinyin Lake system is mechanically concentrated at wetland scenic area, and the water is mechanically concentrated at the hillside of ecological mountain in the Expo Garden, and then the water flows into water system by gravity along the ecological grassed waterway. The process of water diversion combines the water system landscape and adapts STCC carbon water ecological restoration technology to purify the water system (Fig. 7). Ecological grassed waterways are located in the northern mountain. The flow speed in the grassed waterway is controlled to 0.2-0.3 m/s, hydraulic retention time is over 2h and the length of grassed waterway is not less than 2,500 m. The water in northern landscape is equipped with water microcirculation pump station with 15-day cycle period. Yellow flag, canna, umbrella shaped flower, cattail, reed and other plants are planted in the wetland. The whole landscape uses ecological water treatment technology and reasonably controls rainwater source pollution to ensure the safety of water quality.
• Balance of water source using: Rainwater catchment system of the Expo Garden regards the 3rd Ring Road as the boundary to form two relatively independent catchment areas in the north and in the south. The rainwater in the southern area is collected by the pipes and dealt with by discarding facilities, and then flows into artificial lake whose volume is 105,000 m³. Through the rain pipes, the rainwater in northern area flows into the box culvert with three brakes connected. Ecological grassed waterways and rain gardens are set at Jingshan to collect rainwater and lead the surface runoff to the source of southern artificial lake "Chushui" and finally flow into "Chushui" through the plant purification. Landscape ponds are designed in the garden, forming "rain gardens". Surface water is dealt with by the rainwater gardens and then is regarded as the supplement for "Chushui". In order to ensure the garden water quality, water in southern area is elevated to the commanding height of the garden, namely, hillside of Jingshan, and then flows down along the hillside and forms the landscape of ancient Chinese "lofty mountains and flowing water", and finally flows into "Chushui" scenic area(Fig. 8). Therefore, self-circulation aeration of water system is realized, which forms the dynamic water scene and keeps the water quality.
4.2. The Expo Garden water system planning includes the following aspects:

- Water system in garden: regarding artificial lake as the core, exerting landscape water storage, regulation and storage, natural purification and landscape functions.
- Water resource balance: keep the balance of garden water through collecting and using of natural rainfall and water supplement from Jinyin Lake.
- Water quality maintenance: combine ecological treatment with artificial purification technology.
- Ecological design: low impact development of rain water system.

![Chushui scenic area](image)

Fig. 8. "Chushui" scenic area.

4.3. Recycled water system

The recycled water in the Expo Garden is used for community greening, water sprinkling and toilet flushing. Recycled water which is mainly used for ordinary life meets the need of the garden. At the same time, the ecological park has the agglomeration conditions and good management system, in addition to give certain policy and grants, comprehensive arrangement can be done in the construction of recycled water pipe network, facilities maintenance and price management.

5. Construction of the Ecological Low-carbon Architecture and Management

The two main architectures of the Expo Garden are Yangtze River Civilization Pavilion and Garden Art Center, two big service areas and 117 exhibition gardens. Following the principles of “green design in architecture design”, the construction materials mainly include local materials with the proportion of over 60% and recycled materials are used as much as possible (Fig. 9). On the premise of guaranteeing the performance, we choose construction materials made of the waste and use the recycled construction materials. The roofs of the main architecture are covered with soils and the utilization rate of the roof reaches over 70%, which not only saves energy but also collects rainwater. Double composite wall improves heat preservation and heat insulation performance (Fig. 10). The reasonable design of the courtyard strengthens the natural ventilation and lighting between the architecture group and single architecture and effectively regulates the indoor micro climate.

![Construction of the ecological low-carbon architecture](image)

Fig. 9. Construction of the ecological low-carbon architecture.
5.1. Reduction of total energy demand of the architecture

- The first choice of energy-saving way - passive energy saving design
- Necessary complement to energy-saving way - active energy saving design
- Reduce the energy consumption during the manufacturing and transportation of construction materials

5.2. Use of clean energy

- Integration of solar photovoltaic and the architecture: solar thermal and photovoltaic application system should be applied in the architecture as much as possible. Solar power system should be applied in the street lamps and other public facilities as much as possible.
- Solar-driven air conditioners.
- Low temperature geothermal utilization: the public architecture surrounded by water should adapt low temperature geothermal utilization as much as possible; the public architectures should be encouraged to use low temperature of the rock and earth mass and low temperature of the underground water.

5.3. Integrated design based on overall plan and avoiding conflict

This integrated design is on the basis of overall plan and avoiding conflict which mainly reflects site engineering, municipal engineering, landscape engineering, construction engineering and others on one drawing, which speeds up the design work, avoids various professional intersections and increases the speed of design process.

5.4. Wisdom urban plan in the garden

Wisdom parks features interaction with visitors, experience, and integration and mainly reflects the characteristics of region, ecology, science & technology, humanities, and people’s livelihood. It includes four systems, namely, interactive garden, intelligent control, intelligent transportation and intelligent service.

6. Conclusion

Urban parks are important part of the city. As a compound ecosystem, urban parks play a key role in building a low-carbon city quickly and efficiently. Low-carbon urban parks bring new opportunity for the development of the city. Based on the analysis of low-carbon urban park - Wuhan Expo Garden, this paper concludes the current design elements of low-carbon urban parks in China from the aspects of ecological darn repair, low impact development application, water cycle process and sponge city design principles. In order to guarantee the low-carbon function of urban park in life period, integrated design, low-carbon management in whole process and wisdom garden system are adapted so as to provide referential method for the development of low-carbon parks and city’s sustainable development.
References


