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Application of Vertical Greening in Urban Landscape:

A Case Study of Xi'an*

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***Abstract*—Vertical greening is a relatively new form of greening in today's cities, and it is an inevitable trend in urban development. With the rapid development of Xi'an in recent years, compared with ground greening, vertical greening is also an indispensable part of the entire urban landscape. This paper takes the vertical greening of Xi'an as the research object, conducts field surveys and data collection and collation on the vertical greening landscapes of residential areas, enterprises and institutions, indoors, and campuses in Xi'an. And comprehensively and systematically analyze the application of vertical greening in green space in Xi'an, and put forward constructive suggestions for the construction of vertical greening landscape in Xi'an.**

Keywords—vertical greening; urban landscape; applied research

I. INTRODUCTION

With the development of urbanization, the population in urban areas has increased, and the density of buildings has continued to increase. Natural resources in the city are gradually surrounded by hard interfaces such as concrete, the green space in the city has declined sharply, coupled with energy pollution, the ecological environment has continued to deteriorate, and the heat island effect in the urban center has become increasingly apparent. Relevant research believes that the urban green coverage rate must account for 50% to 60% of the total urban land area. In addition to the suburban green space indicators, the ecological environmental quality of the city may be fundamentally improved.

II. BASIC OVERVIEW OF VERTICAL GREENING

A. The Concept of Vertical Greening

With the continuous development of scientific and technological means of vertical greening, its concept is constantly updating and refining. "For example, the definition of vertical greening in the early Landscape Design and Construction of Garden Plants is: "Vertical greening refers to the use of climbing plants to green walls, railings, scaffolding, poles, and steep rocks."

This paper considers that vertical greening uses plant materials to climb, fix, plant, and hang along the building facade or other structures to form vertical greening. It includes the greening of the building's walls, fences, stockades, columns, and overpasses. Corresponding to the greening of the ground, greening in the three-dimensional space can not only increase the artistic effect of the facade of the building, but also make the environment neater, more beautiful and lively. And it has the advantages of small footprint, quick results, high greening efficiency and so on.

B. Vertical Green Planting Forms and Commonly Used Plants

1) Vertical greening planting form: First, modular greening: This form of greening is the use of modular components to grow plants, highlighting the greening of walls. Modular wall greening can also be based on the plants and plant patterns in the module. Plants are first cultivated and maintained, and then installed. This type of cultivation is suitable for large areas of difficult greening. ("Fig. 1")

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Fig. 1. Drawn by the author: modular type.

Second, pavement greening: Pave the plant substrate or module directly on the building or structure to form a wall planting system. ("Fig. 2")

Fig. 2. Drawn by the author: pavement type.

Third, climbing or hanging greening: Climbing or hanging vines are planted on the wall or structure of the building, such as creepers, trachelospermum, ivy, wintercreeper, green dill, etc. This type of vertical greening is simple and feasible, low cost, and good light-transmitted and air permeable. ("Fig. 3")

Fig. 3. Drawn by the author: climbing or hanging type.

Fourth, pendant flower greening: Install potted flowers in a bracket made of stainless steel or reinforced concrete to reflect vertical greening. This wall greening method is similar to the modular form. It is a reduced version of the module, which is more convenient to install and remove. When choosing plants, it should be based on seasonal flowers, which is more suitable for landscaping with three-dimensional flower beds. ("Fig. 4")

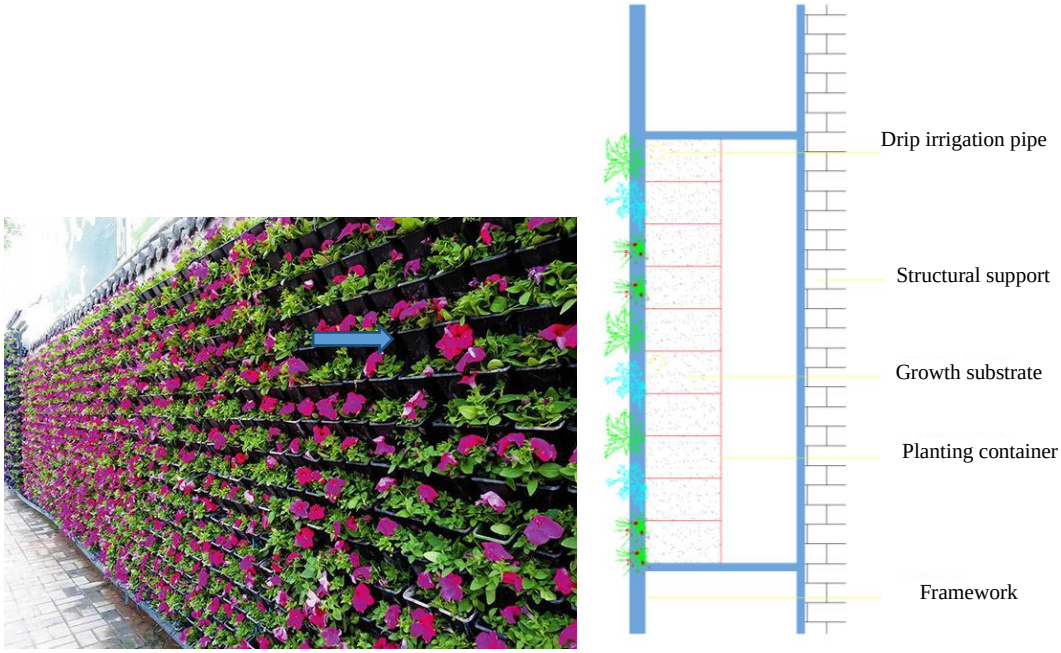

Fig. 4. Drawn by the author: pendant flower type.

2) Commonly used vertical greening plants: The vertical greening plants commonly used are shown as the following "Table I".

TABLE I. COMMONLY USED VERTICAL GREENING PLANTS

No.	Name	Florescence	Usage
1	Creeper	Early June	Buildings, trellises, porches
2	Campsis radicans	Mid-June-Early September	Walls, trellises, porches
3	Climbing Rose	Seasonal	Fences, flower stands, flower walls
4	Honeysuckle	Late April-Late September	Climbings, flower stands, flower galleries
5	Ivy	April-May	Courtyards, buildings
6	Cypress vine	Mid-July-Early October	Lower walls, small rattans
7	Briar rose	Late April-End of May	Flower gates, flower hedges, overhang
8	Virginia creeper	July-August	Buildings, shelvings, porches
9	Wintercreeper	June-July	Trellises, roads, rail-ways
10	Chinese wistaria	Mid-April-Early May	Scaffolding, porches
11	Forsythia	April-May	Courtyards

C. *Application Status of Vertical Greening in Xi'an*

The greening design of the building wall does not combine the architectural characteristics and culture, but only resides in traditional and standardized practices. There is no new technology application, which makes the greening pattern in many places uniform and unchanged.

1) Single plant species: Through surveys in the urban area of Xi'an, the most commonly planted plants are creepers and ground brocades, with few plant species. In fact, there are many available plants, such as ivy, rose, and climbing roses.

2) Inadequate maintenance management: The investigation showed that the climbing plants growing in Xi'an did not grow very well, probably due to inadequate management and lack of professional technicians to manage, resulting in overgrown weeds and affecting the ornamental value of the building wall.

III. INVESTIGATION AND APPLICATION OF VERTICAL GREENING IN XI'AN

A. *Investigation Method*

A comprehensive field survey of various green lands in Xi'an was adopted, and detailed recording, photographing, and measurement methods were used to analyze the application of vertical greening in Xi'an.

B. *Application of Vertical Greening in Xi'an*

Xi'an is a city with a strong cultural heritage. It is mainly characterized by tourism. The most important one is the Tang Dynasty-based tourism city. Xi'an attaches great importance to the greening of the entire city, which has contributed to the development of tourism. It has a great promotion effect in recent years, Xi'an has not only paid more attention to ground greening, but also vigorously developed vertical greening to improve the city's greening rate.

However, there are also some shortcomings in vertical greening in Xi'an. As far as it can be seen from the urban area of Xi'an, there are fewer vertical greenings, and the composition form is relatively simple.

IV. ANALYSIS ON THE APPLICATION OF VERTICAL GREENING IN VARIOUS GREEN SPACES

Xi'an belongs to the warm temperate semi-humid continental monsoon climate with four distinct seasons, and a changeable climate in spring. It is hot and rainy in summer, cooler and rainier in autumn, and dry and cold in winter, lacking rain and snow. The annual average temperature is 13 degrees Celsius.

A. *Survey of Vertical Greening in Residential Areas*

With the rapid development of cities today, the cost of urban land has increased significantly, residential floors are getting higher and higher, and the area of flat greenery is getting smaller and smaller. How to make use of limited land area and create more green, increase green coverage, and improve greening is an important condition to attract owners to stay. Vertical greening can make full use of space, such as planting climbing plants on walls, balconies, windowsills, roofs, scaffolds, etc., to increase the green area and improving the living environment. Not only can it make up for the lack of flat land and green space, it can enrich the greening landscape, but also increase the level of plant landscapes. At the same time, it also has obvious ecological benefits, such as lowering air temperature and reducing dust and noise. ("Fig. 5")

Fig. 5. Vertical greening of a community.

According to the investigation of residential areas in Xi'an, vertical greening is rarely used in residential areas, and there are few vertical greenings in individual communities. The basic commonly used creeper as a greening plant appears to be stiff and rigid; the developer may be due to more vertical reasons. When greening is done,

the ground greening is only carried out blindly. The vertical greening is relatively simple, the design is quite easy to conduct, the landscape effect is good, and the maintenance cost is lower than vertical greening. Therefore, vertical greening is rarely used in residential areas.

B. Campus Survey of Vertical Greening

Vertical greening has the following functions in the campus: it can improve the greening rate of the campus and increase the area of greening; vertical greening in the city occupies less space, can effectively use space, and build greening in vertical spaces. Not only it increases the urban green coverage, but also makes up for the lack of ground greening. It is able to soften the facade of the building and improve the campus environment. In this way, the building can be integrated with other green landscapes in the campus, thereby improving the overall green landscape effect of the campus; absorbing soot and reducing noise. After vertical greening, plants can absorb dust in the air, and can effectively reduce noise; reduce temperature and humidity. Research shows that the indoor temperature with green walls in summer is 3 ~ 4 ℃ lower than that without green walls, and the former is 2 ~ 3 ℃ higher than the latter in winter, and the humidity can increase by 20% ~ 30%. ("Fig. 6")

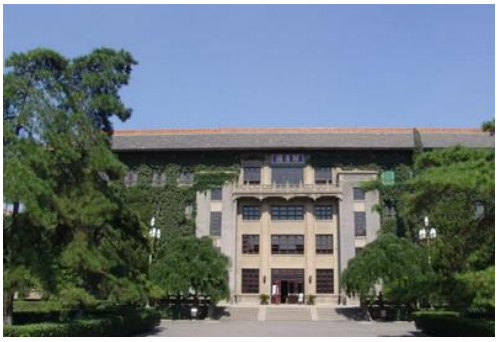

Fig. 6. Green wall of Shaanxi Normal University Library.

The green wall of the old campus of Shaanxi Normal University has been around for many years. The creeper planting outside the library has covered the entire wall, making the library look dignified. However, the planting of plants is relatively simple, and the entire wall is very rigid.

Fig. 7. Medical School of Xi 'an Jiaotong University.

Fig. 8. Green wall of Xi 'an Eurasian University.

The green wall ("Fig. 7" and "Fig. 8") of Xi'an Eurasian College is located in the hall of Eurasian College. Plants are selected from Anthurium, Duckwood, Green Dill, Phalaenopsis Phalaenopsis, Silver-Edged Phalaenopsis, etc. The plants species are rich. Planting trough, which uses humus planting soil to grow plants, drip irrigation automatically waters, the landscape effect is quite good, so regular maintenance and management must be carried out, otherwise the entire indoor effect will be affected. The only disadvantage is that the maintenance cost is relatively high.

C. Survey on Indoor Vertical Greening

Vertical greening, through its colorful plants, gives people vitality, adds vitality to the originally cold and hard indoors, triggers people to be active and love life, regulates body and mind, and relieves stress; vertical greening can also regulate indoor temperature and humidity, reducing air conditioning consumption and reduce noise. At the same time, when carrying out vertical greening indoors, we should also pay attention to the choice of plants. Plants should be shade-resistant, pruning-resistant, and easy to survive, non-toxic and non-thorny, so as to promote physical and mental health. (See "Fig. 9", "Fig. 10" and "Fig. 11")

Fig. 9. Green wall of Angel Hospital

Fig. 10. Green wall of an office building in Xi 'an

Fig. 11. Green wall of Huawei Office.

Through surveys on the indoor vertical greening of many units in Xi'an, some units have paid more attention to the indoor environment. People stay in the office all day, and the air inside will naturally be poor. Therefore, some companies will make a natural atmosphere in the hall. The green wall makes people feel relaxed and happy. Commonly used plants are phnom penh phragmites, reticulated grass, ivy, green dill, star anise gold plate, pocket coconut, etc. Indoor plants are relatively abundant, as long as they are shade-resistant, easy to survive, and have good landscape effects. But the only drawback is the high cost of maintenance and management. Once the maintenance is not appropriate, the entire landscape will be poor, affecting the entire indoor environment.

D. Research on Vertical Greening of City Streets

Urban street greening reflects a city's green coverage, so in order to increase the green coverage of the entire city, all the walls of the street must also be greened. Through the investigation of street greening in Xi'an, Xi'an has developed rapidly in the past two years and pays more attention to the city's environment. Therefore, the corresponding vertical greening of the street walls in each district of Xi'an has been done. The overall effect is good. Pendant flower greening and modular vertical greening are the main forms, and some grass and flower plants such as calendula, salvia splendens, kale, and coleus are planted. ("Fig. 12" and "Fig. 13")

Fig. 12. Green wall of High-Tech Zone streets.

Fig. 13. Viaduct pillars greening.

V. CONCLUSION

A. Analysis of Result

From the above investigation and analysis, it can be seen that most of the vertical greenings in Xi'an are concentrated indoors, so the outdoor greening is relatively small. The reasons may be mainly because, first, indoor greening temperature is well controlled, and there are more plants that can be planted, and the survival of plants mainly depends on temperature, soil, fertilizer, etc. Then, due to the climate of Xi'an, there are few plants that can be planted, so the combination will be relatively single. The relative area of vertical greening in the second room is relatively small and the maintenance management is relatively convenient, while the outdoor large-scale planting is generally difficult to maintain.

B. Suggestion

1) Strengthening the application of vertical greening in all kinds of green space: The shape of outdoor vertical greening landscape should be increased to enrich the level of plant landscape, and the composition should be richer.

2) Enhancing people's understanding of vertical greening: Because people usually see ground greening the most, there may not be much attention paid to vertical greening, so they do not know much about what is vertical greening, and just think that it is greening that climbs on the wall and there is nothing to see.

C. Prospect Forecast

With the development of the city and the high-density building space, vertical greening, as a greening method with

a small footprint and easy landscape formation, will become an inevitable development trend in the future urban development. Xi'an is not an exception. With the increase of population, more and more high-rise buildings, and less and less ground greening, it is necessary to build a large area of vertical greening landscapes to enhance the urban environment and regulate the urban climate.

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