Research Square

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Research Progress on Three-dimensional Greening of High-Density Urban Spaces

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Abstract

Urbanization has resulted in increased population density and scarcity of space, leading to the loss of greenery in urban areas, while also increasing the density of buildings and urban spaces. As an important development direction of urban greening, three-dimensional greening plays an important role in the ecological economy and landscape development of the city, especially for the improvement of the ecological environment of high-density cities. Focusing on the research progress of high-density urban space greening, this paper summarizes the application mode, technical points and plant configuration of three-dimensional greening in high-density urban space, and provides a scientific basis and relevant prospects for the sustainable development of high-density urban three-dimensional greening.

Introduction

"High density" is a comparative adjective(Yikai, 2016). Cities with a population density of more than 15,000 people/km^2 can be regarded as high-density cities(Perez, Coma, Barreneche, de Gracia, Urrestarazu, Bures and Cabeza, 2016). By the end of 2020, China's urbanization rate has reached 63.89%, an increase of 14.21 percentage points from 49.68% in 2010 (National Bureau of Statistics, 2020). In order to improve the quality of the living environment and increase the green space, extending from ground greening to three-dimensional space is an inevitable choice for high-density cities to improve the quality of the ecological environment.

Three-dimensional greening plays a central role in urban greening, and its benefits include noise reduction(Perez, Coma, Barreneche, de Gracia, Urrestarazu, Bures and Cabeza, 2016)., air quality improvement(Radic, Dodig and Auer, 2019)., Increase urban biodiversity(Radic, Dodig and Auer, 2019)., improve the microclimate(Daemei, Azmoodeh, Zamani and Khotbehsara, 2018).and the impact of building energy consumption, etc. Scientific documents at different historical stages have different definitions for three-dimensional greening. Based on the classification of terms used in the literature, three-dimensional greening is divided into two categories: generalized vertical greening system and generalized roof greening. According to the comprehensive analysis of the literature, some scholars further subdivide the vertical greening system into terms such as green facade and living wall (Table 1).

Methods

Identification

The identification phase establishes reproducible search parameters based on eligibility criteria, through a systematic review of the scientific literature, using the following keywords and phrases: "three-dimensional greening", "vertical greening", "green roofs", "high-density urban spaces", "High Density", "Urban Green Space" and "Vertical Greening System".

Check

Among the relevant literature searched, from the 4494 articles obtained by the keyword search of “three-dimensional greening or vertical greening”, and the 727 articles obtained by the keyword search of “high-density city and green space”, the following types of articles were screened out. Articles: Treatment of urban green spaces with three-dimensional greening elements; studies on high-density urban greening; research unrelated to three-dimensional greening patterns; The procedure isolated 69 highly relevant articles for this review.

Classification

Most of the researches involve the classification of urban space's three-dimensional greening system and the study of thermal performance of urban space. To show the latest research content, it was decided to select only the classification and related technical research that mainly emphasizes three-dimensional greening, no earlier than 2016, and a total of 43 recent studies were selected for more detailed analysis (Table 2).

Results

Application of three-dimensional greening in high-density urban space

(1) Commonly used three-dimensional greening forms

To improve the urban ecological environment, various new forms and new technologies of three-dimensional greening have been widely recognized and applied.(Lin, and Yu, 2020).(Table 3), It has become an important way to improve the high-density urban space environment.

Typical design mode of high-density urban three-dimensional greening

According to relevant information, statistics are made on the famous three-dimensional greening projects that have been built in some high-density cities. Among them, cities with more three-dimensional greening projects in high-density cities include Singapore, Hong Kong, Macau and other places in China.(Zhezhen, 2016).(Table 4).

According to the relevant data and statistical tables, the characteristics of the three-dimensional greening arrangement commonly used in high-density cities can be obtained:

- Full-coverage green roofs are rarely used on the roofs of super high-rise buildings, especially dense green roofs(Besir and Cuce, 2018)., Sometimes solar photovoltaic panels are used instead of green roofs on the top roofs of super high-rise buildings to improve solar energy utilization.

- There are many ways of vertical greening on the wall, including direct climbing, direct green wall, indirect green wall, etc.(Coma, Perez, de Gracia, Bures, Urrestarazu and Cabeza, 2017). Among them, the modular vertical green walls are generally used in low-rise buildings, while the plants in high-rise buildings are mainly climbing plants with strong wind resistance.

Technical application of three-dimensional greening

Technical points of vertical wall greening

(1) Application of modular three-dimensional greening in wall facade

Modularity generally consists of single modules, structural systems and irrigation systems(Peiqiang, Mei and Jiayi, 2017). It is fixed on a wooden frame or a stainless steel frame by lap joints. Specifically, it can be cultivated in the early stage according to the plant species and plant form in the module, and maintained for several months after installation. It has a long life and is suitable for large-scale difficult wall greening. In the modular medium, except for the planting holes of the medium, the rest of the medium is wrapped by the base tape, which will not cause soil erosion(Fig. 3)(Xue, 2019).

(2) Application of paving type three-dimensional greening in wall facade

It is a planting system that attaches the watering system and the wall planting bag to the waterproof membrane to form a wall, and can stabilize the planting system on the wall.(Guodong, 2015). The fixed place should use a unique waterproof fastening method, which is mainly composed of non-woven fabric, waterproof layer and automatic irrigation system(Fig. 4)(Qin, Henglin and Ye, 2016).

(3) Application of flower-style three-dimensional greening in building facades

The wall uses various building materials as the supporting structure, and then the flower pots with plants are fixed on the supporting structure to achieve a three-dimensional greening form of a flower arrangement. The advantages of this technology are that it is easy to install, disassemble and quickly build, and can quickly replace plants. It is often irrigated in the form of drip irrigation, and the plants selected for the flower arrangement are mainly flowers, which are mostly used for outdoor temporary construction of festival celebrations or gathering places, and the landscape viewing effect can be achieved in a short time(Fig. 5)(Huang, Lu, Wong and Poh, 2019).

(4) Application of planting through three-dimensional greening in building facades

The planting trough system usually includes a wall, steel frame, drip irrigation system, plant flower trough, etc. The wall is laid with a steel frame, an automatic drip irrigation system is arranged, and plants are finally discharged. The two methods that are used more now are the combination of horizontal strips or small planting troughs. Relatively speaking, the latter has stronger expressive ability and can be combined at will to form a variety of landscape effects. It can also be combined with the sun's movement trajectory and sunlight to meet the sunlight needs of plants(Fig. 6)(Xue, 2019).

Key points of roof greening technology

Load: Green roofs are widely used in countries with flat roofs and high-rise buildings. The weight of the planting substrate and plants will affect the load-bearing capacity of the roof structure(Cristiano, Deidda and Viola, 2021). There are higher requirements for the load capacity of the building structure. According to the "Technical Regulations for Planting Roof Engineering" (JGJ155-2013), the load of simple planting roof should not be less than 1.0kN/m^2, and the load of garden-type planting roof should not be less than 3.0kN/m^2(Huasheng, 2013). The plant load should include the initial plant load and the variable load that increases during the plant growth period. The initial plant load should meet the requirements in Table 5(Huasheng, 2013).

Key Plant Configuration Modes

There are many forms of three-dimensional greening. In the selection of plant materials, the ecological adaptability and garden artistry of plants should be considered first, and local characteristics should be formed by using local plant resources.

(1) The traditional climbing greening form is mainly used in wall greening. It has strong adaptability and rapid growth. Among them, *Brocade* and *Parthenocissus quinquefolia* are especially suitable for shady growth plants. Commonly used plants are *Hedera Helix, Campsis, Lablab purpureus,Ipomoea nil*, etc(Table 6)(Meiping, 2009).

(2) Modular greening uses artificial light soil when filling the planting matrix, and the thickness of the matrix selected according to the type of plants is also different. For example, the thickness of herbs needs to be 20-30cm(Suqin, 2019). Plant varieties need to choose cold-resistant, drought-resistant, shallow-rooted plants, and can choose types such as ground cover, perennial flowers, moss, and succulent. Because the planting container of the greening module is small, the plants generally choose the herb species with small volume and simple management and maintenance(Qin Jun and Yonghong, 2018).Plants such as *Sedum lineare, Sedum sarmentosum, Sedum aizoon*, etc(Table 7) (Qin, Henglin and Ye, 2016).

(3) The plants commonly used in the paving greening system are herbs with strong adaptability and easy maintenance and management. For example, it is easy to cultivate ferns such as *Sedum lineare, Sedum sarmentosum, Ophiopogon japonicus, Asparagus cochinchinensis, Dichondra repens, Lolium perenne, Zoysia tenuifolia*, or *Nephrolepis biserrata* so on(Qin, Henglin and Ye, 2016).The biggest advantage of the paved three-dimensional greening system is not only simple construction, good greening effect, but also easy maintenance and management. In addition to wall greening, it is also commonly used for urban slope greening (Table 8).

(4) The planting trough greening system is more common, and the variety of plants to choose from is more abundant, which needs to be replaced according to the season to ensure a good ornamental effect throughout the year.(Viecco, Jorquera, Sharma, Bustamante, Fernando and Vera, 2021). The optional

plants are *Hedera helix, Epipremnum aureum, Tradescantia zebrina, Ipomoea, Petunia, Jasminum mesnyi, Climbing Roses*, etc(Table 9)(Qin, Henglin and Ye, 2016).

(5)Roof afforest more commonly used plants have *Bidens alba, Tulbaghia violacea, Alopecurus aequalis, Arachis hypogaea, Momordica charantia, Butterfly bush and Kalanchoe blossfeldiana*, etc(Table 10), Green roofs combined with agriculture to grow edible species(Hachoumi, Pucher, De Vito-Francesco, Prenner, Ertl, Langergraber, Fuerhacker and Allabashi, 2021)., which can reduce carbon footprint and increase the function of urban green infrastructure(Grullon-Penkova, Zimmerman and Gonzalez, 2020).

Discussion

In analyzing thermal performance, Shafique et al. show that green roofs play an important role in making cities sustainable and adaptable to climate change(Shafique, Kim and Rafiq, 2018). Coma et al. found that green walls (58.9%) and double green facades (33.8%) have high energy saving potential during cooling seasons(Coma, Perez, de Gracia, Bures, Urrestarazu and Cabeza, 2017). Medl et al. believe that the three-dimensional greening system of buildings can improve people's thermal comfort, thereby reducing the thermal stress of green walls(Medl, Stangl and Florineth, 2017).

In terms of energy saving, Peng et al. used comprehensive simulations of ENVI-met and EnergyPlus to evaluate the cooling effect of block-scale façade greening in different urban forms(Peng, Jiang, Yang, Wang, He and Chen, 2020). Seyam conducts a systematic analysis of the impact of greening systems on building energy use(Seyam, 2019). Indicates that greening systems should be more studied in actual buildings, residents in different activities, to fully assess the impact of greening systems(Seyam, 2019). Suzaini Mohamed Zaid et al. reviewed Vertical Greening Systems (VGS) in the tropics, their benefits, their carbon sequestration potential and their calculation methods, as well as their potential for urban heat islands (UHI) and climate change mitigation(Zaid, Perisamy, Hussein, Myeda and Zainon, 2018).

Through the analysis of 37 emerging areas of three-dimensional greening systems and 6 sources focusing on high-density urban space. It is found that the thermal performance of three-dimensional greening in high-density urban spaces and the energy saving of buildings have received extensive attention, while the research on the overall performance of plants in three-dimensional greening systems is scattered and incomplete.

Conclusion

To achieve sustainable development of urban greening in the limited space of high-density cities, the refined construction and management of three-dimensional greening is an important development direction. By analyzing the greening patterns, distribution forms, technology applications and three-dimensional greening patterns of typical urban spaces in high-density urban spaces, it further provides some ideas for future methods and supplementary research. At present, most of the review studies focus on the comparison of building energy-saving benefits of three-dimensional greening systems for

residential buildings (or similar) in urban areas, while the energy-saving and mitigation of urban thermal benefits of important different plant types in three-dimensional greening have not been studied. widely observed. Therefore, it is necessary to scientifically evaluate the overall benefits of plants in the three-dimensional greening system and the utilization of the remaining space in urban areas.

References

1. Wei Yk (2016) Research on Evaluation Index of Green View Rate in High Density Urban Areas of Macao Peninsula Dissertation, South China Agricultural University
2. Perez G, Coma J, Barreneche C, Gracia AD, Urrestarazu M, Bures S and Cabeza LF. (2016) Acoustic insulation capacity of Vertical Greenery Systems for buildings. Applied Acoustics:218–226. doi: 10.1016/j.apacoust.2016.03.040
3. Radic M, Dodig MB and Auer T (2019) Green Facades and Living Walls-A Review Establishing the Classification of Construction Types and Mapping the Benefits. Sustainability. doi: 10.3390/su11174579
4. Daemei AB, Azmoodeh M, Zamani Z and Khotbehsara EM (2018) Experimental and simulation studies on the thermal behavior of vertical greenery system for temperature mitigation in urban spaces. Journal of Building Engineering:277–284. doi: 10.1016/j.jobe.2018.07.024
5. Cekic S, Trkulja T and Dosenovic L (2020) Typology of vertical greenery system. Gradevinar:1011–1019. doi: 10.14256/jce.2721.2019
6. Yan LZ, Xiao L, Hou LY and Wang XQ (2019) Application of Three-dimensional Greening in Yuxi Sponge City Construction. China Water & Wastewater:91–95.
7. Medl A, Stangl R and Florineth F (2017) Vertical greening systems - A review on recent technologies and research advancement. Building and Environment:227–239. doi: 10.1016/j.buildenv.2017.08.054
8. Ji L, and Zhuang Y (2020) Research on three-dimensional greening and residential energy consumption and applicability in hot summer and cold winter areas——Taking Shanghai as an example Architecture Technique:72–77.
9. Li XY (2015) Research and application of three-dimensional greening in cities Dissertation, Qingdao University of Technology
10. Duan QM (2019) Design and application of three-dimensional greening in urban street landscape of Qujiang New District, Xi'an. Dissertation, Xi'an University of Architecture and Technology
11. Yue Y (2019) Evaluation and optimization of three-dimensional greening plant landscape of urban roads in Changsha Dissertation, Central South University of Forestry and Technology
12. Wu JH, Lin Zhen and Shu Lianfang (2018) Analysis on the application of vertical greening in urban construction. Journal of Sichuan Forestry Science and Technology:116–119. doi: 10.16779/j.cnki.1003-5508.2018.02.026

13. Zhang ZZ (2016) Research on the environmental impact of three-dimensional greening under high-density blocks Dissertation, Tianjin University
14. Huang HQ (2017) Gardens by the Bay South Gardens, Singapore. World Architecture:78–83. doi: 10.16414/j.wa.2017.04.013
15. Feng XL (2015) Analysis and comparison of three-dimensional greening cases in Guangzhou, Hong Kong and Singapore Guangdong Landscape Architecture:41–45.
16. Mabon L, Kondo K, Kanekiyo H, Hayabuchi Y and Yamaguchi A (2019) Fukuoka: Adapting to climate change through urban green space and the built environment? Cities (London, England):273–285. doi: 10.1016/j.cities.2019.05.007
17. Besir AB. and Cuce E (2018) Green roofs and facades: A comprehensive review. Renewable & Sustainable Energy Reviews:915–939. doi: 10.1016/j.rser.2017.09.106
18. Coma J, Perez G, Gracia AD, Bures S, Urrestarazu M and Cabeza LF.(2017) Vertical greenery systems for energy savings in buildings: A comparative study between green walls and green facades. Building and Environment:228–237. doi: 10.1016/j.buildenv.2016.11.014
19. Chen PQ, Yang M and Wang JY (2017) Spatial development strategy of traditional streets in high-density cities——Taking the reconstruction of the entrance node of Guangqi South Road in Shanghai as an example. Housing Science:15–21. doi: 10.13626/j.cnki.hs.2017.08.006
20. Chen X (2019) Research on three-dimensional greening design of office buildings in Shenzhen. Dissertation, Southwest Jiaotong University
21. Tan GD (2015) Discussion on the application of wall greening in gardens Contemporary Horticulture:163. doi: 10.14051/j.cnki.xdyy.2015.12.134
22. Wang Q, Xiao HL and Chen Y (2016) Discussion on vertical greening mode and plant selection in urban public space Contemporary Horticulture:136–138. doi: 10.14051/j.cnki.xdyy.2016.23.087
23. Huang Z, Lu Y, Wong NH and Poh CH (2019) The true cost of "greening" a building: Life cycle cost analysis of vertical greenery systems (VGS) in tropical climate. Journal of Cleaner Production:437–454. doi: 10.1016/j.jclepro.2019.04.275
24. Cristiano E, Deidda R and Viola F (2021) The role of green roofs in urban Water-Energy-Food-Ecosystem nexus: A review. Science of the Total Environment. doi: 10.1016/j.scitotenv.2020.143876
25. Shang HS (2013) Interpretation of JGJ 155–2013 "Technical Regulations for Planting Roof
26. Engineering" China Building Waterproofing:25–29 + 46. doi: 10.15901/j.cnki.1007-497x.2013.15.006
27. He Y, Yu H, Dong N and Ye H (2016) Thermal and energy performance assessment of extensive green roof in summer: A case study of a lightweight building in Shanghai. Energy and Buildings:762–773. doi: 10.1016/j.enbuild.2016.06.016
28. Vijayaraghavan K.(2016) Green roofs: A critical review on the role of components, benefits, limitations and trends. Renewable & Sustainable Energy Reviews:740–752. doi: 10.1016/j.rser.2015.12.119

29. Pearlmutter, Pucher, Calheiros, Hoffmann, Aicher, Pinho, Stracqualursi, Korolova, Pobric, Galvao, Tokuc, Bas, Theochari, Milosevic, Giancola, Bertino, Castellar, Flaszynska, Onur, Mateo, Andreucci, Milousi, Fonseca, Di Lonardo, Gezik, Pitha and Nehls, 2021
30. Coma J, Perez G, Sole C, Castell A and Cabeza LF (2016) Thermal assessment of extensive green roofs as passive tool for energy savings in buildings. Renewable Energy:1106–1115. doi: 10.1016/j.renene.2015.07.074
31. Gu MP (2009) Application of plant materials in three-dimensional greening Northern Horticulture:217–219.
32. Jia SQ (2019) Research on three-dimensional greening mode and technology of northern urban landscape. Dissertation, Dalian University of Technology
33. Qin J and Hu YH (2018) Building facade greening technology
34. Viecco M, Jorquera H, Sharma A, Bustamante W, Fernando HJ. S. and Vera S (2021) Green roofs and green walls layouts for improved urban air quality by mitigating particulate matter. Building and Environment. doi: 10.1016/j.buildenv.2021.108120
35. Hachoumi I, Pucher B, Vito-Francesco ED, Prenner F,Ertl T, Langergraber G, Fuerhacker M and Allabashi R (2021) Impact of Green Roofs and Vertical Greenery Systems on Surface Runoff Quality. Water. doi: 10.3390/w13192609
36. Grullon-Penkova IF., Zimmerman JK. and Gonzalez G (2020) Green roofs in the tropics: design considerations and vegetation dynamics. Heliyon. doi: 10.1016/j.heliyon.2020.e04712
37. Shafique M, Kim R and Rafiq M (2018) Green roof benefits, opportunities and challenges - A review. Renewable & Sustainable Energy Reviews:757–773. doi: 10.1016/j.rser.2018.04.006
38. Peng LL.H., Jiang ZD, Yang XS, Wang QQ, He YF and Chen SS (2020) Energy savings of block-scale facade greening for different urban forms. Applied Energy. doi: 10.1016/j.apenergy.2020.115844
39. Seyam S (2019) The impact of greenery systems on building energy: Systematic review. Journal of Building Engineering. doi: 10.1016/j.jobe.2019.100887
40. Zaid SM, Perisamy E, Hussein H, Myeda NE and Zainon N (2018) Vertical Greenery System in urban tropical climate and its carbon sequestration potential: A review. Ecological Indicators:57–70. doi: 10.1016/j.ecolind.2018.03.086

Tables

Tables 3,6-10 are available in the Supplementary Files section.

Table 1
Summary of three-dimensional greening research

Author(s)	Using terminology	Area of research	Specific classification	Main research	Result
Cekic, Sandra et al.	Vertical Greening System (VGS)	Wall	Green Facade Subsystem and Living Wall Subsystem	Introduce the basic features, classification principles and benefits of vertical greening systems	A VGS classification principle based on the analysis of vegetation mechanism and the combination of substructures is proposed(Cekic, Trkulja and Dosenovic, 2020).
Yan Lizhen et al.	Three-dimensional greening	Wall, Roof Greening, Shelf, Slope	Wall greening, balcony greening, scaffolding greening, slope greening and roof greening, etc.	Application of three-dimensional greening in sponge reconstruction and construction in Yuxi City	List implementation methods and plant selections(Yan, Xiao, Hou and Wang, 2019).
Mina Radic et al.	Vertical Greening System (VGS)	Wall	Green Facades and Living Walls	Review existing VGS building types and their associated benefits	13 types of VGS structures, 4 types of green facades, 9 types of living walls and 10 benefits identified(Radic, Dodig and Auer, 2019).
Medl, Alexandra et al.	Vertical Greening System	Wall	Green facade and green wall	Provides state-of-the-art systems in the field of vertical greening systems and identifies significant gaps in research.	Lack of complementary research focusing on vertical greening systems(Medl, Stangl and Florineth, 2017).

Table 2
The distribution proportion of each topic in the literature

Related topic	Proportion
Classification and importance of three-dimensional greening system	23%
Thermal performance and cooling effect of urban space	28%
High-density urban green space	14%
Three-dimensional greening technology and system components	14%
Characteristics of different plant species	9%
Other	12%

Table 4
Typical design patterns of three-dimensional greening in high-density cities

Project name	Green location	Geographical location	Green distribution	Plant type	Advantage
Gardens by the Bay	Structure	Singapore	18 tree-like structures with a height of 25 ~ 50m and rockery waterfalls.	Climbers, Epiphytes, and Ferns	• Use energy-saving technologies • A wide variety of plants increase the greening rate of Singapore city. (Huaqing, 2017).
Shatin Sewage Treatment Works	Roof	Hongkong	Extensive renovation of the roof and concrete floor	Ground cover plants	• Alleviate air and appearance issues • Reserve maintenance channels for employees to use(Xiliang, 2015).
Fukuoka ACROS Roof Garden	Roof	Japan	Recessed architectural roof design	Shrubs, Herbs	• Dense plants provide a lot of food and habitat for birds and insects. • Thermal insulation performance saves a lot of energy for the building(Mabon, Kondo, Kanekiyo, Hayabuchi and Yamaguchi, 2019).
"Vertical Forest" in Milan	Balcony	Milan	Planted in "tree pond" modules of different specifications with a height of 110cm and a height of 60cm on the balcony. The total area is 20000m^2.	Trees, shrubs, ground herbs, vines	• Has a strong ecological function • Addressing the current state of air pollution in Milan(Zhezhen, 2016).

Project name	Green location	Geographical location	Green distribution	Plant type	Advantage
Quanxintiandi Phase I and Phase II	High altitude	Hongkong	Open-air garden plaza and "upright garden"	Trees, Shrubs, Climbers	• Add vitality to the old town • Facilitate communication in the community(Xiliang, 2015).

Table 5
Reference table of initial planting load

Project	Arbor (with soil ball)	Big bush	Small shrub	Ground cover plants
Plant height(m)or area(m^2)	H = 2.0 ~ 2.5	H = 1.5 ~ 2.0	H = 1.0 ~ 1.5	S = 1(□)
Plant load (kN/strain)	0.8 ~ 1.2	0.6 ~ 0.8	0.3 ~ 0.6	0.15 ~ 0.3
Planting load (kg/m^2)	250–300	150–250	100–150	50–100
Structure: The roof greening design is composed of several parts from top to bottom (Fig. 7) : Vegetation (landscape material), Growth substrate(matrix)(He, Yu, Dong and Ye, 2016)., Filter, Drainage material (moisturizing)(Vijayaraghavan, 2016)., root barrier (Vijayaraghavan, 2016)., waterproof film(!!! INVALID CITATION !!! (Pearlmutter, Pucher, Calheiros, Hoffmann, Aicher, Pinho, Stracqualursi, Korolova, Pobric, Galvao, Tokuc, Bas, Theochari, Milosevic, Giancola, Bertino, Castellar, Flaszynska, Onur, Mateo, Andreucci, Milousi, Fonseca, Di Lonardo, Gezik, Pitha and Nehls, 2021).)., insulation and structural layer(Coma, Perez, Sole, Castell and Cabeza, 2016).				

Figures

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Figure 1

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Figure 2

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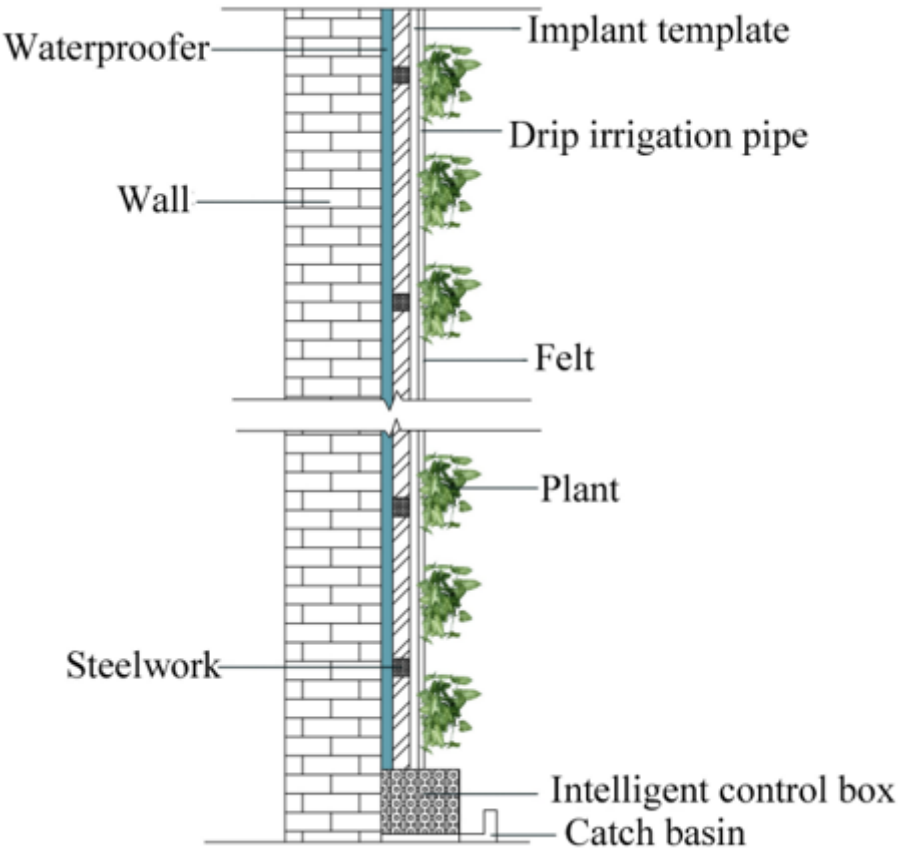

Figure 3

Modular structure

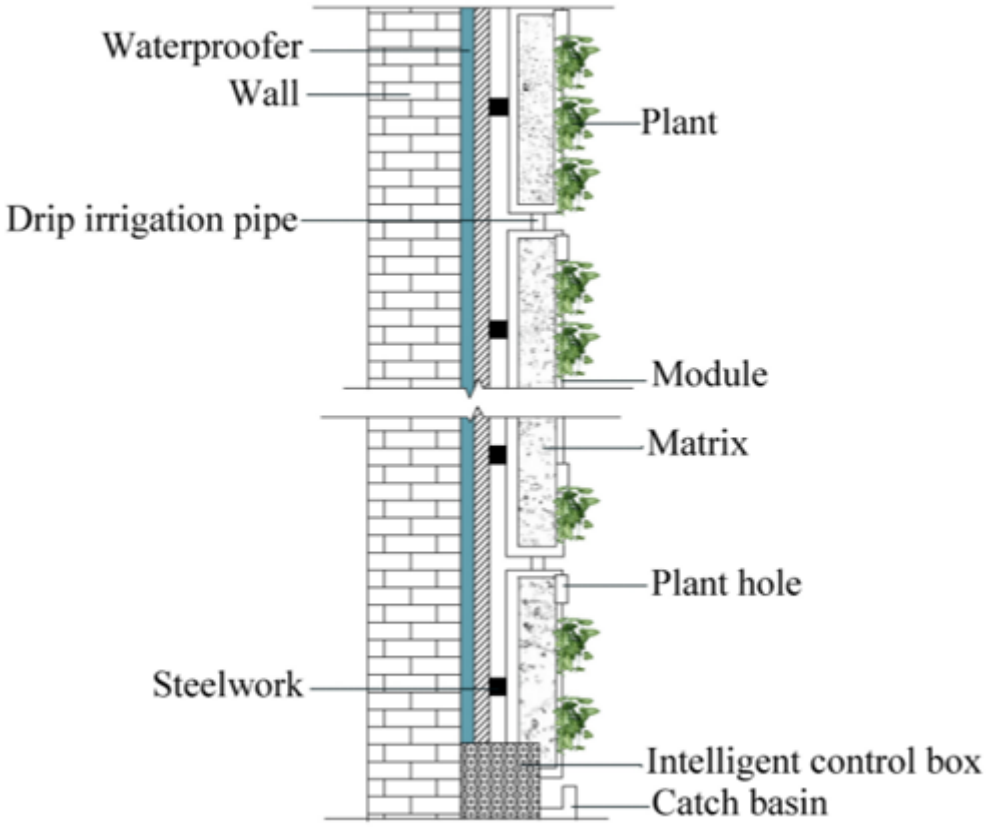

Figure 4

Paved structure

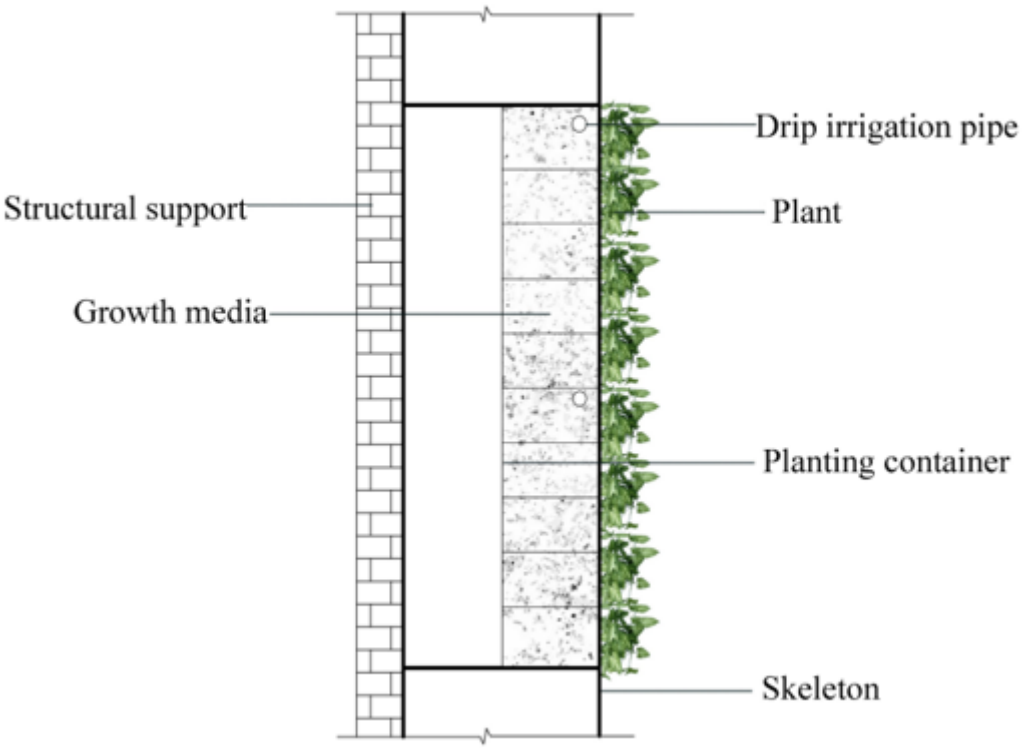

Figure 5

The fancy structure and the real picture

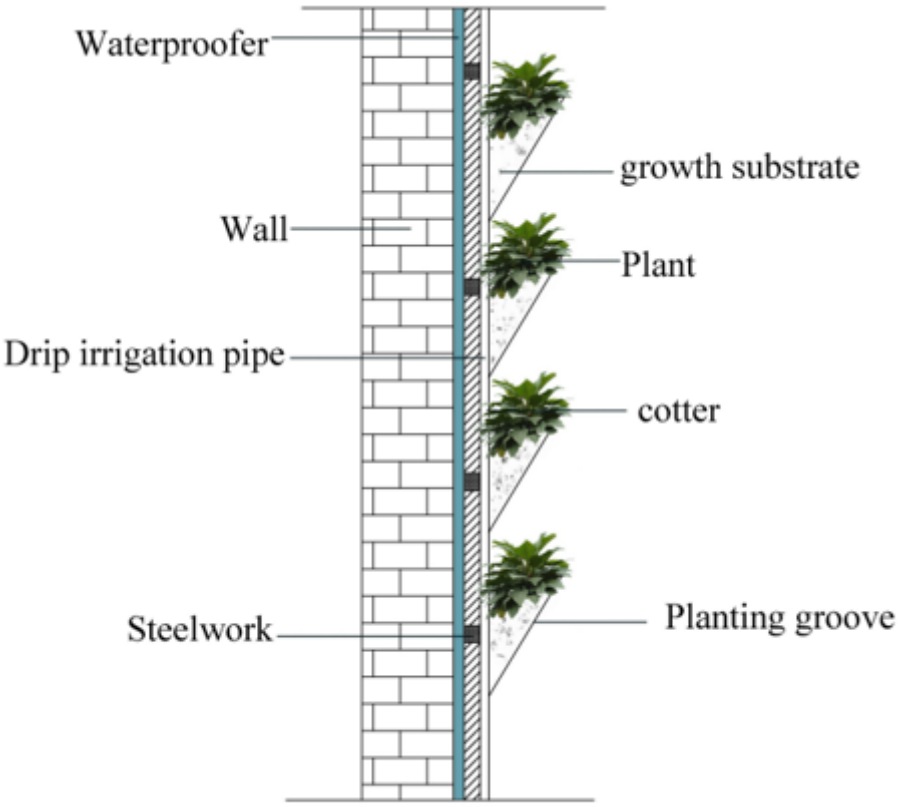

Figure 6

Planting trough and real picture

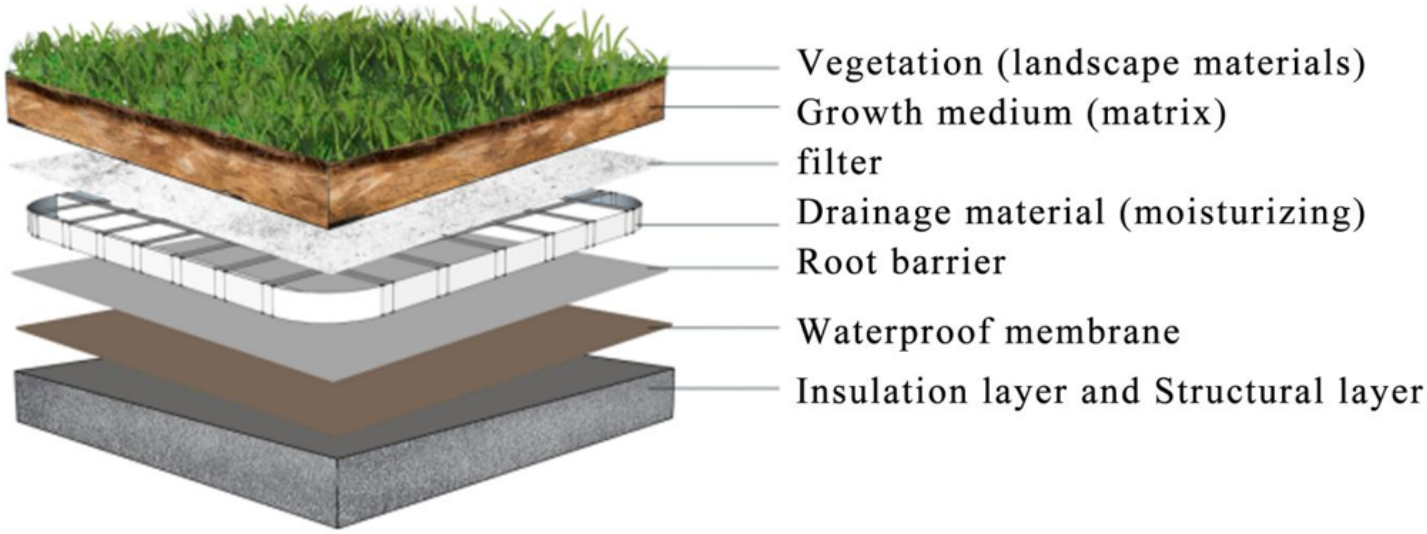

Figure 7

roof greening structure

Supplementary Files

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