

Adaptability Analysis of Artificial Vertical Greening Technology in Interior Design

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Abstract: The paper analyzed the characteristics and components of different technology types in artificial vertical greening systems, and deeply studied the adaptability of different vertical greening systems based on the characteristics of indoor environment. Comparison was applied on various constitutive elements involved in the process of realizing the green wall, such as the plants, growth medium, irrigation, structure, lighting, cost, maintenance, and so on. It is concluded that the vertical module type and the vertical container type in the artificial vertical greening system have the highest adaptability to the indoor environment and are most suitable in indoor design.

1. Introduction

The artificial vertical greening system is a comprehensive product of the combination of plant science, engineering technology and artistic expression. The vertical ecosystem in the tropical rain forest provides the original inspiration and basis for artificial vertical greening, because some plants in the rain forest system survive in harsh places such as towering trunk branches just with some water and minerals. The irrigation method is inspired by waterfalls in nature. With the help of some technical advantages about hydroponics and soilless cultivation of artificial substrates, a mature and stable vertical greening system has been created by combining the conditions mentioned above and several experiments. At present, variety of vertical green walls are under research and development all over the world, and they can be divided into three types according to the type of main technology, namely, hydroponic greening system, vertical modular greening system and vertical container-style greening system.

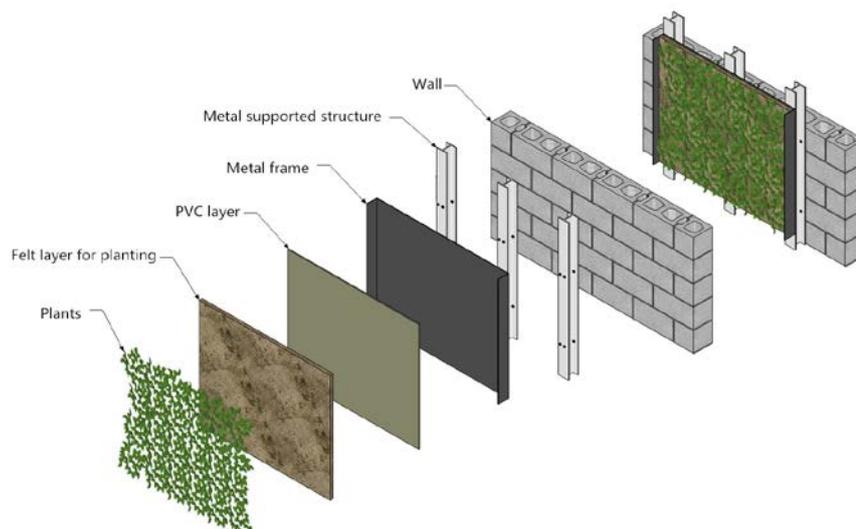


Fig. 1 Schematic structural diagram of hydroponic greening system

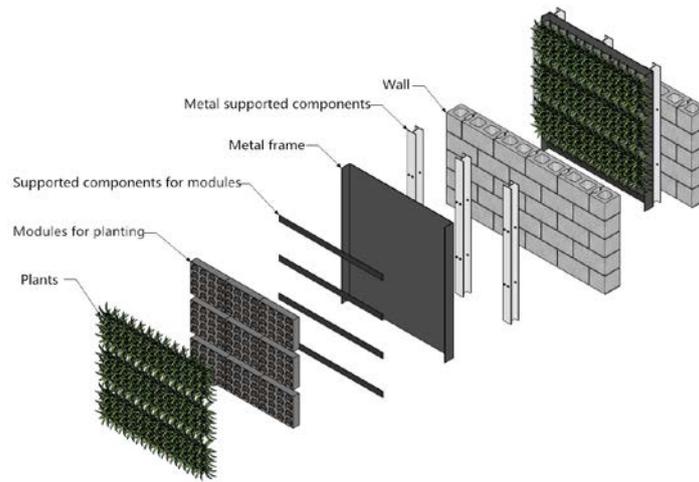


Fig. 2 Schematic structural diagram of vertical modular greening system

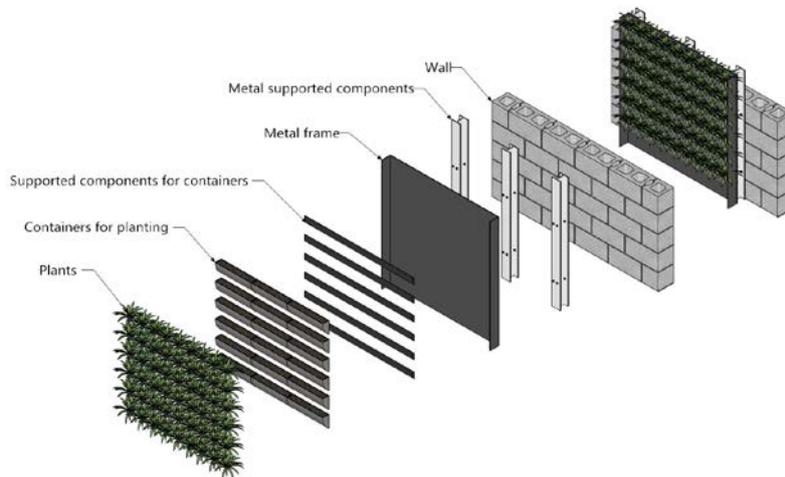


Fig. 3 Schematic structural diagram of vertical container-style greening system

2. Taking the general factors of indoor environment as the object of consideration

There are many differences between the indoor environment and the outdoor environment. Whether the vertical greening system can be successfully applied is related to many indoor and outdoor factors, which can be generally summarized into two major aspects: the certainty of the area, height and carrying capacity of the indoor space and the stability of indoor temperature, illumination and humidity. Considering the general factors existing in the indoor environment, the author discussed the adaptability of the above-mentioned three vertical greening technologies.

2.1 Indoor space structure

The bearing frame system of the artificial vertical greening system is independent of the structure and thus only gives little load to the wall. It can be said that most indoor walls (except movable walls and ordinary partition walls) can be used for the installation of vertical greening systems, and their height and area depend entirely on the designer's needs for project design.

All vertical greening systems need to be covered with plants at last. In this sense, in addition to the structure of the greening walls, the influence of plant factors on the height and area of greening space should also be taken into account. Due to its technical characteristics, artificial vertical greening can adopt a large number of temperate, subtropical and tropical evergreen plants, which can ensure that the green walls remain “lush” all the year round. The vertical greening system supports the growth of plants by means of modules or mutually independent component units. The height at which the planted plants grow depends on the height and position at which the module

components are installed, without the limitation of area and height.

The growth of plants in the artificial vertical greening system depends on nutrient solution rather than soil, which greatly reduces the weight of the whole system. The weight of the whole greening system (including plants, modular components and metal frames) generally does not exceed 30kg per square meter. Therefore, the artificial vertical greening systems have obvious advantages in the bearing capacity of indoor space structure. In the three types of artificial vertical greening systems, the vertical module type and the vertical container type need to be supplemented by auxiliary bearing supports. However, the hydroponics type uses felt instead of soil or other traditional cultivation media, which greatly reduces the thickness of the whole green wall and take up the least space. Compared with the three, hydroponics type has the lightest weight per unit area and the smallest burden on structural walls.

2.2 Indoor lighting

Even for plants with extremely low requirement for light intensity, they need artificial lighting when they are located indoors. Only when the light intensity reaches at least the compensation point (the compensation point means that, under a certain light intensity, the photosynthetic intensity in the plant is equal to the respiratory intensity and the amount of carbon dioxide absorbed and released is the same) can plants grow healthily. When artificial light sources are used to compensate indoor light, the illumination should be between 900 and 10000 lux.

Since the intensity of illumination gradually weakens with the increase of distance from the light source, the distribution of illumination intensity on the artificial illumination surface is uneven. This rule needs to be taken into account when selecting plants. That is to say, a green wall system cannot only use a single kind of plants. Plants with high light demand need to be arranged at a higher position, while plants with low light demand need to be arranged at a lower position. The types of plants that can be used in the artificial vertical greening system are very wide, and plant that do not require much light illumination, such as sciophilous plants or understory plants, can be selected indoors.

3. Taking the technical points of the greening system as the object of consideration

“Fully understanding the environment for vertical growth” is the key point of whether an indoor vertical greening project can established and whether it can be maintained in a good condition for a long period of time. In addition to the indoor temperature, lighting, fixed structure and other factors discussed in the previous chapter, it is also necessary to compare the plant selection, greening effect, growth medium, irrigation system and other technical points in various vertical greening systems. Only in this way can we find the most suitable vertical greening technology for the indoor environment and make the green wall system have good adaptability in the indoor environment.

3.1 Plant selection

The natural lighting indoors is much lower than that outdoors, so tropical sciophilous plants should be chosen even if artificial lighting is adopted as an aid. In the indoor vertical greening systems, plants are usually divided into three areas according to planting height. Large semi-epiphytic plants demanding much light exposure are assembles on the upper part, such as Ficus, *Clusia rosea* Jacq, *Philodendron* Schott, and so on. Adnascent plants that grow on branches or tree trunks (*Medinilla* Gaudich, *Anthurium* Schott, *Philodendron* Schott, *Aeschynanthus* Jack, etc.) can be planted at the middle part. The middle and lower parts are selected from understory plants and riparian plants, such as *Pilea* Lindl, *Elatostema* Gaud, *Fittonia* spp, *Episcia*, *Begonia* Linn, *Spathiphyllum*, etc.

In plant selection, some large tropical plants are not suitable for hydroponics because of their heavy weight. The hydroponic greening system has no soil-like growth medium and relies on felt to fix plants, and thus its carrying capacity is not as good as that of the vertical container-style system and modular system. The hydroponic system is more suitable for plants which grow in rain forests, waterfalls, river banks and other similar environments, because they can still grow freely in soilless

environments. Both the modular system and vertical container-style system have soil-like growth media, so they are more suitable for plants that naturally grow in the soil, especially tropical plants.

3.2 Greening effects

The artificial vertical greening system makes the rich selection of plants and different kinds of plants can be placed in the same planting structural unit. The combination of different forms and colors of plants can form a vertical greening effect with vivid composition, rich colors, different graphics and distinct layers.

3.3 Immediate greening

There should be a realistic estimate of the beauty of vertical greening and the growth trend of plants. For different kinds of green wall systems, the time length that the plants require to grow well and cover the wall is completely different. Compared with the three artificial greening systems, the modular system takes the shortest time. The reason is that it is composed of unit components. The plants adopted in this system can be planted in advance and installed when they are fully grown. The plant supplier can cultivate plants in advance in modules, and then extract corresponding varieties and quantities of plant modules for direct use in green wall installation according to the design scheme.

3.4 Growth medium

In terms of growth media, the soil used in the artificial vertical greening system has many drawbacks, such as large dead weight, the growth of microorganisms and bacteria in the soil, and so on. In comparison, the hydroponic nutrient solution cultivation technique combined with light hairy felt can realize complete inorganic dosing, achieving an effect of inhibiting mold and preserving corrosion. Its disadvantage is that, with the growth of plants, the root system is more and more firmly fixed to the felt layer and the plant weight is also gradually increasing. If a necrotic plant needs to be replaced, the felt layer will be torn and damaged during the removal process.

The growth medium used in the modular system and the vertical container-style system is a highly inorganic solid mixture. Although its weight is more than the felt, it has the advantage of extremely low maintenance cost. Since the growth medium is placed in the module boxes or containers, it is very convenient to replace the module or container of a certain unit when the plant is dead or the design effect needs to be adjusted. In the modular system, only one plant is planted in each card basin, and the impact and damage brought by plant replacement to the surrounding plants in the system is the lowest.

3.5 Irrigation methods

For vertical greening, the location of irrigation system is most important. In an indoor environment, precise irrigation systems are usually used instead of artificial irrigation. Irrigation systems used in artificial vertical greening technology include spray irrigation and drip irrigation.

Mechanical spray irrigation requires the erection of pipelines on the facade of the wall and then the power facility installed can spray water onto plants. Although the initial investment is relatively large, the irrigation speed of mechanical spray irrigation is fast, and it is very suitable for watering large-area green plants. Irrigation pipes can be flexibly arranged on the facade of the wall to irrigate every plant in the green wall. Besides, it will not limit the area and form of vertical greening, which can give more flexible design space to vertical greening.

Drip irrigation requires power facilities. By controlling the water pressure, water is slowly dripped into the growth medium. This irrigation method not only saves water, but also has a better drip irrigation effect. The spray head can be directly inserted into the maintenance matrix of the plants to directly supply water to the plants from their root. However, direct contact between the dropper and the growth medium should be avoided as far as possible to avoid the blockage of the dropper.

Indoor vertical greening also requires special attention to waterproof and drainage of walls and floors. The lowest part of the green wall needs to be installed with a drainage channel to collect and

guide excess water into the recycling container, so as to prevent the ground from being eroded and avoid damage to building components.

4. Taking the implementation cost of the greening system as the consideration object

It is necessary for designers to discuss the implementation cost of the green wall system with customers at the beginning, which mainly includes the cost of construction and the cost of post-maintenance. All vertical greening projects are different, so the cost and benefits are also different. Customers are expected to fully understand these situations. Here are some variables that have the greatest impact on the design, installation and maintenance cost of vertical greening:

- The size of the project;
- The funds needed by the design team;
- System type used;
- Requirements for the load-bearing system;
- The location of the project;
- The complexity of the design and the standard or custom components used;
- The conditions of the location and the convenience of traffic;
- Labor cost for installation;
- Whether local materials can be used;
- Time requirement;
- The type of plant used;
- Cost for short-term and long-term maintenance.

4.1 Cost of construction

The cost of design and construction of artificial vertical greening remains high because of various factors involved in the whole process, such as independent bearing structure, different varieties of plants and component materials, growth matrix, precise node design and irrigation system according to plant varieties, plane design that needs to be specially coordinated with manufacturers, special requirements for the quality and technology of construction personnel, etc. The following is the cost of main materials and component of the three vertical greening technologies.

Vertical container-style system: plant material is 100-200 yuan/m², growth medium 50-100 yuan/m², planting base plate member 200-300 yuan/m², installation member 50-100 yuan/m², irrigation system 50-100 yuan and others (labor, nutrient solution and water consumption) 50-100 yuan/m². The comprehensive cost is 600-1000 yuan/m².

Vertical modular system: plant material is 100-200 yuan/m², growth medium 50-100 yuan/m², planting base plate component 400-500 yuan/m², installation component 50-100 yuan/m², irrigation system 50-100 yuan and others (labor, nutrient solution and water consumption) 100-200 yuan/ m². The comprehensive cost is 800-1000 yuan/m².

Hydroponic system: plant material is 100-200 yuan/m², planting base plate component 500-700 yuan/m², installation component 100-200 yuan/m², irrigation system 50-100 yuan and others (labor, nutrient solution and water consumption) 100-200 yuan/m². The comprehensive cost is 1000-2000 yuan/ m².

It can be found through comparison that, the total cost of the artificial vertical greening system (covering plants, growth media, irrigation system and cost of installation) is several times the cost of materials, and the comprehensive cost of hydroponics is the highest. Of course, the labor cost and material cost often vary because of the location of the specific project, but an experienced supplier can provide a reasonable estimate in the design process. When calculating the installation cost, it is necessary to prepare the plants at least 6 months in advance to avoid any delay in the project due to the plants. In addition, preparation in advance can also reduce cost, because in most cases, the longer the period in advance, the lower the cost.

4.2 Post-maintenance

As a kind of life system, all vertical greening needs a certain degree of post-maintenance, and how much customers are willing to pay for the maintenance is a key factor affecting the whole vertical greening design. Typical green wall maintenance requires the following work:

- Adjusting the monitoring and irrigation system according to seasonal changes;
- Remote monitor alarms and water consumption;
- Adjusting the plant nutrition supplier;
- Using biological measures to control pests and diseases;
- Remove weeds and all debris;
- Trimming the plants regularly;

The cost of post-maintenance is mainly for plants, and the correct selection of plant species will directly affect the maintenance cost. Artificial vertical greening poses a challenge to the growth of plants. These plants are separated from their natural habitat and live in thinner and smaller artificial spaces, and therefore, they require careful post-maintenance to ensure growth. The first year is the critical period for plant domestication, so it is critical to ensure the normal operation of the green wall irrigation system. The fertilizer can be dissolved in water to water the plants through an irrigation system. It is best not to use fertilizer with peculiar smell, or it will cause indoor environmental pollution. The rotten and yellowed branches and leaves should be inspected and removed regularly to maintain the health of the system.

According to the investigation, vertical greening requires about 2 times of maintenance per month on average. Taking the green wall system of Shanghai K11 shopping mall as an example, the maintenance cost is about 10,000 yuan each time. Plants should be clipped once or twice a year. Although all the green wall plants are perennial, a few of them should be replaced over time.

5. Conclusion

The success of artificial vertical greening depends on three factors: growth medium, monitoring irrigation system and plant type. Considering the structural factors of indoor space (including four variables, namely, the space height, area, finished surface thickness of the green wall and weight load), the following conclusions are drawn:

The three types of artificial vertical greening systems have no limitations in height and area of indoor space; The hydroponic green wall has the smallest finished surface thickness and the vertical container-style green wall has the largest finished surface thickness. The total weight of the hydroponic system is the lightest; the straight wall container-style system is the second, and the vertical module type is the heaviest; Based on the above, the vertical hydroponic greening system has the best adaptability from the perspective of indoor space structure. Considering the factors of indoor light, temperature and humidity, the following conclusions are drawn: When a vertical greening system is used indoors, it needs the help of artificial lighting and sciophilous plants should be selected; Due to the uneven illumination of indoor artificial lighting, it is necessary to adopt layered and multi-species plant planting methods, and the natural vertical greening system is not suitable for indoor lighting because it adopts only one single species of plants; The artificial vertical greening technology has no limitations in indoor lighting due to the wide selection of plants; The stability of indoor temperature and humidity is an extremely favorable condition for the growth of green wall plants. The following comparisons are made among the three vertical greening systems based on the technical points of the greening systems, shown in Table 1 and Table 2.

Table 1 Comparisons of three vertical greening systems based on the technical points of the greening systems

Technology type	Category	Plant selection	Adoption of climbing plants	Growth medium	Importance of irrigation system	Irrigation mode
Hydroponics	Artificial	Relatively extensive	Partial adoption	Plant felt, nutrient solution	Important	Spray irrigation and drip irrigation
Vertical module	Artificial	Extensive	Partial adoption	Inorganic solid particle mixture	Important	Spray irrigation and drip irrigation
Vertical container	Artificial	Extensive	Partial adoption	Inorganic solid particle mixture	Important	Spray irrigation and drip irrigation

Table 2 Comparisons of three vertical greening systems based on the technical points of the greening systems

Technology type	Greening effect	Immediate greening	Cost of construction	Maintenance frequency	Maintenance cost
Hydroponics	Rich	Excellent	High	High	Very high
Vertical module	Rich	Optimal	High	Relatively high	High
Vertical container	Rich	Excellent	Relatively high	Moderate	Moderate

It can be seen from the data in the tables above that, among the three artificial vertical greening systems, the vertical modular system and the vertical container-style system have the highest adaptability to the indoor environment and are most suitable for use in indoor design. The specific performance is as follows:

Plants have the widest scope of application, rich and free greening effects and immediate greening ability;

They can fully meet the design requirements for the height and area of the green wall, and the pressure of the weight load on the building structure is relatively small;

Plants have strong adaptability to indoor light, temperature, humidity and other variables;

The clean growth medium is easy to keep, replace and maintain later;

The irrigation system can achieve saving water and cycle use, with perfect waterproof and drainage techniques;

Its cost of construction, maintenance frequency and maintenance cost are lower than those of hydroponics.

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