Special Space and Plant Landscape Design of Urban Ecological Buildings

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Abstract This paper mainly discusses the application of plant landscape design in special space of ecological buildings. From the concept of special space of ecological buildings, it elaborates social benefits and ecological benefits of greening projects in special space. It introduces the classification method for special space of ecological building with habitat as the major part combining characteristics of building form. On the basis of such classification, it discusses green design method and plant selection principle, to provide certain reference for garden designers in green design of ecological buildings.

Key words Ecological buildings, Special space, Greening design, Plant landscape

1 Introduction

With acceleration of the urbanization process, urban problems become more and more serious, urban energy consumption is also increasing, urban residents are eager to "return to nature and be around nature", and urban residents have higher demands for urban living environment, thus urban ecological building is brought into agenda and becomes particularly urgent. For urban ecological buildings, building materials and design should reflect ecology and treatment for vertical space inside and outside buildings also should manifest ecology. As a comprehensive concept, modern ecological building is the construction closely combining architecture, ecology, aesthetics, energy, environmental protection, greening and new and high technologies. To meet this requirement, we will firstly analyze connotation, types and characteristics of special space of ecological building, and then discuss plant landscaping design and the application of special space greening in ecological buildings.

2 Connotation of special space of urban ecological buildings

In the *Ecological Building Evaluation Standard* issued by China, the ecological building is defined as the construction that can conserve resource to the maximum extent, protect environment and reduce environment, and provide healthy, comfortable and high efficient space use, and get along harmoniously with nature in its whole life cycle. This is a definition specified for evaluation of ecological buildings. Obviously, "getting along harmoniously with nature" is the core technology for constructing green buildings, and some experts summarize ecological buildings to buildings with features of Renew, Recycling, Reuse and Reduce (4R)[1]. However, we think that modern ecological buildings are oriented towards function and space design, satisfy functional demand, and create space suitable for demands of the masses. At the same time of satisfying function and space demands, ecological buildings stress resource and environment, and emphasize that it is required to reduce energy and resource consumption and reduce environment pollution in the whole life cycle of buildings. The increase in urban buildings and structures is one of characteristics of urban development. It reduces naturalness of cities, but building space derived therefrom is several times the coverage area of buildings and structures and provides new space for development of urban vegetation. Special green space of urban buildings should include space generated from buildings and structures and conditions for plant growth[2]. Therefore, we define special space of ecological buildings as space and surface formed by urban buildings and structures and possible to support normal growth of plants in natural conditions or artificial measures.

3 Social and ecological benefits of special space greening of ecological buildings

3.1 Conserving energy and adjusting local climate Greening of ecological buildings has gifted advantages in insulating heat and lowering temperature. Traditional heat insulation methods generally lead to rise of surface temperature and increase in energy waste. As a result, it will influence and increase outdoor temperature, intensify tropical island effect, influence urban climate, and lead to vicious cycle of environment quality. Using flowers, grasses, trees, and climbing plants to shade sun and insulate heat can draw support from photosynthesis, transpiration, and photobiomodulation of plants and can convert solar radiation into new energy. Besides, in the transpiration process, apart from converting solar energy to heat effect, it will also absorb energy from ambient environment, so as to reduce ambient temperature and bring about benign cycle of energy use. Building greening project can conserve large volume of energy and accordingly alleviate the problem of

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short supply of urban power supply. Also, the drop of urban ambient temperature is favorable for improving urban climate.

3.2 Increasing urban green capacity and improving green awareness The greatest contribution of building greening project to urban green coverage lies in large green roof, which is reputed as "the Fifth Elevation" of urban buildings. Generally, urban roof accounts 30% of the total urban area and 25% of urban roof can be designed with green plants. Most people take for granted that building greening is microcosmic greening and has limited contribution to cities. In fact, it is not like this. Therefore, "never do things just because it is little". It is particularly important to summon up urban greening awareness.

3.3 Advocating green mode and innovating on life style Building greening and application of a lot of new materials and process in buildings not only create new buildings suitable for human beings and social development, but also beautify environment and improve living quality of human beings. In addition, owners can relax themselves in appreciation and management of building green landscape, cultivate their taste and enhance their awareness of environmental protection.

4 Types of special space of ecological buildings

Knowing and dividing types of buildings and structures are helpful for carrying out ecological research of plants in special space and promoting effective use of such special green space. On the basis of analyzing classification of other scholars, we divide special space of buildings into two types: the first is indoor green space, *i. e.* the internal building space where plants may grow only through artificial measures, such as library and science and technology center; the other is outdoor green space, *i. e.* the external building space where plants can grow naturally or half naturally. The specific situations are as follows.

4.1 Indoor space The indoor space mainly refers to hall and atrium of buildings, some scholars call indoor space atrium space. The atrium space greening has been widely applied in various buildings, such as office building, restaurants and hotels, large commercial facilities, public facilities, and museums. However, other space in these buildings should not be neglected, because ordinary internal space also belongs to indoor space. For indoor greening, it not only has decoration and beautification functions, but also plays a great role in environmental protection and health, improves indoor air and working environment, and adjusts psychology and physiology of people. Therefore, greening of ordinary indoor space, such as entrance hall, meeting room, banquet hall, office room, corridor, guest room, and washing room, should also be integral part of indoor greening.

4.2 Outdoor space Outdoor space mainly refers to external surface of buildings and structures. Greening of outdoor space includes plane space greening and vertical space greening. Plane space greening includes roof garden and roof courtyard, and park in parking lot, as well as surface greening of underground structures; facade space greening is vertical greening in vertical direction of buildings, it takes up little or no land, includes building wall, windowsill, and courtyard fences[3], as shown in Fig. 1.

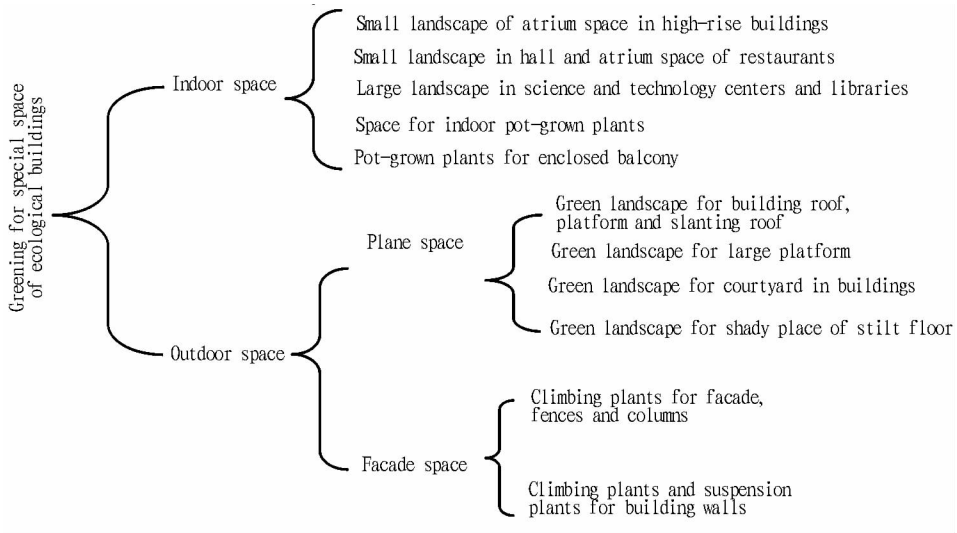

Fig. 1 Classification of special space of ecological buildings

5 Greening and planting design for special space of ecological buildings

Greening system for special space is an important subsystem of ecological buildings. It can play the role of improving internal and external climate conditions of buildings and cleaning up environment through its ecology. Besides, building greening also has function of cultivating taste and satisfying demand of appreciation. Thus, it seems quite important for studying how to create or improve special space of various buildings to set up the greening system. For this, we should know how to scientifically and reasonably conduct greening design, so as to bring into full play ecological benefits of plants. Following three principles should be adhered to when designing the greening system. (i) Greening design should accord with local situations; (ii) Plants should be selected in accordance with local conditions; (iii) Greening should be consistent with landscape and style of build-

ings. The detail is as follows:

5.1 Design for root greening plants Roof gardening not only is garden art, but also involves load bearing of structures, waterproof and drainage structure, plant disposition, and selection of soil, as well as routine maintenance[4]. The selection of plants and soil is the key technology for roof greening. Therefore, plants should be selected according to local climate and natural conditions and should be suitable for local soil type and thickness. The substrate of root planting layer is generally 7 – 9 cm thick. Planting substrate should adopt natural or artificial material with high porosity, small density, resistance to flushing, and suitable for plant growth; for water-proof measure, it is recommended to adopt those materials with root separation function; for water drainage, drainage board is widely applied; for selection of greening plants, it is preferred to select small arbors, shrubs, ground cover, and perennial root flowers with highly comprehensive, low root system, slow growth, cold resistance, drought resistance, and easy management. For example, shade resistant plants can select Mahonia ganpingensis and Fatsia japonica, *etc*. Drought resistant plants include Sedum lineare Thunb., Hylotelephium erythrostictum (Miq.) H. Ohba, Sedum sieboldii, Sedum emarginatum Migo, and Portulaca grandiflora. Health care plants include *Glechoma* hederacea 'Variegata', Bambusa multiplex (Lour.) Raeusch, Camellia sasanqua and Canna indica L[5].

5.2 Greening of balcony and windowsill Since balcony and windowsill are situated in the middle of buildings and belong to suspended space, their greening size depends on the area reserved by the architect in designing. It is difficult to provide greening in balcony and windowsill. In general, greening design is simple and mainly considers selection of plants and position of planting. For example, it is preferable to select more plants that resist drought, have low root system, and high adaptability, such as *Asparagus cochinchinensis* (Lour.) Merr, *Pyrostegia venusta* (Ker – Gawl.) Miers, *Lonicera japonica*, *Hedera nepalensis* var. *sinensis* (Tobl.) Rehd, *Pharbitis nil* (L.) Choisy, azalea, camellia, *Aglaia odorata* Lour, *Murraya exotica*, oranges and tangerines, Chinese rose, and orchid. Also, it is feasible make humanized greening design according to perfect water supply and drainage measures and personal demands.

5.3 Wall greening Wall greening generally has two situations: one is using climbing plants on ordinary walls, and the other is designing walls suitable for greening to vertical flower walls. Wall greening is very difficult and should have unified planning, design, planting and management. It is required to avoid different style of greening influences overall building landscape. Wall surface greening is simple and feasible, and costs little. Generally, we can use absorption, twining, climbing, flagging characteristics of climbing plants to conduct wall surface greening. Common climbing plants include boston ivy, *Hedera nepalensis* var. *sinensis* (Tobl.) Rehd, *Wisteria sinensis*, *Celastrus orbiculatus* Thunb., *Ficus pumila* Linn., *Parthenocissus tricuspidata*, *Campsis grandiflora* (Thunb.) Schum., *Quamoclit pennata* (Desr.) Bojer, *Pharbitis nil* (L.) Choisy, Luffa cylindrical, and *Lonicera japonica*.

5.4 Inner court greening The inner court greening has two types: (i) inner court within the building room; (ii) inner court within the building. Different inner courts have different environment characteristics, therefore it is required to select proper plants in accordance with local situation. For inner court within the building room, it is preferred to select plants that can absorb harmful gases, such as *Chlorophytum comosum* (Thunb.) Baker, *Hedera nepalensis* var. *sinensis* (Tobl.) Rehd, *pilea notata* c. h. wright. Plants with aroma and bactericidal action and health care, such as Zanthoxylum 'Odorum' and lemon, can be applied. For large hall in inner court, it is recommended to select large and colorful plants, such as Chrysalidocarpus lutescens, Phoenix roebelenii, Dypsis decaryi, and Ficus microcarpa. For green of inner court within buildings, it is feasible to select some shade-requiring plants or neutral plants, such as *Elaeocarpus decipiens* Hemsl., *Livistona chinensis*, *Cycas revoluta* Thunb., *Yucca smalliana* Fern., *Magnolia grandiflora* L., *Osmanthus fragrans* (Thunb.) Lour., and *Camellia japonica* L., *etc*.

5.5 Stilt floor greening The stilt floor is relatively independent space formed by columns of buildings. Using building wall and columns, and with the aid of enframed scenery, borrowed scenery and perspective scenery methods, through setting corridor and stand, planting pool and building pond, combining with garden plants, it forms various clever and unique garden landscape, accordingly greatly increases comfort and appreciation of residential landscape[6]. Since there is certain limitation in sunshine and ventilation due to position of the stilt floor, selection of plant varieties is a key factor. In fact, it is preferred to select shade-enduring, drought resisting and shallow root system plants, such as *Fatsia japonica* (Thunb.) Decne. *et* Planch, *Maranta arundinacea* L., var. *variegata* Dombr., *Osmanthus fragrans* var. *semperflorens*, and *Ophiopogon japonicus*. Besides, the plant height should be controlled.

6 Conclusions

Greening for special place of buildings is an essential part of ecological architectural design, while the ecological building is specific manifestation of construction of ecological civilization and also the objective requirement for building resource saving and environment-friendly society. Therefore, to create environment protective, healthy, energy conserving, low-consumption, comfortable and livable working and living space, nature should be incorporated into architectural design and it is required to make people feel, experience and care nature. With scientific and technological development, architects can make bold attempt of various concepts, organically integrate green design and building skills and create new building form. Especially, they should attach importance to applying greening project for special place of buildings, bring into full play ecological function of green project, and make it become an effective way of constructing ecological buildings. The green-

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need different percentage of wetted soil area, as listed in Table 5. In the early stage of crop growth, this percentage may adopt the lower limit; with the crop growth and root system expansion, it can gradually increase to the upper limit. For example, at the early stage of growth, tomato root system is mainly distributed in 0-30 cm; later, it can expand to 0-50 cm. Thus, wetting layer of drip plan and the percentage of wetted soil area should be increased accordingly. Crop growth needs proper soil moisture. Different crops need different soil moisture. For most crops, the field moisture capacity should be kept higher than 70%-80%, but too moist soil is also harmful to crops. With the aid of hand feeling, it is able to judge whether the soil moisture is suitable. Usually, loam should become soil ball and it will not fall apart when slightly tossing; clay soil should be able to become strips when rubbing with hands.

Table 5 Designed percentage of wetted soil area for micro spray

Crops	Drip irrigation//%	Micro spray//%
Fruit trees	25 – 40	40 – 60
Grape and melons	30 – 50	30 – 50
Vegetables	60 – 90	70 – 100
Grain, cotton, oil, and tea, *etc.*	60 – 90	100

4 Conclusions

Fertigation technology is a comprehensive technology. It needs learning application knowledge of facilities and fertigation. Especially, due to influence of many factors, there are still no sufficient and pertinent fundamental data for determining water and fertilizer application of different crops. It needs a long period of research and practice to accumulate experience. However, with the extension of integration water and fertilizer technology, it is expected to obtain better effect than conventional fertilization and irrigation through strengthening construction of management and technical service system. Besides, it is expected to greatly promote improvement of agricultural modernization and make great contribution to strategic objective of "five water treatment" in Zhejiang Province.

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ing for special space of buildings will be a new field of urban green development and will play an important role in design and construction of ecological buildings.

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