

A Study on the Types of Vertical Greening Applying to Urban Existing Buildings in Taiwan

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Abstract -There are more than 30 percent of the buildings were built over 20 years in Taiwan, which occurred the problem of aging such as poor landscape and energy wasting. It suggests that vertical greening could be a relatively easy way to cool down the temperature and reduce the effect on the environment in crowded urban areas. The paper aims on exploring the type of applying vertical greening on buildings, which will hopefully create benefits by increasing urban greenery, reducing urban heat island effect, and improving environmental landscape and achieve a low carbon sustainable eco-city. Therefore, the paper attempts to understand the development of vertical greening by literature review, case study and field survey, then to classify the existing buildings as traditional buildings, detached houses/terraces, apartments, and elevator mansions. In conclusion, a variety of plantings applied to different building types for plantation ecology and visual effects as the development of diversity and sustainability, which indicated a need to stipulate design criteria on the basis of building types and environment, and provide possible types of vertical greening applied to different categories of existing buildings to promote a sustainable city.

Keywords: Vertical Greening, Urban Existing Building, Taiwan

1. Introduction

Global warming has been occurring extremely effects of urban heat island, desertification and compound natural disasters in general, and more than 30 % of the buildings over 20 years which generating poor landscape and energy wasting in Taiwan in particular (Chang, 2006; Peng, *et al.* 2013). Therefore, the Taiwanese government has currently been initiating policies encouraging a project of building façade “Facelift” as one of urban renovations to enhance urban landscaping, decrease environmental impact and CO2 emissions (Peng, 2012). The paper intends to explore the way of applying vertical greening to renovate building’s façade as an alternative of the project.

Taiwan is located in subtropical climate, due to the fact of lacking vertical greening design specifications and criteria that especially fit its subtropical climate and local features. The paper applied literature review, case study and field survey that aimed to analyse the vertical greening development in Taiwan, classify the urban existing building’s types and try to make recommendations of applying possible types of vertical greening to different categories of existing buildings as follows.





2. Type Analysis of Urban Existing Buildings

The paper takes those buildings over 20 years with aging appearances yet no instant dangers of collapses as existing buildings in urban areas, then it classifies four types of buildings, traditional buildings, detached houses/terraces, apartments, and elevator mansions which based on their appearances, heights and characteristics:

1. Traditional buildings: these are mostly three-section compounds, four-section compounds, stone slab houses and rammed-earth houses; as well as south-fujian style buildings and japanese style buildings with ages of 30-40 years and one-storey height; since the walls are made of wood, brick tiles and clay-bamboo walls; therefore, the future vertical greening should take the different wall materials into consideration.

2. Detached houses/terraces: these refer to the housing that reside only one household unit or one family with one building address. Detached houses can be traced back as the early building type in taiwan. Whereas this type of buildings are mainly with ages around 30 years in terms of detached houses or terraces such as farm houses, commercial circles or terraces of existing communities. These building heights range from 1~3 stories and most of them are made of rc, bricks, tiles, washed pebbles and cements.
3. Apartments: these are mostly buildings with multiple levels and floors with different residents and households under one building address. Currently, most of the existing apartments are under 5–story high and without elevators. Since they were built in the early 60~70’s, the communities are now usually found with narrow alleys, high building coverage and lacking statutory open spaces. The external walls of these buildings are majorly made of rc, tiles, rectangular tiles and washed pebbles. Moreover, most of the buildings are accompanied with illegal roof expansions.
4. Elevator mansions: these buildings are similar with apartments but built with more floors and equipped with elevators. They are generally defined as building higher than 10-storey buildings equipped with elevators and ages around 20 years. The external walls are mostly made of rc, src, alc and stone walls with more fashionable modern looks than the previous three types of buildings. The following table 1 shows construction, material and component of four types of existing building:

Table. 1. Construction, material and component of four types of existing building.

	Traditional buildings (three-section compound)	Detached houses/terraces	Apartments	Elevator mansions
Building age	30-40 years	Around 30 years	20~40 years	Around 20 years
Building height	About 3m, 1-storey high	About 11m, 3-storey high	About 15m, 5-storey high	About 105m, over 10-storey high
Wall materials	Wood, brick tiles, clay-bamboo walls	RC, bricks, tiles, washed pebbles, cements	RC, tiles, rectangular tiles, washed pebbles	RC, SRC, ALC tiles
Building & environment features	With central courtyards surrounded with walls, communities	Farm houses, commercial circles, terraces in old communities	early 60~70’s old communities with narrow alleys, high building coverage, no statutory open spaces	Community courtyards and open spaces
Hanging objects over external walls	Rain canopies	Flower stands, air-conditioner stands, window fences, rain canopies, signboards	Flower stands, air-conditioner stands, window fences, rain canopies, signboards	Flower stands, air-conditioner stands, window fences, rain canopies, signboards
Pictures of current status				









Amongst which, the variety of hanging objects over the external walls, including flower stands, air-conditioner stands, window fences, rain canopies, signboards, may significantly affect the future vertical greening; therefore, an overall consideration of the building facades is essential for a most integrated design of vertical greening technology.

3. Application of Vertical Greening to Existing Buildings

The application of vertical greening to the external walls of the existing buildings may not only accelerate the improvement of landscape environment of the old urban communities but also create the 3D ecological stepping island in the urban green networks, as well as the ecological extensions from the existing built environment (Lin, 2004; Blanc, 2008).

Derived from the reference articles in the former section, the paper has found that vertical greening is now still in the promotion stage in Taiwan. However, more applications of vertical greening on the external walls of the existing buildings have been initiated during recent years, mainly by attaching supports directly to the existing walls without any pre-tests or reinforcement in advance. The following four case studies as Table 2 may be applied as references for future vertical greening:

Table. 2. Case studies of application of vertical greening on existing buildings.

Building Type		Traditional buildings	Detached houses	Apartments	Elevator mansions
Building material	Project	Green wall of Yungkuan Community, Taipei	Green wall of Chen's Architectural Firm, Miaoli	Apartment, Dunhua S. Rd., Taipei	Green wall of CMP Park Lane, Taichung
	Establish year	2009	2012	Unknown	2008
	Orientation	South-west, north	North-west	East	Four directions
	Occupancy	Self-residence	Firm studio	Apartment	Department store
	Wall material	RC, bricks	RC, bricks, tiles	RC, tiles	SRC, cement mortar plastering
Green wall technology	Greening floors	1~2	2	6	5
	Greening type	Modular: single-trough	Modular: open type	Wall-climbing: adhesive disc	Modular: block type
	Greening technology	Plant Pots type	Continuous open type	Natural climbing type	Wall panels type
	Container material	Plastic pots, rust-free coating steel	Galvanized iron, coconut fiber rug	n/a	Stainless steel, Non-woven fabric
	Unit price	US\$240	US\$266	Less than US\$100	US\$1300~1500
	Watering system	Automatic drip	Automatic drip	Rain irrigation	Automatic drip
	Plant variety	Croton, sprengeri fern, Boston fern, scandent scheffera	Boston fern, boat Lily	Japanese ivy	African touch- me-not, lantana camara, copperleaf, Boston fern, golden dewdrop
	Picture before greening (Before)				
Picture after greening (After)					
Conclusion	Pros	1. Easy construction 2. Easy plant replacement	1. Good ventilation and drainage 2. No restricted growth of plant roots	1. Easy maintenance 2. Low costs for constructions and maintenances	1. Instant effect of green coverage 2. Enhancement of local economy, upgrade of local greening concept

Cons	<ol style="list-style-type: none"> 1. Clogging of Drip System 2. Water flowing along plant stems and leaves outside of the walls 3. Restricted growth of plant roots 4. No drainage system 5. Rust corrosion on attachment parts connecting with wall bodies 	<ol style="list-style-type: none"> 1. Difficult Plant Replacement 2. Rust corrosion on attachment parts connecting with wall body 	<ol style="list-style-type: none"> 1.No instant effect of green coverage 2.Plain visual effect 3.Insects Inhabitation 4.Damanges to building façade materials 	<ol style="list-style-type: none"> 1.High cost of constructions 2.High cost of maintenances with cranes
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The vertical greening of the urban existing buildings now in Taiwan is mainly applied with the technology of modular type for its instant green coverage and visual effect of landscaping improvement; whereas in the aspect of construction areas, most of the applications are partially greening for eliminating the worries of affecting Fengshui¹ or structures of the entire buildings. However, the maintenance costs of modular greening will certainly higher than natural climbing (Peng, 2015). Taking CMP Park Lane (2015) for example, the green wall on higher levels may have given a wider range of plant variety selections; however, the initial construction cost would be higher, same as the following maintenance costs, resulting from crane and labor costs which may be unaffordable to most of the private sectors. For the other case of Yungkuan Community, the green wall had finally come to its end for the community could not afford to maintain it. Therefore, it is recommended that the community development associations or volunteers should carry out the future maintenance. Whereas the most important issue to accomplish the urban greenery could be to develop greening technologies with low maintenance and management.

4. Recommendations on Applying Vertical Greening to Existing Buildings

















Current development of greening technologies have made them possible to build up vertical living walls as outdoor and indoor applications. The selections of plant variety and wall materials now become the essential issues of living walls; whereas the selections should be based on plant attributes, local climate, building material itself and surrounding environment.

Table 3 shows recommendations on planning and design of vertical greening:

Table. 3. Recommendations on planning and design of vertical greening.

		Recommendations	Illustrations	
Building Type	Traditional buildings (Historical buildings, 3-section compounds)	For the walls and structures of traditional buildings, it is recommended to add on vertical greening supports or modular greening for external wall protections and façade beautification.	After	Before
	Detached houses / terraces (farm houses)	Modular greening and natural climbing greening are recommended. Plant troughs may be installed underneath building façades and planted with wall clinging plants; or alternatively installed on building tops for the plants to hang down naturally.		

¹ Fengshui is a Chinese philosophical system of harmonizing everyone with the surrounding environment. Historically, fengshui was widely used to orient buildings in an auspicious manner. In other words, an auspicious building or site could be decided by reference to local features.

	Old apartments (60-70's No-lift Apartments)	Modular greening and natural climbing greening are recommended. Plant troughs may be installed in the suitable places and planted with vining plants supported with climbing racks.		
	Old elevator mansions (over 5-stroey high)	Half-day sunshine, poor temperature-enduring, light & good clinging, wind-resistant, barren-enduring plants are recommended for the greening of higher floors; whereas modular greening is preferable due to plant growth attributes and periods.		
Wall Building Material	Wood	Modular greening is recommended for the concern that water-soaked wood may easily become rotten.		
	Bricks, stones, tiles	Natural climbing of vining plants with aerial roots or adhesive discs is recommended, or alternatively modular greening.		
	Washed pebbles	Natural climbing of vining plants with aerial roots or adhesive discs is recommended.		
	RC, cement	For smooth surfaces, installation of supportive racks is recommended for wall climbing or modular greening.		
Wall Attachment	Flower stands, balconies	Plant troughs may be installed on the balconies and planted with plants. Fine-textured plants are preferable for the limited areas of the balcony spaces.		
	Arcade columns	Colorful and playful designs may be applied on arcade columns such as 3D flower columns.		
	Eaves	Hanging plant pots on building tops or planting hanging vines are recommended.		

Note: The preferable vertical greening planning and designs recommended by the paper are based on different building types and for references only.

5. Conclusion

The paper comes up with the findings as below:

1. Based on the type variety of vertical greening in taiwan, the paper classifies vertical greening into the three basic types: wall-climbing, hanging and modular greening. Whereas when conducting relation study on vertical greening development system and vertical greening types, the findings of some systems composed of more than two types of vertical greening indicate that a variety of planting types may be applied on different building types for multi-layered plantation ecology and visual effects as the development of diversity and sustainability.
2. The vertical greening of the urban existing buildings in taiwan is mainly applied with the technology of modular type for its instant green coverage and visual effect of landscaping improvement; whereas in the aspect of construction areas, most of the applications are partially greening for eliminating the worries of damaging fengshui or structures of the entire buildings. However, the maintenance costs of modular greening will certainly stay higher than natural climbing, which may not be affordable for most of the private residences.
3. The current development of greening technology makes it possible to build up vertical living walls as outdoor and indoor applications. The selections of plant variety and wall materials now become the essential issues of living walls. Whereas the selections should be based on plant attributes and local climates as environmental factors such as wind speed, temperature, sunshine, humidity and rainfalls that may affect plant growth.

Vertical Greening offers another option of external wall materials, besides of tiles, cements and stones, with advanced technology of sustainability, environmental protection and green aesthetics. Based on the above literature reviews and case studies, the paper comes up with the recommendations as the followings:

1. Coping with the trend of carbon emission reduction and eco-city development, it is recommended to apply the variety of vertical greening as the overall urban aesthetics to the existing settlements or communities with colourful and playful landscapes and designs as the accomplishment of ecological and landscape effects.
2. When selecting plant varieties and support materials for vertical greening, the different attributes of geographical situations, settlements, environments and building materials should be taken into considerations; whereas local native plants should be the first priorities.
3. Different types of old buildings may have different attributes of building ages, building heights and building materials; amongst which, the variety of hanging objects over the external walls including flower stands, air-conditioner stands, window fences, rain canopies, and sign boards may significantly affect the future vertical green walls. Therefore, an overall consideration of the building facades is essential for a most integrated design of vertical greening technology.
4. New vertical greening technology and plantation methodology should be facilitated on the old housing buildings for the reductions of installation and maintenance costs. Selecting local native plants as green wall materials may be the solution to cost reductions of installations and maintenances, as well as the fulfilment to the demand of sustainable cities.
5. Different environmental factors such as building orientations and heights, surrounding environments, wind speed, temperature, humidity, and rainfalls should be taken into considerations. They may have great impacts on the plant varieties and materials of green walls.
6. It is recommended to stipulate vertical greening assessment and design criteria based on the typology of urban renovation and maintenance areas, old building types and environmental factors as well as case studies on the projects for the selections of vertical greening types and plant varieties and attributes, thus facilitating vertical greening in every corner of the cities as the accomplishment of the goals for sustainable cities.

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