Green Roof Systems in Hong Kong

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Introduction

- Problems in urban cities
  - Urban heat island (UHI)
  - Lack of greenery space
- Green roofs can mitigate the adverse effects
  - Bring the nature back to urban area
  - Make better use of roof space
- Green roof market in Hong Kong
  - Still developing and immature
  - Lack of technical guidelines & policy
Examples of green roofs in the world

Solar Campus Jülich, Germany (11 Jul 2001)  IBN-DLO Wageningen, the Netherlands (2 Jul 2001)

Putrajava Int. Conven. Centre, Malaysia (30 Jun 2006)  Beitou Taipei Library, Taiwan (6 Aug 2007)

(Photos taken by Dr Sam C M Hui)
Examples of green roofs in Singapore

Carpark roof of public housing (modular green roof)  Carpark roof of housing estate (built-in green roof)

Carpark roof of public housing (intensive green roof)  Lawn green roof (Nanyang Techn. Univ.)

(Photos taken by Dr Sam C M Hui, 29 May & 1 Jun 2009)
Examples of green roofs in Hong Kong

Ocean Park Hong Kong

EMSD Headquarters

Parklane, Tsimshatsui

A school in San Po Kwong

(Photos taken by Dr Sam C M Hui)
Green roof systems

- **Green Roofs**: roofs bearing vegetation – FLL
  - “Living vegetation installed on the roofs”
  - “Vegetated roof”
- **Green Roof System** – Definition
  - “A roof area of plantings/landscape installed above a waterproofed substrate at any building level that is separated from the ground beneath it by a man-made structure.” – *NRCA Green Roof System Manual 2007*
- Other terms: Eco-roof, Living roof
Green roof systems

- Major types of green roofs (see Table 1)*
  - Extensive
  - Semi-intensive
  - Intensive

- Roof gardens: usually intensive greening with other features such as potted plants, pond, etc.
  - Examples in HK: podium gardens, sky gardens

- Classify green roof systems by basic design:
  - Built-in green roofs vs Modular green roofs

* Could also be combined as hybrid systems
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Extensive</th>
<th>Semi-intensive</th>
<th>Intensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of material</td>
<td>150 mm or less</td>
<td>Above and below 150 mm</td>
<td>More than 150 mm</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Often inaccessible</td>
<td>May be partially accessible</td>
<td>Usually accessible</td>
</tr>
<tr>
<td>Fully saturated weight</td>
<td>Low (70-170 kg/m²)</td>
<td>Varies (170-290 kg/m²)</td>
<td>High (290-970 kg/m²)</td>
</tr>
<tr>
<td>Plant diversity</td>
<td>Low</td>
<td>Greater</td>
<td>Greatest</td>
</tr>
<tr>
<td>Plant communities</td>
<td>Moss-sedum-herbs and grasses</td>
<td>Grass-herbs and shrubs</td>
<td>Lawn or perennials, shrubs and trees</td>
</tr>
<tr>
<td>Use</td>
<td>Ecological protection layer</td>
<td>Designed green roof</td>
<td>Park like garden</td>
</tr>
<tr>
<td>Cost</td>
<td>Low</td>
<td>Varies</td>
<td>Highest</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Minimal</td>
<td>Varies</td>
<td>Highest</td>
</tr>
</tbody>
</table>
Green roof systems from Germany (left) and Japan (right)
Vegetated mat system (www.elteasygreen.com)

Tray system (www.liveroof.com)

Sack system (www.greenpaks.com)
Modular green roof system from Japan

G-WAVE Ecom construction distance

1. Waterproofing
2. Roof barrier layer
3. Drainage layer
4. Install modules
5. Fix modules (if needed)
6. Completed

(Source: www.tajima-roof.jp)
Table 2. Initial and maintenance costs of green roof systems

<table>
<thead>
<tr>
<th></th>
<th>Intensive</th>
<th>Extensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial cost (HK$/m²)</td>
<td>1,000 to 5,000 (average: 2,000)</td>
<td>400 to 1,000 (average: 500)</td>
</tr>
<tr>
<td>Maintenance cost (HK$/m²/yr)</td>
<td>6.5 to 44 (average: 20)</td>
<td>0.8 to 2.25</td>
</tr>
</tbody>
</table>

(Source: (Urbis Limited, 2007))
Benefits of green roofs

- Green roofs provide many benefits to the society (public) and building owners (private)
  - 1. Environmental benefits
  - 2. Economic benefits
  - 3. Amenity and aesthetic benefits

- Important considerations:
  - Some benefits are common to all green roofs, but many are project design specific; some benefits will be apparent if roof greening is on a large scale
<table>
<thead>
<tr>
<th>Public benefits:</th>
<th>Private benefits:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic value</td>
<td>Increase roof life span</td>
</tr>
<tr>
<td>Mitigate urban heat island</td>
<td>Reduce cooling loads</td>
</tr>
<tr>
<td>Stormwater retention</td>
<td>Contribute to green building rating credit points</td>
</tr>
<tr>
<td>Create natural habitat</td>
<td>Better use of space</td>
</tr>
<tr>
<td>Functional open space</td>
<td>Reduce noise levels</td>
</tr>
<tr>
<td>Agricultural space</td>
<td>Reduce risk of glare for surrounding buildings</td>
</tr>
<tr>
<td>Filter dust and pollutants</td>
<td></td>
</tr>
<tr>
<td>Filter rainwater</td>
<td></td>
</tr>
</tbody>
</table>
Benefits of green roofs

1. **Environmental benefits:**
   - Biodiversity and wildlife value
   - Stormwater management
   - Rainwater runoff quality
   - Air pollution mitigation
   - Carbon sinks (sequestration)
   - Mitigation of urban heat island
   - Control of noise pollution
Green roofs can reduce stormwater runoff and control peak stormwater flow.

(Source: Stormwater Academy, University of Central Florida)
Benefits of green roofs

2. Economic benefits:
   - Extends roof life
   - Reduces air conditioning & heating costs (energy and maintenance)
   - Reduces capital costs for equipment and installation (air conditioner, drainage and pipes)
   - Reduces water and sewerage charges
   - Attracts buyers and tenants
   - Attracts and retains employees
Thermal properties of green roofs

Outdoor

Evapo-transpiration

Shading

Thermal mass

Insulating property

Roof slab

Indoor
Benefits of green roofs

3. **Amenity and aesthetic benefits:**
   - Aesthetically pleasing, useful space
     - If roof loading is sufficient, green roofs can be planned for amenity and recreational use
   - Food production (e.g. community gardens)
     - Opportunity for growing healthy food in urban areas
     - A range of marketable products (vegetable, fruit)
   - Local job creation (direct and indirect)
     - On green roof maintenance, urban agriculture, etc.
     - Useful for low-income group
Urban farming & education

Horticultural therapy & social functions
Rooftop urban farming in the world

- Bangkok, Thailand (with rice and fruits)
- Tokyo, Japan (rooftop greenhouse)
- London, UK (with bee keeping)
- San Francisco, USA (for kitchen/restaurant)

(Source: www.time.com)
Container garden in Taiwan

(Source: http://yiu.com.tw/green.htm)
Sustainable rooftop farming 可持續的天台農耕

Wind energy

Greenhouse

Composting

Solar energy

Rainwater harvesting

(Source: www.skyvegetables.com)
A green roof project with integrated systems

- Micro-wind turbines
- Rainwater recycling
- Modular system
- Built-in system

Space for green roof research and urban farming
Hong Kong situation

- Some intensive green roofs can be found on:
  - Landscape podium roof gardens
  - “Sky gardens”
  - Public open spaces built on government structure
- Extensive green roofs and other urban greening technologies is still limited
  - No government policy and requirement
  - Little incentives for private to invest on it
A landscape podium garden in North Point, Hong Kong

(Photos taken by Dr Sam C M Hui)
A landscape podium garden in Tseung Kwan O
Hong Kong situation

- Greening policy set up in recent years (www.devb.gov.hk/greening)
  - Aims to improve urban greenery and maximise greening opportunity
  - Greenery and landscaping in the planning of new towns and new development areas
- Space constraints limit greening in urban areas
  - Green roofs is a promising choice
    - However, a clear policy for green roofs is not available
Potential of promoting green roofs in urban areas

Kwun Tong

(Source: http://hk.centamap.com)
Hong Kong situation

- Government pilot projects, e.g. by:
  - Architectural Services Department (ArchSD)
  - Drainage Services Department (DSD)
  - Housing Authority (HA)
- But, the technical requirements and actual performance of the green roofs are not well defined and understood
  - This will hinder development of the local green roof or greenery market and technology
Hong Kong Wetland Park Phases II
(the largest green roof in Hong Kong)

(Source: Architectural Services Department)
Green roof on a water treatment plant in Hong Kong

(Source: Drainage Services Department)
Hong Kong situation

- Green roof research
  - In 2006-07, the Government commissioned a consultancy study on “Green Roof Application in Hong Kong” (Urbis Limited, 2007)
  - In the past few years some research projects on green roof are developed; but most of them focuses on field experiments and measurements
  - A lack of research on practical design issues and technical codes (c.f. FLL in Germany & CUGE in Singapore)
Worldwide experience

- Germany and Japan are more advanced
- Germany: FLL guidelines (FLL, 2008)
  - By Research Society for Landscape Development and Landscape Design (Forschungsgesellschaft Landschaftsentwicklung und Landschaftsbau e.V.) (www.fll.de)
  - Set quality standards for green roof systems
  - Complement the construction regulations in Germany and the DIN standards of landscape contractors
Worldwide experience

• Japan guidelines on rooftop & wall greening
  • Started in 1990 by the Organization for Landscape and Urban Green Technology Development (www.greentech.or.jp)
    • Organise annual competition on greening technology since 2002
    • Coordinate R&D work, conferences and incentive schemes on urban greening
  • Local provincial governments also developed their requirements and standards
Worldwide experience

- Other places which have developed guidelines and codes for roof greening:
  - UK: GRO Green Roof Code 2011
  - Canada
  - Australia
  - China (Beijing, Guangzhou, Shenzhen)
  - Singapore
  - UAE
  - USA
Worldwide experience

- Some countries have also developed technical standards, e.g.
  - ASTM standards
  - SPRI standards (on wind and external fire)
  - Singapore standards (on design loads and safety)
  - Toronto Green Roof Construction Standard 2010
Developing techn. guidelines

• A research project sponsored by CIBSE Hong Kong Branch
  • Prepare technical guidelines for green roof systems in Hong Kong
  • Learn from experience of other countries/cities
  • Will also consider and adapt the local conditions of Hong Kong

• Project duration:
  • September 2010 to March 2011 (~ 6 months)
Table 4. Proposed contents of the guidelines

<table>
<thead>
<tr>
<th>Part 1</th>
<th>1. Introduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Scope</td>
</tr>
<tr>
<td></td>
<td>3. Definitions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 2</th>
<th>4. Planning Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5. Design Considerations</td>
</tr>
<tr>
<td></td>
<td>6. Construction</td>
</tr>
<tr>
<td></td>
<td>7. Maintenance</td>
</tr>
<tr>
<td></td>
<td>8. Project Management</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part 3</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Appendices (with case studies)</td>
</tr>
</tbody>
</table>
| Planning Requirements | - Functions and effects  
|                       | - Structural loading  
|                       | - Accessibility  
|                       | - Site conditions (wind, shade)  
|                       | - Water proofing condition  
|                       | - Green building credits  
| Design Considerations  | - Landscape design  
|                       | - Irrigation & water supply  
|                       | - Stormwater drainage  
|                       | - Plant species  
|                       | - Wind design (e.g. typhoons)  
|                       | - Sustainable technologies (e.g. solar)  
|                       | - Food production (farming)  
|                       | - Rainwater recycling  
|                       | - Roof slope  
| Construction          | - Safety issues (preventing falls)  
|                       | - Vegetation planting method  
|                       | - Testing & monitoring  
| Maintenance           | - Maintenance requirements  
|                       | - Warranties  
|                       | - External fire hazard  
|                       | - Safety issues  
| Project Management    | - Green building assessment  
|                       | - Financial incentives  
|                       | - Regulatory measures  
|                       | - Contractual matters |
Developing techn. guidelines

- Considerations for Hong Kong:
  - **High-density urban areas**
    - Very limited roof area
    - More effective to apply green roofs to podiums and medium- or low-rise buildings/structures
  - **Green roof on existing buildings**
    - Limited by loading capacity
    - Guidance to help people select a suitable green roof system (usually light-weight)
  - **Typhoon and stormwater**
Developing techn. guidelines

- **Green Building Assessment Methods**
  - Such as LEED 2009 and BEAM Plus
  - They are becoming more and more popular and important
  - In fact, greening technology has significant implications to the assessment results
  - Our guidelines will include information to help people optimise the credit points from green roofs
Table 6. LEED 2009 credit points of green roof systems

<table>
<thead>
<tr>
<th>LEED criteria impacts:</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sustainable Sites (SS)</strong></td>
<td></td>
</tr>
<tr>
<td>Credit 6.1: Stormwater design – quantity control</td>
<td>1</td>
</tr>
<tr>
<td>Credit 6.2: Stormwater design – quality control</td>
<td>1</td>
</tr>
<tr>
<td>Credit 7.2: Heat island effect – roof</td>
<td>1</td>
</tr>
<tr>
<td><strong>Water Efficiency (WE)</strong></td>
<td></td>
</tr>
<tr>
<td>Credit 1: Water efficient landscaping</td>
<td>2-4</td>
</tr>
<tr>
<td><strong>Energy and Atmosphere (EA)</strong></td>
<td></td>
</tr>
<tr>
<td>Credit 1: Optimize energy performance</td>
<td>1</td>
</tr>
<tr>
<td><strong>Materials and Resources (MR)</strong></td>
<td></td>
</tr>
<tr>
<td>Credit 4: Recycled content (roof components)</td>
<td>1-2</td>
</tr>
<tr>
<td>Credit 5: Local/Regional materials</td>
<td>1-2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary credit impacts:</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Efficiency (WE)</strong></td>
<td></td>
</tr>
<tr>
<td>Credit 2: Innovative waste water technologies</td>
<td>2</td>
</tr>
<tr>
<td>Credit 3: Water use reduction</td>
<td>2-4</td>
</tr>
<tr>
<td><strong>Innovation in Design (IN)</strong></td>
<td></td>
</tr>
<tr>
<td>Credit 1: Innovation in design</td>
<td>1-5</td>
</tr>
</tbody>
</table>

Source: extracted from USGBC (2009)
Table 7. BEAM Plus credit points of green roof systems

<table>
<thead>
<tr>
<th>BEAM Plus criteria impacts:</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sites Aspects (SA)</strong></td>
<td></td>
</tr>
<tr>
<td>Perequisite: Minimum landscape area</td>
<td>Req’d</td>
</tr>
<tr>
<td>SA 5: Ecological impact</td>
<td>1</td>
</tr>
<tr>
<td>SA 7: Landscaping and planters</td>
<td>1-3</td>
</tr>
<tr>
<td>SA 8: Microclimate around buildings (roof)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Materials Aspects (MA)</strong></td>
<td></td>
</tr>
<tr>
<td>MA 7: Recycled materials (roof components)</td>
<td>1</td>
</tr>
<tr>
<td>Credit 5: Local/Regional materials</td>
<td>1-2</td>
</tr>
<tr>
<td><strong>Energy Use (EU)</strong></td>
<td></td>
</tr>
<tr>
<td>EU 1: Reduction of CO₂ emission</td>
<td>1-15</td>
</tr>
<tr>
<td>EU 2: Peak electricity demand reduction</td>
<td>1-3</td>
</tr>
<tr>
<td><strong>Water Use (WU)</strong></td>
<td></td>
</tr>
<tr>
<td>WU 1: Water efficient irrigation</td>
<td>1</td>
</tr>
<tr>
<td>WU 6: Effluent discharge to foul sewers</td>
<td>1</td>
</tr>
<tr>
<td><strong>Secondary credit impacts:</strong></td>
<td><strong>Points</strong></td>
</tr>
<tr>
<td><strong>Water Use (WU)</strong></td>
<td></td>
</tr>
<tr>
<td>WU 4: Water recycling (rainwater)</td>
<td>1-2</td>
</tr>
<tr>
<td><strong>Innovations and Additions (IA)</strong></td>
<td></td>
</tr>
<tr>
<td>IA 1: Innovative techniques</td>
<td>1-5</td>
</tr>
</tbody>
</table>

Source: extracted from BEAM Society (2009)
Developing techn. guidelines

- Green roof performance and quality
  - Avoid poorly designed/constructed green roofs
  - Consider the true value of green roof systems and their impacts
- Types of performance
  - Thermal and energy performance
  - Hydrologic or stormwater management performance
  - Air quality/ pollution control
- Ecological function is also important
# Green roof inspection report – Checklist

## Testing:

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood test</td>
<td>Electrical field vector mapping</td>
</tr>
<tr>
<td>Impedance test</td>
<td>Infrared (IR) thermal imaging</td>
</tr>
<tr>
<td>Low voltage test</td>
<td>Moisture sensors</td>
</tr>
</tbody>
</table>

## Inspection:

<table>
<thead>
<tr>
<th>Inspection</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Green roof size and location</td>
<td>H. Waterproofing</td>
</tr>
<tr>
<td>B. Gravity loads</td>
<td>I. Drainage</td>
</tr>
<tr>
<td>C. Slope stability</td>
<td>J. Water retention</td>
</tr>
<tr>
<td>D. Parapet height and/or overflow scupper</td>
<td>K. Vegetation performance</td>
</tr>
<tr>
<td>E. Wind uplift</td>
<td>L. Plant selection</td>
</tr>
<tr>
<td>F. Fire safety</td>
<td>M. Irrigation</td>
</tr>
<tr>
<td>G. Occupancy and safety</td>
<td>N. Maintenance plan</td>
</tr>
</tbody>
</table>

(Extracted from Toronto Green Roof Construction Standard, www.toronto.ca/greenroofs)
Developing techn. guidelines

- In Germany, FLL has developed a performance rating system for green roofs based on the desired ecological functions:
  - Water retention capacity of the growing medium
  - Water retention capacity of the drainage layer
  - Number of plant species for extensive green roofs
  - Plant biomass or volume for intensive green roofs
- It also help to judge whether a project is suitable for ecological compensation
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Quality of soil</td>
</tr>
<tr>
<td>Water</td>
<td>Improvement in surface water quality</td>
</tr>
<tr>
<td></td>
<td>Reduction in load of the sewer system</td>
</tr>
<tr>
<td></td>
<td>Improvement in groundwater recharge</td>
</tr>
<tr>
<td></td>
<td>Purification of stormwater</td>
</tr>
<tr>
<td>Air &amp; temperature</td>
<td>Filtering of air</td>
</tr>
<tr>
<td></td>
<td>Contribution to oxygen production</td>
</tr>
<tr>
<td></td>
<td>Contribution to urban temperature levelling</td>
</tr>
<tr>
<td>Habitat</td>
<td>Contribution to establishment of flora and fauna habitat</td>
</tr>
<tr>
<td>Landscape</td>
<td>Contribution to landscape and urban scenery</td>
</tr>
<tr>
<td>Amenity</td>
<td>Contribution to amenity for people / leisure / healing</td>
</tr>
</tbody>
</table>

Note: * Each parameter is deemed “possible to fulfill completely”, “possible to fulfill partially”, or “slightly or not possible to fulfill.”
Developing techn. guidelines

Example: “Karlsruhe Performance Rating System” for green roofs, according to five natural functions:

1. Type and depth of soil used (Soil) – 15%
2. Impact on climate due to evapotranspiration (Climate) – 15%
3. Type and variety of vegetation (Flora) – 30%
4. Impact on zoological biodiversity (Fauna) – 30%
5. Average annual stormwater retention (Water Balance) – 10%
Conclusions

• Urban cities like Hong Kong can benefit from green roofs and walls
• There is a need to develop local technical guidelines for planning, designing and commissioning green roof systems in HK
• To achieve a sustainable urban environment
  • Financial incentives & public awareness
  • Promote roof and multi-level greening
• Green roof movement in HK has just begun!
THANK YOU 謝謝!!

(More information: www.hku.hk/bse/greenroof/)