Hydrologic Design of Vegetated Roofs

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Session Overview

- (Very) Brief Introduction to Vegetated Roofs
- Hydrologic Performance
- Monitoring Data
- Hydrologic Design Parameters
Types of Vegetated Roofs

Extensive

Intensive
Intensive Roof
SC4 Extensive Roofs
Typical Cross Section

- Vegetation
- Growing Medium
- Drainage, Aeration, Water Storage and Root Barrier
- Insulation
- Membrane Protection and Root Barrier
- Roofing Membrane
- Structural Support
Vegetation
## Comparing the Two Roofs

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Intensive</th>
<th>Extensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Typically one foot or more of soil depth</td>
<td>Requires only 1 to 5 inches of soil depth</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Accommodates large trees, shrubs, and gardens</td>
<td>Various vegetative ground cover, sedums, and grasses</td>
</tr>
<tr>
<td>Load</td>
<td>Adds 80-150 pounds per square foot of load</td>
<td>Adds only 12-50 pounds per square foot</td>
</tr>
<tr>
<td>Access</td>
<td>Regular access accommodated &amp; encouraged</td>
<td>Usually not designed for public accessibility</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Significant maintenance required</td>
<td>Annual maintenance walks are performed</td>
</tr>
<tr>
<td>Drainage</td>
<td>Complex drainage systems</td>
<td>Simple drainage system</td>
</tr>
</tbody>
</table>
Vegetated Roof Performance

- Hydrologic response is diverse due to:
  - variation in the physical properties of the media
  - layered structure of the various proprietary systems
  - local climatic conditions
Vegetated Roof Design

- Most roof companies report annual retention values – not helpful for storm design
- $CN$ and $C_v$ will vary for each storm – need site specific information or modeling
Lawrence Tech Vegetated Roof

- 10,000 sq ft Hydro Tech 6125 extensive Garden Roof Assembly.
- Research project to determine the long term effectiveness with regards to water quality and quantity (USEPA and LTU COE).
LTU Vegetated Roof Cross-Section

- 10,000 sq ft Hydro Tech 6125 extensive Garden Roof Assembly.
Experimental Set-Up

- Performance monitoring equipment was set up on three full scale roof systems on campus:
  - 3496 sq ft section of HydroTech Extensive Garden Roof
  - 912 sq ft new rock ballast roof
  - 1647 sq ft existing asphalt roof
Monitoring Equipment

- Teledyne ISCO Avalanche Samplers
- Teledyne ISCO 730 Bubbler Flowmeter
- Teledyne ISCO 674 Rain Gauge
- 4" Palmer-Bowlus Flumes
- Microdaq USB Temperature sensors
Flow Monitoring Equipment
“Curve Number and Runoff Coefficients for Extensive Living Roofs” by Elizabeth Fassman-Beck, William Hunt, Donald D. Carpenter, Robert Berghage, Timothy Kurtz, Virginia Stovin, and Bridget Wadzuk


- Meta-analysis of 21 sites in five countries
  - Brownstown and Lawrence Tech
Climate Classification

Main Köppen-Geiger Climate Classes for US counties
updated with CRUTS 2.1 temperature and VASClimO v1.1 precipitation data 1951 to 2000

A: equatorial  W: desert
Af Am As Aw BWk BWh BSh BSk Cfa Cfb Cfc Csa Csb Csc Cwa
Cwb Cwc Dfa Dfb Dfc Dfd Dsa Dsb Dsc Dsd Dwa Dwb Dwc Dwd EF ET

Main climates
B: arid
C: warm temperate
D: snow
E: polar

Precipitation
f: fully humid
s: summer dry
w: winter dry
m: monsoonal

Temperature
h: hot arid
k: cold arid
a: hot summer
b: warm summer
c: cool summer
d: extremely continental

Cv – Warm Temperate Climates

- Horizontal lines show empirical $C_v$ averaged across all sites in climate zone for P range.
- Curved lines are averaged regression results across all sites in climate zone.
- Vertical bars show 1 standard deviation; bars are shown intermittently for figure clarity.

(a)
Cv – Snow/Humid Hot Summer

![Graph showing volumetric runoff coefficient (Cv) vs. rainfall (mm). The graph includes two lines: one in blue labeled Dfb/Cfa (n=1) and one in yellow labeled Dfa (n=4). Error bars are present for data points.]
CN – Regional

- Pittsburgh, PA (CN=96, r^2=0.97) Dfb/Cfa
- Toronto (CN=92, r^2=0.67) Dfa
- Chicago (CN=80, r^2=0.81) P=Q

Runoff, Q (mm) vs Rainfall, P (mm)
CN – Regional

- Brownstown, MI (CN=96, $r^2=0.93$)
- Southfield, MI (CN=91, $r^2=0.96$)
- State College, PA (CN=91, $r^2=0.91$)

Runoff, Q (mm) vs. Rainfall, P (mm)

Dfa/Dfb

$d$
Extensive Vegetated Roofs

Design Parameters

- Recommend Modeling for Performance BUT...

- Runoff Volume Coefficient
  - $0 < C_v < 0.8$

- Curve Numbers
  - $CN = 85$ for events greater than moisture holding capacity (ASCE Green Roof TC)
  - $CN = 65$ for rain events 3 x’s depth of media (MI LID Manual)
  - $CN > 90$ for many regional vegetated roofs
Summary

- Vegetated roof systems must be designed according to local climatic conditions.

- Performance expectations must be based on vegetated roof system and the climatic conditions for which published performance data was collected.

- Important to understand performance in the region of application and preferably from full-scale monitoring or performance modeling results.
Thanks!

Questions?

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http://www.ltu.edu/stormwater/index.asp