GREEN ROOF SYSTEMS
ACHIEVING HIGH PERFORMANCE PROTECTION

Presented by:

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Thank you!
Green Roofs
A “Green Roof” is a roofing/waterproofing system which incorporates habitable or green space consisting of vegetation and/or landscaping over a building structure".
2006 Survey

Growth of North American Green Roof Industry in 2006, by Green Roof Type:

<table>
<thead>
<tr>
<th>Green Roof Type</th>
<th>Square Footage</th>
<th>Percent Growth Over 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (362 projects)</td>
<td>3,064,200</td>
<td>24%</td>
</tr>
<tr>
<td>Extensive (259 projects)</td>
<td>1,957,217</td>
<td>10%</td>
</tr>
<tr>
<td>Intensive (88 projects)</td>
<td>1,033,196</td>
<td>112%</td>
</tr>
<tr>
<td>Mixed/Semi-intensive (15 projects)*</td>
<td>73,787</td>
<td>-63%*</td>
</tr>
</tbody>
</table>

*Please note that the small sample sizes of Mixed/Semi-intensive projects means that the growth rate was disproportionately influenced by three large projects in 2005.

Square footage of green roofs submitted for 2005 for North America:

<table>
<thead>
<tr>
<th>Green Roof Type</th>
<th>Square Footage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (313 projects)</td>
<td>2,471,550</td>
</tr>
<tr>
<td>Extensive (232 projects)</td>
<td>1,784,755</td>
</tr>
<tr>
<td>Intensive (64 projects)</td>
<td>488,109</td>
</tr>
<tr>
<td>Mixed/Semi-intensive (17 projects)</td>
<td>198,686</td>
</tr>
</tbody>
</table>
2006 Survey

Top ten cities, by square footage planted in 2006:

<table>
<thead>
<tr>
<th>City</th>
<th>State/Province</th>
<th>Total square footage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chicago</td>
<td>IL - Illinois</td>
<td>358,774</td>
</tr>
<tr>
<td>2. Washington, DC</td>
<td>DC – District of Columbia</td>
<td>301,751</td>
</tr>
<tr>
<td>3. Wildwood Crest</td>
<td>NJ - New Jersey</td>
<td>240,000</td>
</tr>
<tr>
<td>4. Dulles</td>
<td>VA - Virginia</td>
<td>230,000</td>
</tr>
<tr>
<td>5. Kansas City</td>
<td>MO - Missouri</td>
<td>178,008</td>
</tr>
<tr>
<td>6. Phoenix</td>
<td>AZ - Arizona</td>
<td>168,517</td>
</tr>
<tr>
<td>7. Milwaukee</td>
<td>WI - Wisconsin</td>
<td>79,513</td>
</tr>
<tr>
<td>9. Portland</td>
<td>OR - Oregon</td>
<td>64,442</td>
</tr>
<tr>
<td>10. Columbus</td>
<td>OH - Ohio</td>
<td>58,025</td>
</tr>
</tbody>
</table>
**Benefits...**

- Minimize Storm Water runoff
- Extend roof membrane life
- Energy Savings Impact
- Public Relations/Marketing
- Health/Employee Benefits
- Qualify for LEED points
- Visual Value
Vegetated Roofs Decrease Stormwater Runoff Rates

An extensive green roof with 4” of growing media can:

- Reduce stormwater runoff by about 95%
- Control runoff from over 95% of storms
- Prohibit any immediate runoff from the smallest 25% of all storms
- Substantially reduce peak flow rates

A 4” green roof would provide peak control for storm magnitudes of up to 3.5”.
Pollutant Reductions Achieved with a 4” Extensive Green Roof

Köhler & Schmidt (2003)
Waterproofing System Protection

- Shields roof from sun’s harmful UV rays
- Protects from abrasion and physical wear
- Reduces daily expansion and contraction caused by temperature variations

Vegetated roof covers can extend the service life of roofs by a factor of 2 to 3.
Reflective Air Temperatures

(At 2 inches above roof surface)

Reference Mod Bit 102°F
Green Roof 82°F
Ambient Air Temperature 64°F
Reduces Urban Heat Island Effect

Infrared image of Washington D.C.

Green roofs provide over 8,000 BTUs of cooling energy for every gallon of water that is evaporated.
**Six LEED Credits Can Be Earned By Incorporating Green Roofs Into a Project.**

### B. LEED Points (Potential)

<table>
<thead>
<tr>
<th>Credit Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Heat Islands</td>
<td>1 Point</td>
</tr>
<tr>
<td>Reflectance Reduction</td>
<td>1 Point</td>
</tr>
<tr>
<td>(Green Roof for 50% of roof area)</td>
<td></td>
</tr>
<tr>
<td>Limit Use of Potable Water for Irrigation</td>
<td>1 Point</td>
</tr>
<tr>
<td>(graywater for 50% needs)</td>
<td></td>
</tr>
<tr>
<td>Only Graywater for Irrigation (or) no Irrigation System</td>
<td>1 Point</td>
</tr>
<tr>
<td>(temporary irrigation on Green Roof)</td>
<td></td>
</tr>
<tr>
<td>Decrease Stormwater Runoff</td>
<td>1 Point</td>
</tr>
<tr>
<td>(parking deck Green Roof)</td>
<td></td>
</tr>
<tr>
<td>Recycled Content</td>
<td>1 Point</td>
</tr>
<tr>
<td>Recycled Glass (mulch)</td>
<td></td>
</tr>
<tr>
<td>Recycled Rubber (track)</td>
<td></td>
</tr>
<tr>
<td>Recycled Green Roof Drainage Mat</td>
<td></td>
</tr>
</tbody>
</table>

Possible Total: 6 Points
What are your expectations?
THIS BUILDING EMBRACES ITS SITE.
THE SCULPTURAL PRECAST CONCRETE
 PANELS HARMONIZE WITH THE LOCAL
 COLORS AND TEXTURES. THE LOBBY AND
 CEREMONIAL STAIR PULL GARDEN AND
 INTERIOR TOGETHER, AND THE ROOFTOP
 TERRACE OFFERS A PANORAMIC VIEW OF
 FRESNO AND THE CENTRAL VALLEY.

JURY COMMENT

Fresno Court House

JOINT VENTURE ARCHITECTS
GRUEN ASSOCIATES/ MOORE RUBLE YUDELL
LOS ANGELES, CALIFORNIA
SANTA MONICA, CALIFORNIA
**GREEN ROOF**

**History**

- Date’s back to the Roman Empire & Vikings,
- 1960’s Switzerland and Germany has renewed interest in developing Green Roofs,
- 1980’s Germany 20% growth rate in Green Roof applications,
- 1990’s European Government policies support Green Roofing programs,
- “Green Roofing” used in North America since 1967.
- Drainage panels and waterproofing systems have spurred the growth
Traditional Earth Sheltered Roof
Ordinary Soil with Gravel Drainage

• High in clay content, weeds, etc.
• Prone to compaction - especially at shallower depths
  – Loss of oxygen/nutrients
  – Soil acidification
• Very heavy
  – especially when wet
• Poor drainage – no specialized drainage medium
  – Fungus growth
  – Root rot
• Poor aeration
Modern Green Roof Components

- Vegetation
- Growing Medium
- Drainage, aeration, water storage, and root barrier
- Insulation
- Membrane protection and root barrier
- Roofing membrane
- Structural support
Green Roof Design Elements

GREEN ROOF SYSTEMS

- Pavers
- Extensive
- Intensive
- Veg. Free
The venacular...

- **Extensive Roof**
- **Intensive Roof**
- **Growing Medium**
- **Water Retention**
- **Water Harvesting**
Green Roof Classifications

GREEN ROOF SYSTEMS

Extensive System

Low maintenance
Lightweight systems
Shallow: 3-6 inches growing medium
Drought tolerant plants

- Mosses
- herbs
- grasses
Green Roof Classifications

GREEN ROOF SYSTEMS

Intensive System

Regular maintenance
Heavier systems
Deeper growing medium: 9 inches or greater
Regular irrigation required
Variety of plant species
  • shrubs
  • small trees
Waterproofing Membrane

The most critical design element of any Green Roof System is the Waterproofing Membrane. No matter how good it looks on top, it must keep the water out!
Hot Applied Rubberized Waterproofing

Green Roof Systems

Why Hot Applied Rubberized Waterproofing?

- 40 Year Track Record
- 2 ply fully bonded and seamless membrane
- Easier melting
- Easier application
- Cost effective
- 25% recycled content
- Recyclable packaging
Hot Rubberized Asphalt
Why use hot rubber for a Green Roof?

Deck Considerations

- Concrete
- Gypsum Roof Cover Boards
- Plywood
Hot Rubberized Asphalt
Why use hot rubber for a Green Roof?

Slope & Application
Temperature Limitations?

None!
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Primer
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Waterproofing Membrane
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Protection Course
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Root Barrier
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Insulation
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Drain Board
Hot Applied Rubberized Asphalt Waterproofing

**Green Roof Systems**

Filter Fabric
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Growing Medium
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

$ 20 - $$\$$ sq/ft
$ 3-4.00 sq/ft
$ 8-15.00 sq/ft
Roof Durability & Maintenance Worksheet

Background
An increase in waterproof membrane durability accrues cost savings to a building owner through a diminished need for re-roofing over a building’s lifetime. N. American roofs have an average life span of 10-15 years (Hutchison, 2001), whereas membranes in greenroof applications in Germany typically last 30 to 40 years. Admittedly, the life span of green roofs in N. America may deviate from the German value, varying by region, climatic zone and waterproofing membrane type. Protected membrane roofs (PMR) assemblies, those where the membrane is covered by insulation, have similar performance attributes as a green roof in terms of membrane durability. These assemblies typically have an average lifespan 20-25 years in N. America and may be more indicative of the rate of re-roofing required for green roof applications (Mutton, 2004). Green roofs prolonged life span postpones the generation of end-of-life roofing materials going to landfill and may result in reduced annual maintenance costs.

Roof Durability & Related Cost Calculator

<table>
<thead>
<tr>
<th>Units</th>
<th>Quantities</th>
<th>Notes/Typical value ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of Roof</td>
<td>m²</td>
<td>385</td>
</tr>
<tr>
<td>Landfill cost-including transportation</td>
<td>$/m ton</td>
<td>85 varies btw $20-$115/m ton</td>
</tr>
</tbody>
</table>

Scenario 1:

<table>
<thead>
<tr>
<th>Notes</th>
<th>Typical value ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated life span yrs</td>
<td>16 Copied to roofing replacement interval</td>
</tr>
<tr>
<td>Estimated replacement cost $</td>
<td>25,412 in today’s $</td>
</tr>
<tr>
<td>Est. mass per unit area of roof kg</td>
<td>45 typically varies btw 20kg-80kg/m²</td>
</tr>
<tr>
<td>Est. % of mass going to landfill %</td>
<td>100 deduction for material reuse</td>
</tr>
<tr>
<td>Annual maintenance cost $/yr</td>
<td>408 e.g., estimated at 1% of initial capital cost</td>
</tr>
<tr>
<td>Landfill costs $</td>
<td>1,473 calculated</td>
</tr>
<tr>
<td>Periodic Salvage Value $</td>
<td>0 in today’s $, copied to periodic salvage value</td>
</tr>
<tr>
<td>Est. Replacement + Landfill cost $</td>
<td>26,885 calculated &amp; copied to periodic costs</td>
</tr>
<tr>
<td>End of life Residual Value $</td>
<td>1,1118 in today’s $ - copied to end of life residual value</td>
</tr>
</tbody>
</table>

Roof Durability Statistics

<table>
<thead>
<tr>
<th>Roof Type</th>
<th>Athena Institute</th>
<th>C. Cash Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Roofs</td>
<td>Protected Membrane</td>
<td>Minimum Life</td>
</tr>
<tr>
<td>PVC</td>
<td>12 to 15 yrs</td>
<td>15 to 19 yrs</td>
</tr>
<tr>
<td>TPO</td>
<td>15 to 19 yrs</td>
<td>15 to 22 yrs</td>
</tr>
<tr>
<td>EPDM</td>
<td>14 to 17 yrs</td>
<td>15 to 22 yrs</td>
</tr>
<tr>
<td>BUR</td>
<td>16 to 20 yrs</td>
<td>18 to 22 yrs</td>
</tr>
<tr>
<td>Mod.Bit.</td>
<td>16 to 21 yrs</td>
<td>19 to 23 yrs</td>
</tr>
<tr>
<td>Rubb. Asph.</td>
<td>16 to 20 yrs</td>
<td>16 yrs</td>
</tr>
</tbody>
</table>

Source:
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Heating 790-11 in double jacketed kettle
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

100% Solids
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Removal of dust and debris before priming
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

930-18 Rubberized Primer and Crack Detailing
Hot Applied Rubberized Asphalt Waterproofing

**Green Roof Systems**

**Hot Rubber**
Low Profile Expansion Joint System-
High performance expansion joint and ties in with hot rubber
Hot Rubber
Detail Work Includes Flashings-Simple upturn detail with Polyfab
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

SBS modified flashing sheets set in hot asphalt.
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Neoprene flashing set in Hot Rubberized Asphalt
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Base coat applied at 90 mils
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Hot Rubber
Application Method-Squeegee used to spread membrane
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Polyfab applied into hot rubberized asphalt
Hot Applied Rubberized Asphalt Waterproofing

Green Roof Systems

Hot Rubber
Top Coat Application-125 mil top coat applied over Polyfab
Hot Applied Rubberized Asphalt Waterproofing

**Green Roof Systems**

Protection membrane laid into hot rubberized asphalt
Hot Applied Rubberized Asphalt Waterproofing

**Green Roof Systems**

Waterproofing membrane complete – ready for insulation, drainage, and other green roof components
Electric Field Vector Mapping (EFVM)
Electric Field Vector Mapping (EFVM)
Optional - Install WPM Permanent Monitoring System

Leak Locate Grid

LeakLocate Array™ Termination Panel
Vegetative roof Installation
Growing medium should not be confused with soil. It is usually a synthetically produced expanded clay which is considerably less dense and more absorbent than natural minerals.

There are a large number of growing medium “recipes” commercially available, with bulk dry densities ranging from 25 to 50 lbs/cf.
Vegetative roof Installation

Green roof ready for vegetation
Vegetative roof Installation

Planting vegetation (plug system shown)
Design Considerations

FLL Guidelines for Green Roof Media

- Mineral content
- Organic content
- Granulometric distribution
- Frost-resistance
- Water permeability
- Water-storage capacity
- Maximum water capacity
- Air content
- pH-Level
- Carbonate and salt content
- CEC
- Nutrient content
ASTM & Green Roofs


E2397 Standard Practice for Determination of Dead Loads and Live Loads Associated with Green Roof Systems

E2398 Standard Test Method for Water Capture and Media Retention of Geocomposite Drain Layers for Green Roof Systems

E2399 Standard Test Method for Maximum Media Density for Dead Load Analysis*

E2400 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems
Design Considerations

1) Structural Considerations

Determine the allowable load capacity of the structure intended to support the green roof – add 35 to 50 lbs. min
   a) Conventional roof
   b) Structural concrete

Factor in deflection
<table>
<thead>
<tr>
<th>Growing Medium Depth in inches</th>
<th>Weight/sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 – 3</td>
<td>12 – 18 lbs.</td>
</tr>
<tr>
<td>3 – 4</td>
<td>18 – 24 lbs.</td>
</tr>
<tr>
<td>4 – 6</td>
<td>24 – 36 lbs.</td>
</tr>
<tr>
<td>6 – 9</td>
<td>36 – 54 lbs.</td>
</tr>
<tr>
<td>12+</td>
<td>72+ lbs.</td>
</tr>
<tr>
<td>+ Plants &amp; Waterproofing</td>
<td></td>
</tr>
</tbody>
</table>
Design Considerations

2) Source of Water

Though green roofs are meant to have minimal maintenance, mother nature is still unpredictable. An irrigation system is common on most Intensive Systems.
Irrigation Systems

Extensive Systems
• None
• Surface drip or spray
• Capillary Fabric
• Active base trickle irrigation

Intensive Systems
• Active Base Trickle Irrigation
3) Drainage

Poor drainage is one of the major reasons why most potted plants die. Excessive water simply drowns the plant or causes root disease or rot. Green roofs are nothing more than a system or grouping of potted plants.
Installation of DBR-50 or DBR-100

Function of DBR 50/100:

• Acts as water retention layer, storing water to hydrate soil above. Extremely important on Extensive systems with little growing medium (soil).

• Serves to drain excess water away from system. Most important function for extensive and intensive systems.

• Root barrier fabric (copper hydroxide treated) to prevent roots from penetrating into membrane and clogging retention/drainage core.

• Holes in top of drainage core allow for aeration
Design Considerations

- Specialized Drains Available
- Perforated Inspection Chambers
4) **Budget**

- Conventional protected membrane roofs cost between 6 to 12 dollars per square foot.
- Green roofs generally will start at the high end of the ballasted protected roof and go up from there, depending on the plant selection and overall design.
- Life Cycle Cost could be reduced by savings due to water retention and reduced energy consumption.
Design Considerations

5) Habitat Creation
Gardens attract vermin, squirrels, and rats - cover all exposed membrane flashing with metal.

Gardens attract insects ants and termites – specify treated wood
Design Considerations

6) Access and Maintenance

- Extensive roofs
  - Low maintenance
  - Typically not intended for recreation or frequent foot traffic

- Intensive Roofs
  - Require regular maintenance (mowing, fertilizing, watering)
  - Can be used as recreational space
Design Considerations

7) Vegetation Free Zones

Accessory areas to the green space to allow for free drainage and evaporation. Perimeter edge treatment adjacent to o/s parapets.
8) Fire Resistance

- Thoroughly tested in laboratory and field
- Initial review by Underwriters Laboratories (UL) and International Conference of Building Officials (ICBO)
  “. . .no deleterious effect upon the fire resistant properties of the system.”
- FLL Guidelines
- Consult with green roof manufacturer
9) Slope Considerations

- Maximum slope 2” in 12”
  - Standard for Inverted Roofs
- Possible steeper slopes
  - Typically can be considered only for extensive roofs
  - Battens/restraints for loose-laid elements need to be considered
  - Soil erosion control measures need to be implemented
  - Expert advice essential
Fooling Mother Nature

Wind Erosion Stabilization  XPS Creates Rolling Terrain
Design Considerations

10) Wind Uplift

- Cover Vegetation with restraints.
- Bury turf pavers to serve as an anchor at the base of the green roof
- Install pavers around the perimeter
Traditionally, these systems were constructed as:

“Earth Sheltered Roofs”

- Ordinary Soil
- Gravel
- Hot RA System
  With 4’ x 8’ Protection
Green Roof Growing Medium Characteristics

- Vital to the successful green/garden roof
- Must be able to retain moisture/nutrients and drain freely
- pH level must be correct
- Lighter in weight than ordinary soil

Growing Medium Composition

- Expanded Shale, Slate or Clay blended with sand and organic materials
Plugs

- Resistant to direct radiation
- Drought resistant
- Frost resistant
- Wind resistant
- Regenerative
- Native to region
- Self-sustaining
- Sedums are most popular
- Plant cost low
- Labor intensive
Clippings

- minor labor required
- Sedums are most popular
- Regenerative
- Native to region
- Self-sustaining
- low initial cost
Trays

• Resistant to direct radiation
• Sedums are most popular
• Drought resistant
• Frost resistant
• Regenerative
• Native to region
• Self-sustaining
• Medium plant costs
• Pre-grown
• Ease of installation
• ‘Edge effect’
Mats

- Resistant to direct radiation
- Sedums are most popular
- Drought resistant
- Frost resistant
- Wind resistant
- Regenerative
- Native to region
- higher initial cost
- Pre-grown
- Sod layout pattern
CONCLUSION

• Beneficial to our environment.
• Driven by Storm Water Management & LEED points.
• Waterproofing/Roofing System Integrity/Longevity.
• Collaboration of multiple team members.
• Read manufacturer’s Technical Data Sheets.
• Well written Specifications are essential.
• Talk to a manufacturer you can trust!

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Roofing

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Above Grade Waterproofing

Vegetative Roofing
Achieving High Performance Protection

THANK YOU