The evolution of tree soil under pavement

James Urban, FASLA
In 1978, I met Tom Perry an eccentric tree lover and Harvard PhD who preached that Landscape Architects were **killing trees with our designs**. He taught though a simple analogy that a **tree was a wine glass on a dinner plate**.

30 years later Up By Root was published to teach Landscape Architects how to build **healthy soils and trees**.
A vision of downtowns full of mature trees
Up By Roots
Healthy Soils and Trees in the Built Environment
James Urban
35 years of research, investigation, innovation
ca 1986

The soil chart – Myth, truth or half truth?
1,000 cf per tree or 3,000 cf?
Shared volumes vs isolated volumes?
Tree soil under pavement only solves 1 of 6 critical requirements:

1. **Sufficient soil volume**
2. **Zone of rapid root taper**
3. **Water in**
4. **Water out**
5. **Room for canopy growth**
6. **Quality nursery stock**
Christian Science, Boston
First significant tree, soil trench
600 cf/ tree  ca 1975
Soil trench
480 CF (13.55 M3)
Total usable soil

Tree space soil
115 CF (3.25 M3)

Usable Soil
365 CF (10.3 M3)
Soil trench installation along backside of curb

Excavate 3’ deep 4-5 feet wide.

Install drain lines.

Install topsoil or planting mix compacted to approximately 75-80% proctor.

Cover with reinforced concrete paving designed to span over loose soil.
400 CF (11.3 M3) TRENCH AT YEAR 12
This system is limited in the amount of soil that can be provided (about 500 cf max) and is dependant on the tree breaking out of the trench into the adjacent soil.
Original Central Artery trees
Planted in 2003 loam soil trenches
Root paths

Tree pit soil
115 cf

Root path
Soil 25 cf

Ca 1990
Root Path Installation

- Vibrate compact soil along edge of trench after topsoil is placed.
- Topsoil around drain
- Strip drain in trench

Diagram:
- Compact soil on trench sides after top soil is placed
- 4" (100mm)
- 12" (300mm) wide strip drain
- 12" (300mm)
- Concrete Paving
- Gravel Base Course
- Compacted Soil
- Topsoil
Structural soils
Aggregate based structural soil

A mixture of 80% crushed rock and 20% clay loam soil.

Compacted to 95% proctor density.

Proposed 1986
released 1996
Structural soil
315 CF (8.9 M3)
Total usable soil

Tree space soil
115 CF (3.25 M3)

Usable Soil
200 CF (5.65 M3)
Large structural soil and small loam soil have equal amounts of loam soil.

Source: Growth response of Ficus benjamina to limited soil volumes and soil dilution in a skeletal soil container study. Loh, Grabowsky, and Bassuk
Urban Forest, Urban Green, 2 (2003)

What is the value of the soil in structural soil vs the rock.
What are you really buying and how much does it really cost.

Structural Soil: how to calculate volume and cost

Tree at planting

Tree after 10 years

Using CU-Structural Soil™ in the Urban Environment

Cornell University

Urban Horticulture Institute
Cornell University
Department of Horticulture
154A Plant Science Building
Ithaca, NY 14853
www.hort.cornell.edu/UHI
Structural soil

Loam soil
Trees grew well!

BUT… this is not a true Structural Soil. It is only compacted to a maximum of 90% and some settlement was accepted.
Sand based Structural Soils in Boston
Similar to A'Dam Tree Soil but with more soil and compacted to 95%

Oak trees planted in 2005 @ 12”CLP

Beds
CLP avg 15.32
Growth 0.55”/yr

Pavers
CLP avg 13.22
Growth 0.20/yr
Sand Based Structural Soils
Significant differences in canopy density over trees in loam soil beds

Beds

Pavers
Sky Forest, Japan / PWP 2000
Bringing the idea to the profession 2003-2006
Bringing the idea to the profession
Silva Cells
1005 CF (28.25 M3)
Total usable soil

Tree space soil
115 CF (3.25 M3)

Usable Soil
890 CF (25 M3)
Silva Cell Installation

Cells and soil

Aggregate and paving
Over cell decks

Soil installation

Decks and geotextile
Reuse of existing soil at the site
Small Soil Volume Application

Tree space   1.4m³
Silva Cells  5.6m³
Total Soil   7.0m³
Trees / Rain Water and Structural Cells
Parking areas
1200 CF (34 M3) Soil volume
Treats 300 CF (8.5 M3) Water
Manages
3,600 SF (335 M2) Impervious area
1” rain event
Perforated distribution pipe is installed to bring water from the catch basin through the Silva Cell system.

Queensway Installation
The entire bioretention system is under pavement.
Trees and Stormwater
2nd and Marquette
Minneapolis, MN
Can we expect to grow large trees in urban areas?
Charlotte, NC Tree Comparison – 29 year growth period - Willow Oak

Uptown Business District
Suspended pavement soil volumes
approx 700 cf loam soil

Ridgeloch Neighborhood
Continuous open loam soil

Research and photos by Tom Smiley and Peter MacDonagh
Can we expect to grow large trees in urban areas?  
Charlotte, NC Tree Comparison – 29 year growth period

**Results**

<table>
<thead>
<tr>
<th>Location</th>
<th>DBH inches</th>
<th>Height feet</th>
<th>Condition</th>
<th>Number of trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uptown</td>
<td>18</td>
<td>70.2</td>
<td>1.45*</td>
<td>151</td>
</tr>
<tr>
<td>Ridgeloch</td>
<td>18.5</td>
<td>68.8</td>
<td>1.24*</td>
<td>161</td>
</tr>
</tbody>
</table>

* Highly significant difference using a T-Test.

Research by Tom Smiley and Peter MacDonagh
DBH Increase Inches / Year
Planting to 2013

Loam Soil / Suspended Pavement
Loam Soil / Open Planter
Sand based Soil
VALUE OF URBAN TREE BENEFITS over 50 YEARS

Tree In Compacted Soil
Estimated Lifespan
13 Years

- Total Benefits: + $2,717.66
- Total Costs: - $5,811.95
- Net Lifecycle COST: - $3,094.29

Tree 1,000 cf Loam Soil Volume
Estimated Lifespan
50+ Years

- Total Benefits w/Bio-ret: + $41,769.00
- Total Costs: - $16,341.75
- Net Lifecycle BENEFITS: + $25,427.22

Source: MacDonagh & Shanstrom 2010
Options for planting soil under pavement (15!)

**Rock based Structural soils**
1986 /1996
CU Structural soil
Expanded Shale Structural Soil
Structural soils other formulas

**Sand Based Structural Soils**
ca 2006
Pine Swallow formula
Tim Craul formula

**Suspended pavement trenches**
ca 1975 and 1981
Precast
Cast in place

**Suspended pavement precast vaults**
ca 2004

**Plastic structures**
2006
Silva cells
Brentwood boxes
Stratta vault
Stratta cells

**Reinforced Concrete forming systems**
ca 2000 / 2010
Custom built “Sono” tube
Cupolex
structure

**Root Paths**
1989

**Hybrid systems**
What are the critical issues?

Large mature trees need large open structures
Effective Rooting Space

Silva Cells: One large, continuous, horizontally and vertically connected rooting space

109 segmented soil spaces w/ 40% less soil

80% less soil, excessively drained
Flexibility of layout
Flexibility of layout
Incorporate broad range of soil types and weather conditions

- **Existing site soil amended with compost**: Most sustainable approach. Local soil knowledge required.
- **Unscreened loam soil**: Sandy loam, sandy clay loam, loam, silt loam topsoils from local sources. Excellent plant growth potential.
- **80/20 Bioretention soil**: All types of bioretention soil to meet local codes and requirements for storm water treatment applications.
- **Screened, moist soil mixes**: Local standard and custom soil blends.
Concrete form systems vs load bearing structures
• Open framework = total flexibility
• Works with utilities that bend
• Easy for new and existing utilities

• Limited ability to run new utilities greater than 5” other than in a straight line
• How do you incorporate existing utilities?
Repairs & Maintenance

Independent structures

Interconnected structure
Tree Requirements

1. Sufficient soil volume
2. Zone of rapid root taper
3. Water in
4. Water out
5. Room for canopy growth
6. Quality nursery stock
Elements to evaluate in a under paving tree soil system

Cost per CF of effective soil volume!

Water and root migration out of the system into adjacent soils

Water into soil
- Pervious pavers
- Water harvesting option
- Water exfiltration piping
- Drip irrigation

Layout flexibility
- Horizontal / Vertical obstructions
- Independent structure

Ease of utility installation / repair / modification
- Independent structure
- Restoration after utility repair
Elements to evaluate in a under paving tree soil systems

Soil types and soil installation flexability

**Paving system**
- Depth of paving over system
- Unreinforced concrete
- Asphalt
- Pervious pavers
- Gravel
- Lawn

**Contractor acceptance**

**Installation track record**

**Drawing and engineering construction support**

**Published research**

**Research and professional support**
Waterfront Toronto – Sugar Beach
August 2013 Planted 2010
The evolution of tree soil under pavement

James Urban, FASLA