The Great Soil Debate Part II: Structural soils under pavement
ASLA Annual Meeting Handout
11 September 2010

Introduction
Today landscape architects are using highly specified soils for planting that need to perform in intensive urban environments. Yet there is no settled science in this field. This is especially true when Landscape Architects approaching the question are faced with competing approaches to soils design for planting in pavements. The questions abound: How are we to know which approaches work best for our specific applications? How are we to make choices between approaches? And how are we to present these choices intelligently to clients, regulators, and design review panels? What is a sustainable soil? With the Sustainable Sites Initiative having selected pilot projects, the issue is front and center. Pending guidelines have the potential to direct landscape architects toward one approach or remain open to multiple systems. What are the next steps in this developing science?

At last year's presentation, three leaders in the field presented differing approaches to soils design. This year is the debate. Each leader will advocate for their design approach to planting soils under pavement in a moderated discussion giving landscape architects the tools they need to make educated and sustainable choices, lead a collaborative design process, and advocate for the soils design to owners, regulators, and contractors.

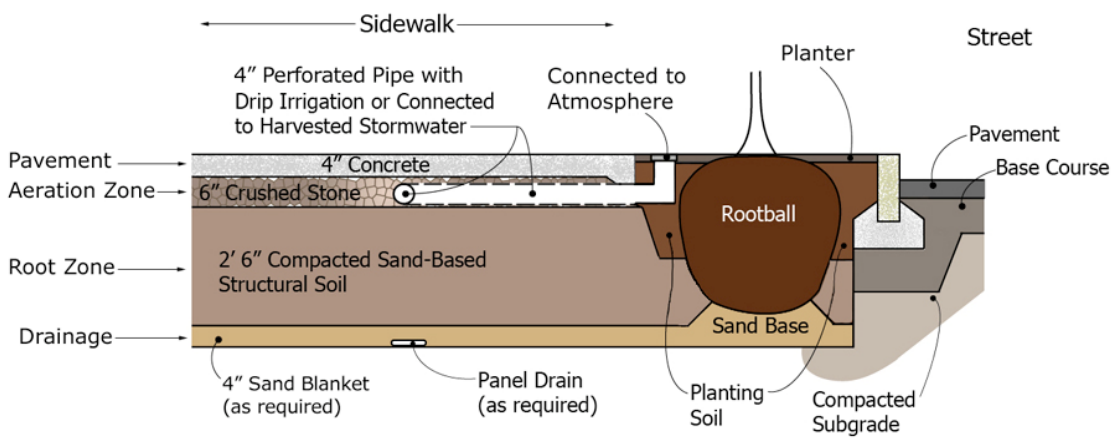
Presentation Outline
This is a continuation of the essential discussions from last year's presentation with a focus on soils for planting in pavement. The first portion of the session will be a brief presentation summarizing each approach. Then, an open moderated discussion between the panelists to assess the comparative values of each approach in different situations; and finally, the discussion will be opened to questions from the audience.

1) Summary of Approaches

a) Sand-Based Structural Soil: a system to create viable rooting zones beneath pavements

Bob Pine, Pine & Swallow Environmental

Sand-Based Structural Soil (SBSS) is a comprehensive system designed to create natural, sustainable growing environments beneath pavements. The SBSS system includes provisions for aeration, irrigation, drainage, root development and ongoing control of nutrients, soil chemistry and soil biology. The system is non-proprietary and does not require a license. The components are economical, universally available and easily installed by contractors The system is related to 'Amsterdam Soil' but with major advances in soil design and rooting environment. A typical SBSS profile is shown below.



uniform gradation of the sand allows for a high degree of compaction yet bulk densities remain low and particles can not pack into a hard mass. Excavations near street trees planted in SBSS have shown rapid root growth into the soil medium. Installations throughout the United States have demonstrated that SBSS supports pavements without settlements, yet is readily penetrated by plant roots.

All soils placed beneath pavements, or in confined spaces, can face stressed conditions. Moreover, if problems develop, access to these soils can be extremely disruptive and costly. Sand-Based Structural Soil has been designed to minimize potential risks of soil failure while enhancing long-term sustainability as a rooting zone.

Healthy soils in general, and tree roots in particular, require oxygen to sustain microbial and plant metabolism. Pavements reduce such exchange, so a mechanism to provide exchange of atmospheric and soil gases is essential. By utilizing porous crushed stone beneath the pavement, and by providing for an exchange of air through perforated pipe connected to the open air, the crushed stone – planting media interface acts as a normal air-soil interface for air exchange. Tree roots can then proliferate within the SBSS zone without causing heave of pavements. The stone also provides added structural support. Its thickness depends on the anticipated loading, ranging from six inches for paths where pickup trucks are possible, to twelve inches under roads for heavier vehicles.

Protection against anaerobic conditions is particularly important in these environments. The SBSS medium has high aeration capacity to enhance air exchange, good drainage to prevent saturation of the soils, and controlled organics to ensure adequate available water capacity and favorable soil biology.

Fertilizing, as necessary over time, can occur through the irrigation system and applications of compost tea can be made through the perforated pipe aeration system. Since the SBSS growing medium is economical to produce, adequate volumes to support the full growth of street trees can be installed without excessive cost. Typically, 600 to 1,500 cubic feet or more of SBSS growing medium is provided per tree, depending on tree species. Planting zones can be designed in non-standard configurations and can be integrated with adjacent non-paved planting areas to extend rooting zones. Moreover, because SBSS is structurally sound, it can be installed around existing utilities or under new utilities, as necessary, and it provides excellent stability for trees against winds.

SBSS installation
Front left: Drip irrigation in aeration pipe
Middle: Worker testing density
Rear: conventional construction equipment

Project Completed

Vassar Street, Cambridge, MA (Carol R. Johnson and Associates Design)

Providing adequate moisture for trees, especially during establishment periods and during droughts, is a critical aspect of ensuring successful plantings. Soils beneath pavements can become hot and will dry out and remain dry unless moisture is added. The three normal strategies for providing moisture are permeable pavements, stormwater harvesting, and controlled irrigation. However, for soils beneath pavements or in confined structures, each of these approaches introduces significant risk. SBSS has been designed to be compatible with each of these strategies.

The preferred irrigation systems are permeable pavements and stormwater harvesting since these operate with minimal maintenance. Porous pavement provides optimal distribution of water but does require periodic cleaning of the pavement. Stormwater harvesting can be used with slot rains (see photo below) or catch basins. Collected water is distributed through the perforated aeration pipes.

The primary risk associated with these strategies is saturated soils and consequent development of anaerobic soils. Anaerobic conditions beneath pavements are extraordinarily difficult and costly to correct. High rates of inflow can not saturate SBSS soils and good aeration ensures a soil environment where aerobic microbes can thrive.

SBSS has been designed to have a high infiltration rate and high aeration capacity. A risk associated with irrigation systems is clogging. Since the lines are below grade, repair can be extremely difficult. When irrigation lines are used with SBSS they are placed in the perforated aeration pipes so they can be easily removed and replaced as necessary.

Top: Design section through plaza showing rootballs in SBSS
Bottom left: Photo of mature trees installed in SBSS
Bottom right: Slot drain for stormwater harvesting
Central Wharf Plaza, Boston, MA (Reed Hilderbrand Design)

Urban environmental conditions are particularly challenging for any street tree plantings. Wind, heat, compacted soils, limited maintenance and sometimes direct physical abuse all provide potential stress to plantings. Sand-Based Structural Soil is flexible, adaptable and has been demonstrated to be successful in these environments. The system creates natural, sustainable and reliable soil rooting environments beneath pavements and does so economically.

b) Using CU-Structural Soil to Grow Trees Surrounded by Pavement.

Nina Bassuk, Cornell University, Ithaca NY, e-mail NLB2@cornell.edu

Soils under pavement need to be compacted to meet load–bearing requirements so that sidewalks and other pavement won't subside and fail. Soils are often compacted to 95% peak (Proctor or modified Proctor)) density before pavements are laid. When trees are planted into these soils root growth is severely reduced or eliminated beyond the tree-planting hole. When root growth is restricted, tree growth suffers as water, nutrients and oxygen are limited.
The need for a load-bearing soil under pavement gave rise to the development of CU-Structural Soil, a blended soil that can be compacted to 100% peak density to bear the load of a pavement while allowing tree roots to grow through it.

The concept behind it
CU-Structural Soil is a mixture of crushed gravel and soil with a small amount of hydrogel to prevent the soil and stone from separating during the mixing and installation process. The keys to its success are the following: the gravel should consist of crushed stone approximately one inch in diameter, with no fine particles, to provide the greatest large void space. The soil needed to make structural soil should be loam to clay loam containing at least 20% clay to maximize water and nutrient holding capacity. The proportion of soil to stone is approximately 80% stone to 20% soil by dry weight, with a small amount of hydrogel aiding in the uniform blending of the two materials. This proportion insures that each stone touches another stone, creating a rigid lattice or skeleton, while the soil almost fills the large pore spaces that are created by the stone. This way, when compacted, any compactive load would be borne from stone to stone, and the soil in between the stones would remain uncompacted.

CU-Structural soil uses the concept of uniformly graded sands and 'supersizes' the sand to accommodate large tree roots. In our experience the use of uniformly sand /soil mix cannot be compacted to 95% Proctor density without limiting tree root growth.

How is it used?
CU- Structural Soil requires a large volume of soil under pavement, approximately 2 cubic feet of soil for every square foot of envisioned crown diameter. We recommend a 36" soil depth, although several projects have been successful using as shallow as 24". We would not recommend any less than 24". CU-Structural Soil has an available water holding capacity between 7% and 12% depending on the level of compaction. This is equivalent to a loamy sand or sandy loam. Based on water holding capacity, you would need about 1.5 times the amount of CU-Structural Soil as you would need for an equivalent sized tree growing in sandy loam (See the table below for soil volume recommendations). Because of its well-drained nature, trees that prefer well-drained soils do best in CU- Structural Soil. Depending on the stone type used to make CU-Structural Soil, the pH of the soil may be affected (e.g. limestone vs. granite). Good tree selection practices and establishment procedures should be used with CU- Structural Soil as would be done with any tree installation.

It is important to maximize the water infiltration through the pavement to replenish CU-Soil as with any soil. A porous opening around the tree of approximately 50 square feet is recommended to allow for water infiltration.
Although CU-Structural Soil is made of readily available local crushed stone and soils, it is essential to make it correctly. To insure quality control, CU-Structural Soil is made by licensed producers who make it according to its specification all over the country (76 producers currently).

Samples from the licensed producers are tested at an independent soils lab for compliance. Over 1100 CU-Structural Soil projects have been installed successfully all over the US, Canada and Puerto Rico during the past 13 years. Costs range from $40-$75 per cubic yard.

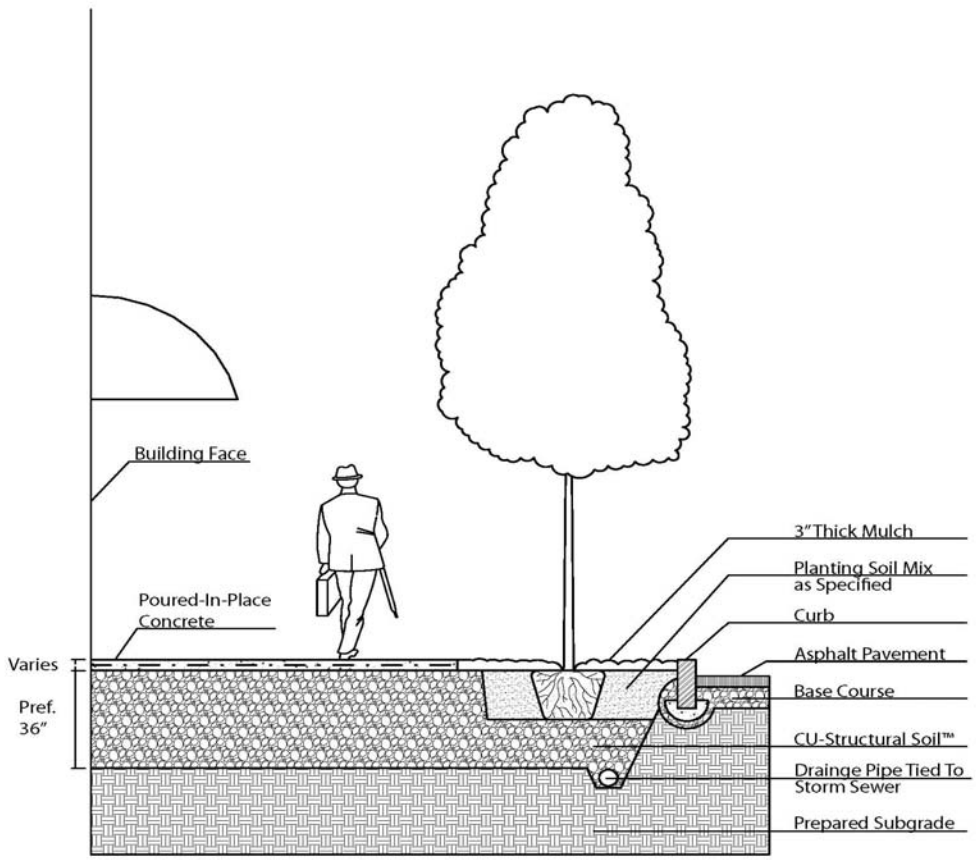


Figure 1. Cross-section of typical tree installation into CU-Structural Soil under pavement from curb to building face. Note where the tree pit is open, topsoil should be placed around the tree ball, but CU-Structural Soil should be placed under the ball to prevent tree ball subsidence.

CU-Structural Soil for stormwater capture
CU-Structural Soil has a rapid infiltration rate (>24" per hour) and has 26% porosity after it has been compacted to 100% peak density. Ordinary loam soil compacted to 100% peak density has an infiltration rate of 0.5"/hour. This allows CU-Structural Soil to be used for stormwater capture under porous pavements. 24" of CU-Structural Soil can hold the 100-year storm in Ithaca, NY of 6" of rain in 24 hours.

Soil volumes of CU-Structural Soil, Sandy Loam and Loam necessary to support trees in the Midwest or NE US without irrigation after establishment

Tree size	Crown projection, (square feet)	Available water 8% (CU-Soil)	Available water 12% (Sandy loam)	Available water 15% (Loam)
Small-medium tree, Crown diameter 20'	314	420 cubic feet* (16 cu yards)	400 cubic feet (15 cu yards)	325 cubic feet (12 cu yards)
Large Tree, Crown diameter 30'	706.5	1175 cu. feet* (44 cu. yards)	910 cubic feet (34 cu. yards)	725 cubic feet (30 cu. yards)

*420 and 1175 cubic feet of CU-Structural Soil assumes loam soil will be placed around the tree ball, but not under the ball in the pavement opening of 7' x7' or 5' x 10. CU-Structural Soil will only be used under adjacent pavement. If CU-Structural Soil were used in the pavement opening and under the pavement, the total amount of CU-Structural Soil would have to be raised to 600(22 cu. yards) and 1363 (50 cu. yards) cubic feet, respectively.

For more information on the research and use of CU-Structural Soil go to:
Cornell Urban Horticulture Institute Structural Soil website:
http://www.hort.cornell.edu/uhi/outreach/csc/

c) Suspended pavement with organic mineral loam soils

James Urban, FASLA, ISA

Reuse, recycle the underpinnings of sustainable design
Reusing or recycling mineral soil for use under pavement supported by structural cells for urban tree plantings in pavement is the most advantageous approach to building sustainable, long lived landscapes. This approach uses the existing organic mineral soil and even subsoil at the site, or recycles suitable mineral soil resources from other sites close to the project. Mineral subsoil deficient in organic matter may often be recycled by adding compost. They may have been previously disturbed, graded or compacted.

Setting the limits of the types of soil that may be reused or recycled, and how best to restore them should not be beyond the skill set of a landscape architect who is willing to invest a reasonable amount of time in understanding the basic dynamics of soil and plants. This information is readily available in books, and seminars currently distributed to landscape architects.

Preserving or reusing this resource reduces a project's carbon footprint, provides the highest levels of soil nutrient and water holding capacity, accommodates the most diverse planting options, and is the most efficient use of space for tree rooting in locations where there is fierce competition for space below the pavement.

Structural Cells
Organic soils at low compaction densities have been used under pavements since the late 1970's in narrow soil trenches with reinforced sidewalks spanning the trench. Thousands of trees have been planted in these trenches. The volume of soil in the trench, which normally has a maximum of 500 cubic feet of soil, is the main limitation to this approach. If the trees were able to escape

the trench they prospered. If not, they languished once they reached the limitations of the provided soil volume.
The introduction of structural cells solved the limitation of soil volume by placing a structure that supported the pavement allowing much larger, low compaction soil volumes. Without having to respond to the structural requirements of the pavement, the soil is free to meet the challenges of providing the tree with excellent water holding capacity drainage, fertility and long term soil biological functions. The soil, protected within the cells from compaction, can support bulk densities that are ideal for tree growth.

Soil efficiency
Organic mineral soils at low densities are the most productive soil possible for growing large trees. The low density allows oxygen and water infiltration are excellent throughout the profile. These soils do not require screening, which destroys most of a soils natural structure and soil peds (or clumps). Fine grained organic soil where peds are retained are loosely mixed with optimum organic matter, a soil, which has excellent water and nutrient holding capacity, is produced.

A remarkable range of soils can be incorporated into the structural cells from compacted clay loam, silt or sand loam subsoil, found at the site or within reasonable trucking distance. These soils can be mixed with compost to form suitable soils. Available standard planting mixes and topsoil are also suitable. Soils can be tailored to the tree type or trees selected to fit the available soil. The belief that heavy clay soils are not suitable for urban landscapes does not account for the low soil densities possible within the soil profile as a result of the cell structure.

Approaches that try to make the planting soil meet both the compaction requirements of the pavement and support the growth requirements of the trees result in a compromise to tree growth potential. Structural soils are quite dry and require consistent supply or water.

Skills needed to design soils for suspended pavement:
In order to design with this sustainable option, practitioners must develop an understanding of the native soil resources at the site or within its vicinity, and have an introductory understanding of soil science. The skills needed to perform this task are the same skills they will need to work with the soil section requirements of the ASLA Sustainable Sites Initiative.

Storm water and urban trees
Structural cells also offer the potential to make large areas of paving function as storm water management using native soils superior filtering capability to clean and hold water in ways previously reserved for natural areas.

Cost
When determining the cost of the system, the cost must be stated in cost of effective soil volume provided. When factored using that basis. The actual cost per cubic foot of soil, usable by the tree is normally less than the equivalent volume of stone based structural soil.

For further information on suspended pavements and to develop basic soil science skills read “Up By Roots: Healthy Soils and Trees in the Built Environment” by James Urban, Amazon.com

Less soil movement and damage, significantly less energy consumption

Soil not screened

Screened soil

Utilizes many types of unscreened loam soil. Screening destroys soil pore space and structure

Advantages of using loam soil within suspended pavement soil system

Soil can be recycled soil from the site or nearby locations.

The ASLA Sustainable Sites Imitative gives credit and applies great importance to reusing and recycling existing soil.

Greater water and nutrient holding capacity
Less or no irrigation

Suspended paving system “Silva Cells” being installed in Vancouver, BC. A wide range of soil types can be used to fill the cell system, which is capable of supporting the weight of large trucks.

Tree thriving at the Vancouver site with between 18 and 30”of tip extension in its second growing season.

2) Moderated Discussion
   a) Similarities and differences in approaches to soils under pavement
   b) Testing, evidence, and science
   c) Constructability
   d) Sustainability

3) Questions and Answers with the audience

Bios

Nina Bassuk
Nina Bassuk is currently a professor and program leader of the Urban Horticulture Institute at Cornell University. She is also a member of the Sustainable Sites Initiative technical committee and sits on the executive board of the New York State Urban Forestry Council. Along with co- author, Peter Trowbridge she wrote 'Trees in the Urban Landscape,' a text for landscape architects and horticultural practitioners on establishing trees in disturbed and urban landscapes. A native New Yorker, Nina's current work focuses on the physiological problems of plants growing in urban environments, including improved plant selections for difficult sites, soil modification including the development of 'CU-Structural Soil' and improved transplanting technology.

Robert Pine, ASLA
Bob Pine is a professional engineer and a landscape architect. He holds an MS in geotechnical engineering from Cornell University and an MLA from Harvard's GSD. As a principal of Pine and Swallow Environmental he has provided consulting services in soil and drainage design, horticulture and landscape construction for thirty years. Recent projects include: Asian University for Women in Bangladesh; The Highline, Brooklyn Bridge Park and Hudson River Park in New York City; Don River Park in Toronto; Crystal Bridges Museum in Bentonville AR; and sustainable streetscape projects at Harvard University and MIT.

James Urban, FASLA
James Urban, FASLA specializes in the design of trees and soils in urban spaces. He has written and lectured extensively on the subject of urban tree planting and has been responsible for the introduction of many innovations including most of the current standards relating to urban tree plantings. His 2008 book 'Up By Roots: Healthy Trees and Soils in the Built Environment', is becoming one of the principle references on tree and soil issues. In 2007 he was awarded the ASLA Medal of Excellence for his contributions to the profession and knowledge of trees and soils. Recent ASLA lectures include: 2007 Alternatives to Structural Soil for Urban Trees and Rain Water, and Successful Landscape Planting Techniques in Difficult Clayey Soils: Soil Amendments & Fertility; 2008 Healthy Trees and Soils, and Sustainable Sites Initiative - Vegetation and Soils, Draft Standards and Guidelines

Chris Moyles, ASLA
Chris Moyles is an associate and senior designer with more than eighteen years of experience. He is a graduate of the University of Virginia with a Master in Landscape Architecture. Chris has taught at the Arnold Arboretum of Harvard University and the Boston Architectural Center. Chris has designed and implemented projects for many institutions including Massachusetts Institute of Technology, the Phoenix Art Museum, Cornell University, and numerous residential projects. Chris is a member of the American Society of Landscape Architects and the Boston Society of Landscape Architects. He is a registered Landscape Architect in the State of Massachusetts. Current projects utilizing structural soils include: The Parrish Art Museum, NY; Chazen Museum of Art, WI; The National Foundation for Poetry, IL; and Long Dock at Beacon, NY.