Two Different Approaches to Improve Growing Conditions for Trees

Comparing Silva Cells and Structural Soil

By James Urban, FASLA, ISA

Of the many approaches to improving the growing conditions for trees in urban spaces, Silva Cells, manufactured by DeepRoot Green Infrastructure, and Structural Soil, marketed as "CU Soil" by Amereq Inc., are often considered as equal alternates. There is a belief that equal amounts of the two products have similar capabilities and support similar size trees, but this is simply not correct.

Structural Soil is made of 80% crushed rock and 20% loam soil coating the rock, thus only 20% of structural soil is actually usable by the tree's roots. The mix is compacted to 95% Proctor Density. Crushed rock has approximately 30% void space and the soil fills these voids, remaining un-compacted with the compaction force and paving loads transferred through the rock matrix. Clay loam soil is required in the mix specifications. Tree roots grow in the soil-filled void spaces with access to air and water. Vehicular loaded paving can be built over Structural Soil.

Silva Cells are a plastic/fiberglass structure of columns and beams that support paving above optimally compacted planting soil and transfers the force to a base layer below the structure. The structure has 92% void space, plus additional soil space between the cells, depending on the spacing. The Cells are designed for vehicle loading and have a AASHTO H-20 load rating, which is the required rating for vault covers and grates in sidewalks and parking lots. Since the soil within the Cells remains at optimum compaction, ideal conditions for tree roots are created. Silva Cells are designed for a wide range of soils, such as heavy clay loam, silt loam or sandy loam to sandy bio-retention soils. The use of recycled or reused soil makes Silva Cells an extremely sustainable approach. Even the soil at the project site may be suitable if sufficient compost is added.

Construction of Silva Cells begins with the excavation of the target site where the Cells are set on a 4-inch layer of aggregate. The outer edges of the assembly are wrapped

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The Why's and How's of Using CU-Structural Soil® to Grow Trees in Pavement

By Nina Bassuk, Ph.D., Cornell University

Why was CU-Structural Soil® Developed?

Soils under pavement need to be compacted to meet load–bearing requirements so sidewalks and other pavements 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 that prevents 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 (20–50% is the general range) to maximize water and nutrient holding capacity. It should also have 3–5% organic matter. 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 is being borne from stone to stone, while the soil between the stones avoids compaction.

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in geogrid fabric. Planting soil is placed inside the Cells and compacted very lightly to optimum density for root growth. After the soil is installed, a deck is placed on top of columns. Geotextile is laid over the deck and aggregate is laid on top of the geotextile—4 inches of aggregate is required under concrete sidewalks, while porous modular pavers require 12 inches. The sidewalk base aggregate is then compacted for pavers or concrete. The trees are planted in traditional spaces between the Cells. To accommodate mature tree trunk flares, designers are advised to make the tree planting space as large as possible. Specifications and details are available at www.deeproot.com.

Soil Volume Comparisons

While tree roots grow in both Structural Soil and Silva Cells, the net amount of soil available to the tree can be significantly different. The primary reason to use either of these systems is to increase available soil volume. Yet 100 cubic feet of Structural Soil provides only about 20 cubic feet of loam soil because of the amount of rock required (80%) to meet structural requirements. By comparison, 100 cubic feet of Silva Cells provides 92 cubic feet of soil or more depending on spacing. In environments where space and budgets are limited, the ability to more efficiently provide soil creates an advantage for using Silva Cells.

Comparative Research

There are few tests that compare Silva Cells to Structural Soil, but enough data and anecdotal information exist to make informed conclusions. In the most complete study at the Bartlett Labs in North Carolina (Smiley 2006-2012), trees in a suspended pavement mock up of Silva Cells are significantly out performing trees in Structural Soil after seven growing seasons. The trees in the suspended pavement over loam soil were taller and had broader canopies with significantly larger, greener leaves.

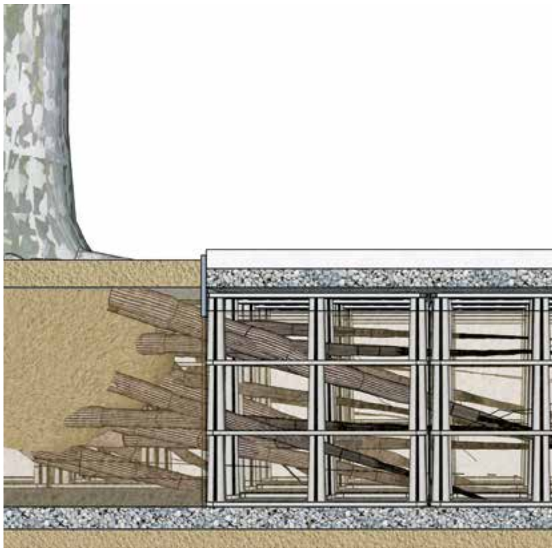
A 2003 study conducted at Cornell University (Bassuk 2003) concluded that trees in containers of Structural Soil were similar in growth to trees in small containers with the same net volume of loam soil that was in the Structural Soil. In that same study, trees in volumes of loam soil equal to the total volume of structural soil grew significantly larger than the Structural Soil trees.

Long-term observations of Structural Soil tree growth compared to loam soil volumes have been observed (Urban 2008-2010). In comparably sized spaces, some filled with Structural Soil and some filled with loam soil, trees in the loam soils have been observed to consistently grow larger. At a Structural Soil prototype planting in Staten Island, NY, one row of trees was planted in Structural Soil and one row was planted in loam soil in an adjacent open planter. The open planter contained approximately 275 to 300 cubic feet (cf) of loam soil per tree. The Structural Soil trees were grown in 350cf of Structural Soil that contained a net 70cf of soil with an additional 55cf of loam soil in the planting hole. The Structural Soil trees were in a total of 405cf of material, but this volume only contained a net 125cf of loam soil per tree, less than half of the net 275 to 300cf of loam soil available to the trees in the open planter. Twelve years later, the trees in the open loam soil planters were healthier than the Structural Soils trees, many of which were in decline.

In a nine-year-old planting in Columbus, OH, trees in Structural Soil started out growing well, but are now showing signs of decline. At another location in the same Columbus planting, trees were grown in Structural Soil in one portion of a block, while the rest of the street was planted with similar trees in similarly sized loam soil panels. Ten years later, the trees in the Structural Soil were starting to decline, while those in the loam soil panels were continuing to thrive. Similar

Structural Soil

Silva Cells



Silva Cell structure filled with soil to allow root zones below pavement observations have been made in cities as diverse as San Francisco, Chicago, and Ft. Worth. At one of the original structural soil plantings in Union Square, New York, the trees have failed to prosper after 10 years.

Soil Volume

The net volume of soil in the design is critical to predicting the long-term growth of a tree. A typical large canopy tree needs in excess of 1,000cf of loam soil to reach a large enough size to create significant environmental benefits. It is often quite difficult to find the space and budget for this amount of soil along urban streets. Before considering Silva Cells or Structural Soil, it is critical designers understand existing soil conditions. In more cases than we might expect, the existing soil under the pavement is actually suitable for tree growth. If this were not true, our cities would have far fewer trees that we see today. But there are still many places where installing new soil under pavement is justified.

The difference in soil volume efficiency of Silva Cells compared to Structural Soil is the most important difference. The 92% vs. 20% difference noted above allows larger soil volumes to be provided in the smaller spaces. In many cases, it may never be possible to provide the required soil volume with Structural Soil due to the limitation on urban space—full of utilities, foundations and other structures that compete for space. Urban excavation is more costly and there is great value in spatial efficiency that reduces excavation. To provide similar soil volumes, one needs to provide almost five times the volume of Structural Soil than provided by Silva Cells.

Soil Types

Trees grow best in loosely compacted loam soil, the type that can be installed in Silva Cells. The ideal growing conditions mean faster transplanting recovery and more rapid growth. Trees growing in loam soil in Silva Cells have responded exceptionally well in numerous applications throughout the six years since their introduction. Structural Soil must be made from a specific clay loam soil texture, which is normally not a problem to locate, but has created sourcing issues in some market areas where clay loam deposits are rare, such as some areas of New England.

Suspended Pavement tree

Gravel/Soil tree

Bartlett Study at seven years. Suspended Pavement trees are a mock-up of Silva Cells. Gravel/Soil trees are structural soil.

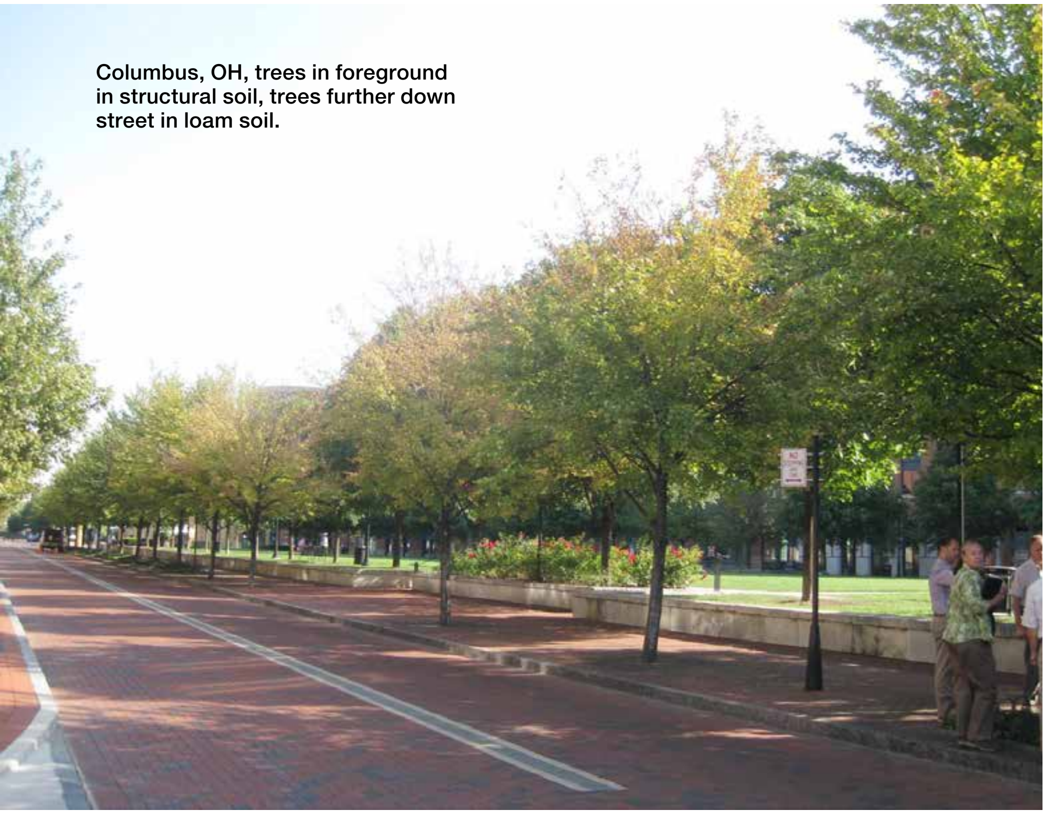
Silva Cells can accept any type of soil considered appropriate for the proposed planting. Of course, locally available topsoil should be considered, but in many markets this soil is increasingly less available. Research at Virginia Tech has shown that subsoil and other types of mineral soil, when un-compacted and loosely mixed with compost, can make a fine growing medium for trees.

In the soil industry, most soils are heavily screened. During the process, soils lose all soil structure, which is critical to drainage. Large quantities of sand are added to make up for the lost drainage capability. If we were to stop screening most soils, accept a reasonable amount of rock and debris in the soil (5–8% by volume)and add in small amounts of compost (10–15% by volume), we could use little to no sand and still have great growing mediums. Silva Cells allow the use of lumpy compost soil while protecting the fractured soil from re-compaction. This fracturing and adding compost can even be applied to subsoil under much of the paving in cities. When the subsoil must be excavated and removed from the site, it can be reused and boost the sustainability of the project along with any savings in installation costs.

In areas where only limestone rock is available, the pH of Structural Soil may be greater than the proposed trees can accommodate. Either high pH tolerant trees must be used or more expensive non-limestone rock must be trucked in. Silva Cells accept a wide range of soil textures and sources that allow lower pH soil to be created.

Water Harvesting and Availability

Both Structural Soil and Silva Cells need a water source to support the trees. Often, this need is not incorporated into the design. Pervious pavers are the best way to harvest rainwater and both approaches work well with this paving type. If concrete paving is used, then a piped water harvesting and distribution system is needed below the paving. The soft, easily worked soil within the Silva Cells make adding this feature easier than digging pipe channels within the structural soil.


Columbus, OH, trees in foreground in structural soil, trees further down street in loam soil.

The fine-grained, slower-draining, continuous soil volume in Silva Cells allows significant horizontal capillary action when compared to the rapidly draining Structural Soil where water is quickly lost to vertical drainage. Good capillary capability allows a wider and more even distribution of water throughout the soil. In Silva Cells, water availability is a key factor in the calculation of soil volume requirements. While water availability within the clay loam soil in Structural Soil is significant, and the reason this soil is specified, it still represents a small part of the overall system volume. There is one study that looked at the water holding capacity of structural soil compared to other soil types (Grabosky *et al.,* 2009). This study shows favorable results, but has a significant issue that calls into question the interpretation of the results. The methods used to calculate the available water in structural soil used plant response. This is a significant change from the pressure plate method used in the studies referenced as the soil available water base data. Do these two methods really look at exactly the same factors and provide the same results in identical soil? And if structural soil had reasonable levels of soil moisture, why do trees growing in this medium often exhibit drought stress symptoms when compared to similar trees in loam soils?

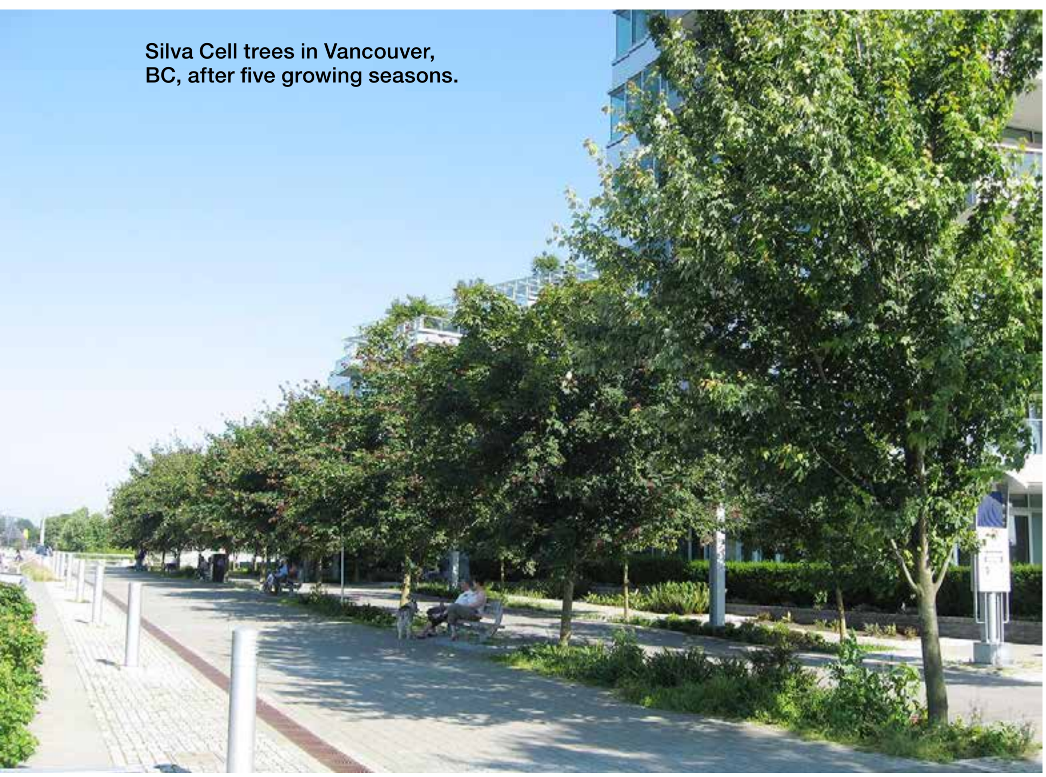
Rainwater Applications

There is a growing trend to use the soil volumes for trees to also treat and retain rainwater runoff in cities. Both Silva Cells and Structural Soil have been used for this purpose; however, there are significant differences in the effectiveness of each approach. Structural Soil is a very rapidly draining material (approximately 24 inches per hour). Water moves through it so fast that it does not effectively retain significant amounts of water for meaningful periods of time. This rapid drain down rate also reduces its ability to remove pollutants.

In a 2006 report on bio-retention effectiveness, North Carolina State University found that the optimum infiltration rate for various pollutant removals were: total nitrogen 1–2 inches per hour; total phosphorus 2 inches per hour; and metals, TSS (Total Suspended Solids) pathogens: 2–6 inches per hour (Hunt/Lord 2006). These rates are significantly lower that the 24 inches per hour in Structural Soil. Washington State Department of the Environment only accepts bio-retention soils with infiltration rates of between 1 and 12 inches per hour (Hinman 2009). With this information, it is not surprising that Structural Soil was found to filter an average of 53% of the nutrient pollutants in a 2008 study (Xiao and McPherson 2008). Studies on pollutant removal in bio-retention soils are significantly higher, (Coffman 2002, Hsieh/Davis 2003) particularly in deeper soil depths. The soil within Silva Cells can be designed to both retain significant amounts of water and filter a wide range of water pollutants. Soil infiltration rates can be designed to be much slower than Structural Soil, thereby increasing filtering capacity, the volume of water retained and the time of that retention.

Sustainability

Structural Soil is made from processed hard aggregates that require significant energy to mine, crush and ship. Quarry activity can be damaging to the local environment. In many markets, clay loam soil is often shipped from outside the project area and rock quarries are typically located far from metropolitan centers. Both the stone and soil must be shipped to the mixing site, processed and then reloaded for delivery. The total energy footprint of choosing this material can be significant, and the energy footprint is compounded by the need to install four to five times the volume of material compared with using Silva Cells to achieve similar results.



Silva Cell trees in Vancouver, BC, after five growing seasons.

While Silva Cells are made of 70% plastic material and in most markets are shipped long distances, they represent 3% of the total mass of the required soil assembly. The efficiency of the soil system makes for far less effort to achieve similar results as Structural Soil. When locally sourced, recycled or reused site soil is added to the design, significant positive impacts to the overall sustainability equations are realized. The ability to use local, natural soils may also mean local native tree species are suitable selections.

Cost Comparisons

Silva Cells have been criticized as being more expensive than Structural Soil. However, this is only if that comparison is looking at the total cost per unit of planting soil provided in the Silva Cells compared to the total volume of the rock and soil in Structural Soil. As noted above, this is not a reasonable comparison. Cost must be compared on delivered soil volume in each approach. If the products are to be bid as equals, then the bid should require providing a specific volume of loam soil. When you take that approach, in the typical market, Silva Cells are about 30–45% less costly than Structural Soil to provide the same loam soil volume. Both systems do not fit into the same place if you want equal results. Value engineering recommendations to substitute equal volumes of Structural Soil for Silva Cells should not be accepted. 100 cubic feet of Silva Cells will require 400 to 500 cubic feet of Structural Soil to provide for equal tree growth and there may not be sufficient room to install enough Structural Soil to equal the amount of soil provided in the Silva Cell design. If comparative bidding is required, two sets of drawings, one for the Silva Cell option and one for a Structural Soil option, must be prepared to reflect the difference in system size and different types of coordination required with the other elements in the urban fabric.

Structural Soil Conclusions

Structural Soil is limited in the amount of overall soil provided due to the amount of rock that it contains. Trees generally grow well until the amount of soil in the mix is exhausted; the trees must then either find a way out of the provided soil or they will begin to decline. When calculating Structural Soil to use for each tree and making predictions on the effect of the material on tree growth, only the amount of soil in the mix, approximately 20% of the total volume, should be considered in the calculation.

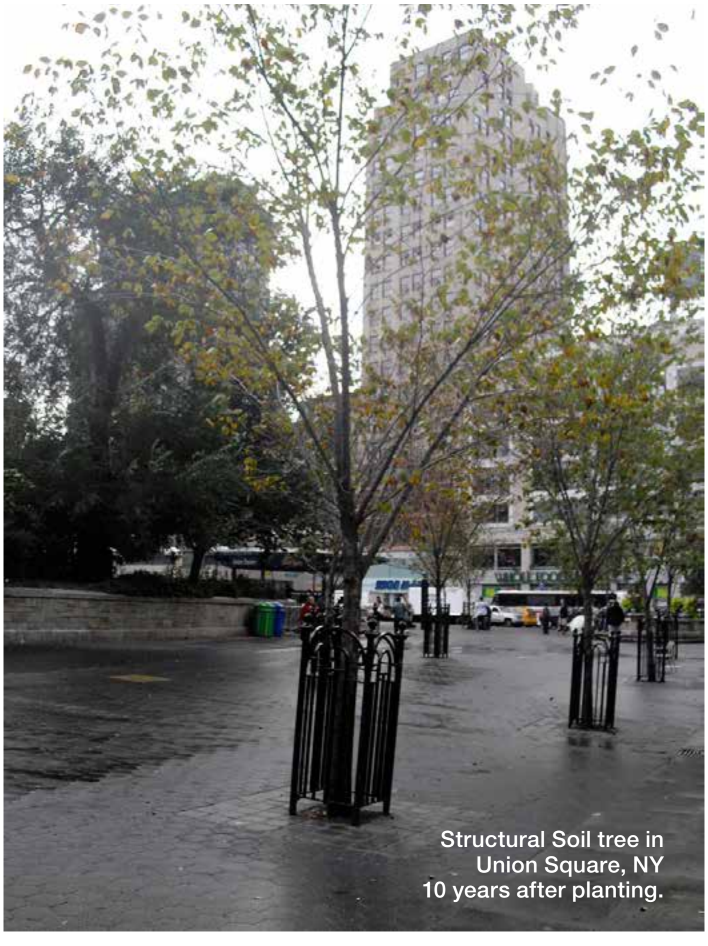
The limitations of clay loam soil availability and use of limestone with any increase in pH has disadvantages that may require understanding soil type availability and the geology at the site. Tree selections need to be adjusted for any local conditions.

Structural Soil is limited in use as a rainwater management application because rapid drain down limits time of retention, reducing the amount and time water is held from waterways and the amount of pollutants that can be filtered from the water.

The greatest advantage of Structural Soil is, it can fill odd shaped excavations and fit in places where Silva Cells are limited by their dimensional constraints. Structural Soil has been used in conjunction with Silva Cells to bridge spaces around utility lines and obtain incremental improvement to rooting volume around the edges and underneath Silva Cells in tight spaces.

Silva Cells Conclusions

Silva Cells offer the ability to install very large volumes of soil in compact urban environments to help grow mature street trees and manage rain water on site. The soil can be high-quality loam topsoil or other soil types that meet the project and tree species requirements, including specialty bio-retention soils and recycled or reused soil from the project site or found locally. The system is the most efficient and cost effective approach to deliver good-quality soil under pavements.



Structural Soil tree in Union Square, NY 10 years after planting.

The ability to reuse local soil makes the system very sustainable. The modular nature of the product has proven to allow installations in tight urban spaces along side utilities and adjacent structures. The system's flexibility and the varieties of soil that can be used makes it ideal for rainwater management where trees and soil can become a significant part of the rain water management solution.

James Urban, FASLA, ISA is an urban soil and tree consultant in Annapolis, Maryland. He is the author of "Up By Roots: Healthy Soils and Trees in the Built Environment". He was involved in the development of structural soils in the 1980's and 90's and also was on the design team for Silva Cells. As a matter of full disclosure, as part of the Silva Cell design team, he receives a royalty from the sales of Silva Cells and is a technical consultant to the DeepRoot Green Infrastructure, LLC.

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How Is It Used?

CU-Structural Soil® requires an adequate volume of soil under pavement, approximately 2 cubic feet of soil for every square foot of envisioned crown diameter. We recommend a 36-inch soil depth, although several projects have been successful using as shallow as 24 inches. Less than 24 inches is not recommend. CU-Structural Soil® has an available water holding capacity from between 7–12%, depending on the level of compaction. When soil volumes for CU-Structural Soil® are calculated, to be on the conservative side, a water holding capacity of 8% is suggested (Bassuk, *et. al.*, 2009). This is equivalent to loamy sand. Based on water holding capacity, you would need approximately 1.3 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 upon 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 at least 50 square feet to allow for water infiltration is recommended. Or, low volume, trickle irrigation may be used in regions where rainfall is not adequate.

Although CU-Structural Soil® is composed 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 (71 producers currently). Samples from the licensed producers are tested at an independent soils lab for compliance. More than 1300 CU-Structural Soil® projects have been successfully installed all across the U.S., Canada and Puerto Rico during the past 15 years. Costs range from $40-$75 per cubic yard.

CU-Structural Soil® for Stormwater Capture

CU-Structural Soil® has a rapid infiltration rate (>24 inches 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 inches per hour. This allows CU-Structural Soil® to be used for stormwater capture under porous pavements—24 inches of CU-Structural Soil® would hold the 100-year storm in Ithaca, NY that generated 6 inches of rain within 24 hours.

Things We Have Learned From 15 Years of Experience

Tree Selection Matters

CU-Structural Soil® is very well drained and may have an altered pH depending upon the stone type that is used. Limestone gravel will result in a higher pH (about 8.0), while granite and other stone types will have less effect. There are numerous tree species that grow very well at a variety of soil pH. Also, as CU-Structural Soil®

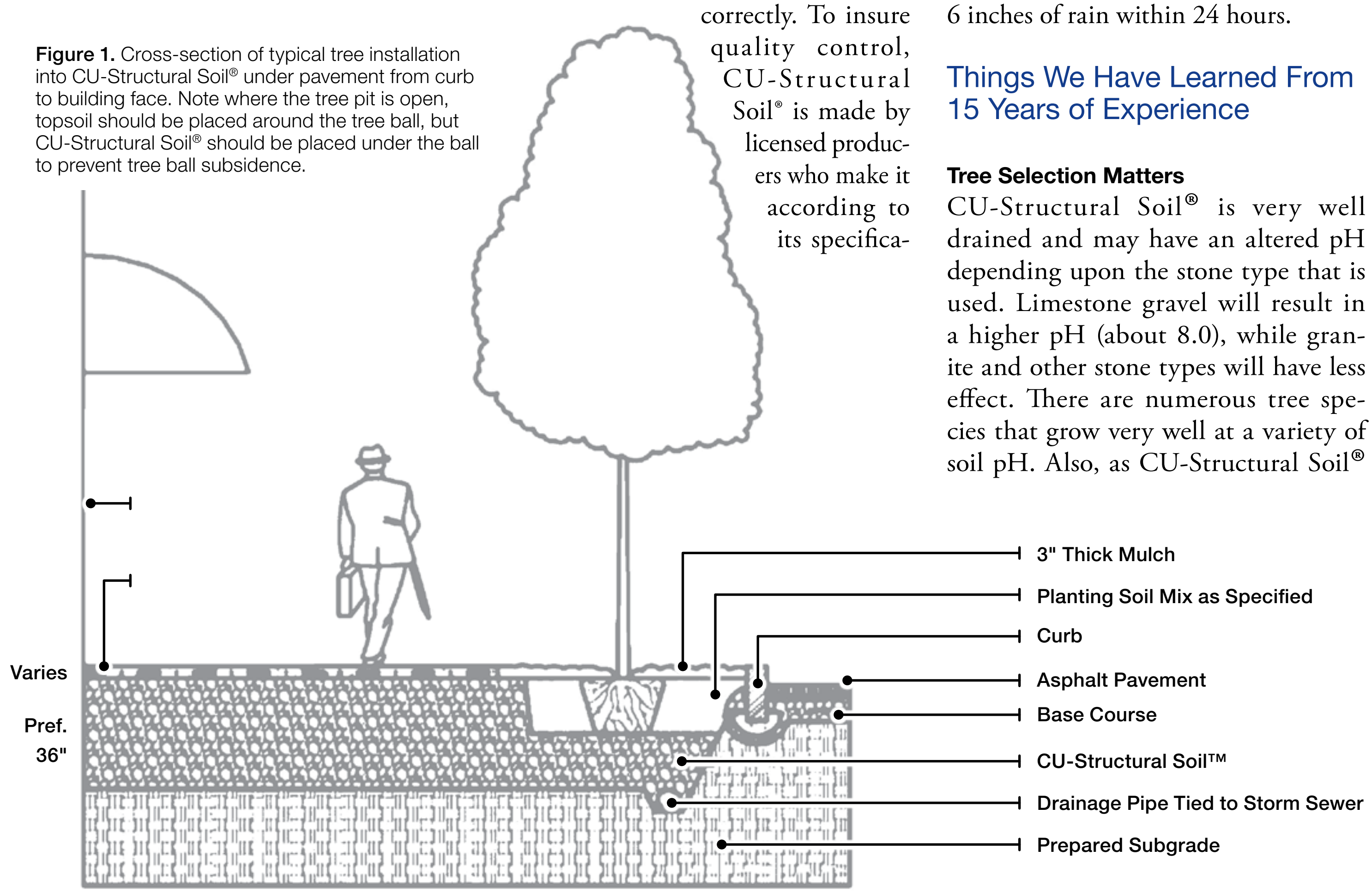

Figure 1. Cross-section of typical tree installation into CU-Structural Soil® under pavement from curb to building face. Note where the tree pit is open, topsoil should be placed around the tree ball, but CU-Structural Soil® should be placed under the ball to prevent tree ball subsidence.

is well drained, species that prefer these soils conditions should be chosen. See Recommended Urban Trees at http://www.hort.cornell.edu/uhi for recommendations on the tree species that tolerate a range of pH and soil moisture conditions.

Initial Maintenance Matters

As with any tree, initial watering is important to get it off to a good start. This may not matter in a lawn or park situation, however, it is critical when pavement limits water from entering the soil. This happens more frequently when trees are planted in pavement. Twenty gallons of water every five to seven days is generally adequate for newly planted trees in areas where there is adequate rainfall. In areas where trees are normally irrigated, low volume trickle irrigation works well for trees planted in CU-Structural Soil®.

Soil volumes of CU-Structural Soil®, Sandy Loam and Loam necessary to support a large tree in the Midwest or Mid Atlantic U.S. without irrigation after 3 years of establishment.

Tree size	Crown projection: (square feet)	Available water holding: 8% (CU-Soil)	Available water Holding: 12% (Sandy loam)	Available water holding: 15% (Loam)
Large Tree, Crown diameter 30'	706.5	40 cu yards	30 cu. yards	25 cu. yards

(40 cubic yards of CU-Structural Soil® assumes loam soil will be placed around the tree ball, but not under the ball in the pavement opening of approximately 7' x 7' or 5' x 10')

Soil Volume Matters

Structural soil less than 24-inches deep is inadequate for tree growth. Earlier trials with 12 or 15-inch depths of structural soil did not result in good tree growth after 12 years. Soil volume should be sized to at least 2 cubic feet per square foot of envisioned crown projection (the area under the tree's drip line). CU-Soil depth should be at least 24 inches, but preferably 30 or 36 inches. The deeper the soil, the greater the soil's water holding capacity. It will also be less likely that tree roots will heave sidewalks. Research has shown the roots grow to the full depth of structural soil, so radial growth of tree roots and their resulting upward force would be spread across a larger area, compared to roots that grow right under the sidewalk.

Production of CUSS According to Research-Based Specification Matters

Many years of research and testing went into the development of CU-Structural Soil®. When there is at least 20% clay in

Using CU-Structural Soil® *continued*

the soil, the soil coats the stone and there is greater surface area for roots to gain the water and nutrients they need. This clay content is critical to achieve adequate nutrient and water storage. There is also 3–5% organic matter in the soil helping it achieve a good cation exchange capacity and to feed soil microorganisms.

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

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CTLA Update *continued*

April 2013 CTLA Meeting

- An editor from the ISA, Amy Theobald, attended the meeting
- The first three chapters of the 10th Edition rewrite are now going to include: Core Concepts, Process, and Data Collection
  - » The Core Concepts chapter has been reduced considerably, only to address key concepts that need to be understood regarding common tree and landscape appraisal problems and assignment results. With the exception of understanding the difference between costs and values as assignment results, the concepts related to any type of market values have been removed from the Core Concepts chapter and are tentatively being considered for an exclusive chapter regarding economic principles and market value-type assignments.
  - » The Process Chapter has been reduced in content, but expanded with supplementary flowcharts and checklists to aid appraisers with making appropriate assignment-driven decisions throughout the process of solving a landscape appraisal problem.
  - » The Data Collection Chapter has been significantly reduced to only capture the importance of collecting relevant and accurate types of data for differing appraisal assignments. Much of the detailed information regarding what and how to collect data are being considered as supplementary information that could be referenced in the appendices.
- All three chapters currently appear to have eliminated derogatory and/or cautionary language and have limited references to market value-type appraisal problems and assignment results.

Looking Forward

- Logan Nelson debriefed Beth Palys, Gordon Mann, Patrick Brewer, Jim Ingram, and Brian Gilles on the CTLA April meeting during a conference call, one week after the meeting.
- CTLA authors are currently making revisions to Chapters 1, 2, and 3 based on council members' comments and discussion during the April meeting.
- A CTLA June conference call has been scheduled to discuss finalized revisions for these chapters. Following the conference call, it is anticipated that chapters 1, 2, and 3 will be released to each of the member organizations for early review and feedback, prior to the formal peer review of the second draft in its entirety.
- A CTLA meeting is tentatively scheduled for October to discuss the rewrite of the Cost Chapter. Logan Nelson and Brian Gilles will be working with A3G to prepare for the October meeting, as the Cost Chapter will be one of the most significant chapters in the Guide.
- A second formal peer review of the second draft in its entirety, is anticipated for the Fall of 2014.