CU-Structural Soil

An Update after More than a Decade of Use in the Urban Environment

by Nina Bassuk, Director, Urban Horticulture Institute, Cornell University

These *Pyrus calleryana* 'Chanticleer' were planted in a plaza space in Ithaca about five years ago. They have grown exceptionally well. Our experience with species that do well in CU-Structural Soil suggests that those trees that are both alkaline soil tolerant and moderately to highly drought-tolerant make the best candidates for this soil type.

In 1995, Jason Grabosky (now a professor at Rutgers University) and I published the first scientific paper on what would come to be known as structural soil—later, CU-Structural Soil. The development of this soil medium came about as we recognized that the single most important factor limiting the healthy growth of trees in urban areas was a lack of an adequate volume of soil.

There appeared to be plenty of soil under sidewalk pavement and gravel for tree roots to grow into. However, most of that soil was so highly compacted as to make it inaccessible to tree roots. The soil was too dense. So tree roots were contained within the hole into which they were planted, or managed to grow out of the hole into the gravelly base course directly under the paved surface—often heaving sidewalks in the process. Neither outcome was acceptable. Trees in sidewalk "containers" grew poorly and never attained the envisioned size for which they were planted, and tree roots that "broke out" under the sidewalk often caused a tripping hazard as the pavement was raised.

Soil under pavements of any kind—concrete, asphalt, block pavers, etc.—is required to be compacted to bear the weight of the pavement surface. Engineering specifications for pavement installation call for a high degree of compaction, often specified as 95% Proctor or peak density, to ensure that pavements would not subside, crack, or fail.

Thus the problem for us: trees require a large volume of soil in order to grow and provide the benefits for which we plant them, yet pavement installation specifications require that the soil below the pavement be highly compacted, limiting root growth. Could we develop a soil that would meet engineers' requirements for soil compaction while allowing tree root growth? The outgrowth was CU-Structural Soil.

Simply put, 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. Many years of research went into finding the right blend of these three elements so that the requirements of pavement installation and the growth of the tree could be satisfied. The keys to success were the following: the gravel should consist of crushed stone approximately one inch in diameter, with no finer particles, to provide the greatest porosity. The soil needed for structural soil was loam to clay loam that contained at least 20% clay to maximize water and nutrient holding capacity. The proportion of soil to stone was 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 ensured that each stone touched another stone, creating a rigid lattice or skeleton, while the soil almost filled the large pore spaces that were created. This way, when compacted, the load would be born from stone to stone, and the soil in between the stones would remain uncompacted.

Here is the Ithaca, NY parking lot in the first year after planting. 'Accolade' elms were planted in the porous asphalt and traditional asphalt. Both surfaces have CU-Structural Soil underneath. We will be evaluating the growth of all trees in both surfaces over time.

The comparison of traditional asphalt (left) and porous asphalt (right). Porous asphalt lacks the fine particles of stone and binder course that makes it impervious. Porous asphalt works very well; however, it is important not to use sand for de-icing as that will clog up the pores. It is recommended that once a year the surface be vacuumed to remove debris that has fallen on the site.

This is a 14-car parking lot in the city of Ithaca entirely built on 24" of CU-Structural Soil. In this rainy picture you can clearly see the traditional asphalt as it looks slick from the water running off it compared with the porous asphalt, which looks dull as rainwater goes through its surface. Subsequent to this construction, areas of both types of asphalt were cut out and elm trees were planted.

'Accolade' elms in the parking lot towards the end of their second year of growth in CU-Structural Soil overlaid with porous or traditional asphalt. All trees are doing very well, putting out one-and-a-half to two feet of new growth in their second year, with no differences due to surface treatment at this date. Evaluations will be ongoing.

These *Acer campestre* have grown for nine years in a trench of CU-Structural Soil overlaid with un-mortared concrete pavers. Although when these trees were planted, we only used 15″ of CU-Structural Soil in a continuous trench under the brick pavers, we now believe that 24″ should be the minimum depth of structural soil, appropriate for smaller trees, while 36″ is preferable in order to maximize rooting space and water availability.

After testing this soil in controlled experimental sites at Cornell, we were ready to begin using it in installations. We also decided that we needed to patent the material to ensure its quality control. As we were developing CU-Structural Soil, we often spoke about it at conferences so that several people decided to try it for themselves. Often during these attempts the user would change the proportions of soil to stone by adding more soil than we specified. In doing this, stone did not touch stone, because stones were pushed apart by too much soil. When that mixture was compacted, the stone lattice would not occur and the end result was compacted stony soil. These mixes were also called "structural soil," yet they had nothing to do with the carefully researched proportions we had developed. Therefore we decided to patent our structural soil as CU-Structural Soil® in 1998 (U.S. Patent # 5,849,069). Cornell University owns the patent and Amereq, Inc. (*www.amereq.com*) is the licensee who sublicenses it all over the U.S. and Canada. There are other structural soils; however, only CU-Structural Soil has over a decade of research and hundreds of installations.

There are now 71 licensed producers of CU-Structural Soil in the U.S. and Canada and over 500 installations, from Quebec to Puerto Rico to California. CU-Structural Soil has been used in many different climates and is compatible with irrigation when that is necessary. As with any new technology, we're learning more about it as we continue to do research on its uses.

Frequently Asked Questions

What is the average cost of CU-Structural Soil?

Our most recent analysis from licensed producers across the country showed an average selling price of CU-Structural Soil of between $35-$42 per ton. There are some producers that are able to sell the material for a little less, but this is a very good estimate of the average price.

What volume of CU-Structural Soil is needed for a given tree?

The Urban Horticulture Institute at Cornell has found that, with the exception of the desert Southwest, two cubic feet of soil is needed for every square foot of crown projection (the anticipated area under the drip line of the tree at expected maturity). Trees growing in CU-Structural Soil in areas that normally use irrigation to grow trees should also provide low-volume drip irrigation in CU-Structural Soil installations.

What is the recommended depth for CU-Structural Soil?

We suggest a minimum of 24", but 36" is preferred. Roots will grow to the full depth of CU-Structural Soil. A base course of gravel is not needed on top of CU-Structural Soil below the pavement, because it was designed to be as strong as a base course. Properly compacted to 95-100% Proctor Density or Modified Proctor Density, it has a CBR (California Bearing Ratio) of 50 or greater.

Is CU-Structural Soil compatible with underground utilities?

If underground utilities are encountered within the proposed rooting zone, CU-Structural Soil can conform to the backfill needed around utilities and can be easily installed.

What is the recommended length and width for CU-Structural Soil installation?

There is no established minimum. However, CU-Structural Soil was designed to go under the entire pavement area. This homogeneity would ensure uniform engineering characteristics below the pavement, particularly in regard to frost heaving and drainage. Ideally, the installation should focus on a whole sidewalk section from building face to curb, potentially for a whole block. If it is impossible to use the entire sidewalk area using CU-Structural Soil, it can be placed in a 5- to 8-feet-wide trench parallel to the curb.

Should CU-Structural Soil be used in a tree pit if it is not placed below the surrounding pavement?

This is the wrong use of this material. The success that we've seen with CU-Structural Soil is due the large soil volume that the roots can grow into. CU-Structural Soil was designed to be used where soil compaction is required, such as under sidewalks, parking lots, medians, plazas, and low-access roads.

Where soils are not required to be compacted, a good, well draining soil should be used.

Won't the soil migrate down through a CU-Structural Soil profile after installation?

The excavation of a seven-year-old installation did not show any aggregate migration. The pores between stones in CU-Structural Soil are mostly filled with soil so there are few empty spaces for soil to migrate to.

Does hydrogel break down over time?

Over a long period of time, the soluble salts from which the hydrogel was produced, i.e. potassium (from potassium hydroxide) and ammoniacal nitrogen (from acrylamide) are released. The inert hydrogel becomes a very minimum part of the soil system. Beyond that, we believe that colonizing roots and other organisms will, over time, replace the spatial and tackifying roles of the hydrogel. Research on this subject is ongoing.

What happens when roots expand in CU-Structural Soil?

There will come a time when larger buttress roots will likely displace the stone, but if the roots were, as we have observed, deep down in the profile, the pressure they generate during expansion would be spread over a larger surface area. We have seen roots move around the stone and actually surround and encapsulate some stones in older installations, rather than displace the stones.

Is CU-Structural Soil susceptible to frost heave?

This topic has not been rigorously tested, but we have not observed frost heave damage in the Ithaca, New York installations. Based on drainage testing and swell data on this extremely porous system, CU-Structural Soil appears quite stable.

Can you add normal soil in the tree pit and CU-Structural Soil under the pavement?

If the tree pit is sufficiently large, greater than 5 feet x 5 feet, and the opening unpaved, a conventional soil should be used in the open tree pit surrounding the root ball with CU-Structural Soil extending under the pavement. The available water in CU-Structural Soil is approximately 7%. Using a good sandy loam or well-structured loam in the tree pit opening will provide more moisture.

What type of trees should be grown in CU-Structural Soil?

Depending on the stone type and subsequent soil pH, moderate to highly drought tolerant and alkaline soil tolerant trees should be used. In Ithaca, New York where we make CU-Structural Soil using limestone as the crushed gravel in the mix, we have had success with numerous trees. For more information see *www.hort.cornell.edu/uhi/outreach/csc/index.html*

Can you use balled-and-burlapped, bare root, containerized or boxed trees in CU-Structural Soil?

Trees from any production system can and have been used. It is important to water the newly planted tree as would be expected in any soil.

Can you store large quantities of CU-Structural Soil?

CU-Structural Soil is produced by licensed producers and is preferably not stockpiled. It is mixed as necessary and should be delivered and installed in a timely manner. If any stockpiling is required, protection from rain and contamination should be provided.

Can CU-Structural Soil be utilized around existing trees?

There are several instances where CU-Structural Soil was utilized adjacent to existing trees. It appears that if few tree roots are damaged during the installation, the trees continue to grow well. Research is currently underway to investigate this issue.

Has CU-Structural Soil been used to mitigate storm water runoff?

Through the efforts of Ted Haffner, graduate student at Cornell, and Ithaca City Forester Andy Hillman, we created a parking lot in Ithaca that combined porous asphalt and CU-Structural Soil. This parking lot reduces or eliminates surface run-off and allows trees to grow within it. The porosity of CU-Structural Soil after compaction is about 26%. Moreover, of that porosity, about 31% are large pores that determine water infiltration.

The infiltration rate of water through porous asphalt into CU-Structural Soil is greater than 24" per hour. Conventional loamy soil compacted to engineers' specifications for pavement installation has only about 2% large pores and 0.5 inches water infiltration per hour. A 24" base of CU-Structural Soil under a porous asphalt parking lot can accommodate 6" of rainfall in 24 hours within its pores. The water will then seep back into the ground water over time.

Can turf be grown on CU-Structural Soil?

Trials at Cornell University have shown that tall fescue grows well on compacted CU-Structural Soil and is wear tolerant. Sod installation or seed with cellulose mulch works well when laid directly on the compacted CU-Structural Soil. Irrigation needs to be applied in both installations to establish the turf and can be subsequently eliminated where turf can be grown without irrigation.

We are continuing to work on CU-Structural Soil. Given the need for trees within heavily urbanized paved areas and the requirements for compacting the soil under pavement, CU-Structural Soil is a proven, viable option to help green our cities.

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