Growing Trees in a Cement Forest

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Research & Technology Lead to Success in Urban Landscapes
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Less than ten years ago, planting trees along sidewalks, roads, and other hardscapes was like mixing oil and water. The two just could not successfully co-exist. Fortunately, through the dedicated research conducted by Dr, Nina Bassuk and others at Cornell University’s Urban Horticulture Institute, trees can now thrive in a cement forest.

The major impediment to establishing trees in paved urban areas is the lack of an adequate volume of soil for tree root growth. Soils under pavements are highly compacted to meet load-bearing requirements and engineering standards. This often stops roots from growing, causing them to be contained within a very small useable volume of soil without adequate water, nutrients or oxygen. Subsequently, urban trees, with most of their roots under pavement, grow poorly and die prematurely. Studies (Moll, 1989 Craul, 1992; American Forests, 1997) show that an urban tree in the United States placed in this type of setting lives for an average of only 7-10 years, where we could expect 50 or more years with better soil conditions.

Those trees that do survive within such pavement designs often interfere with pavement integrity. Older established trees might cause pavement failure when roots grow directly below the pavement and expand with age. Displacement of pavement can create a tripping hazard. As a result, the potential for legal liability compounds expenses associated with pavement structural repairs. Moreover, pavement repairs that can significantly damage tree roots often result in tree decline and death.

Typically, the scenarios detailed above are not the result of improper tree installation but with the material below the pavement in which the tree is expected to grow.

In the mid-1990s, Cornell University developed a material specification that provides both the structural or load-bearing capacity needed to support pavements and flatwork and the root growth/penetration, aeration, and drainage needed by trees.

Patented in 1999 by Cornell University's Research Foundation, this new revolutionary urban tree mix can safely support pavements and sidewalks and is designed to provide ample rooting area for street trees, decreasing tree mortality and sidewalk failure and is marketed under the name CU-Structural Soil™ or CU-Soil™.

CU-Structural Soil is a patented blend of coarse aggregate, amended clay loam, and hydrogel, proportioned so that when compacted in-place, the aggregate is in a dense state but the soil within the aggregate void matrix is not over-compacted. The long-term benefits of this mix include significantly improved tree growth, health, and life expectancy, and reduced movement, failures, and maintenance costs for adjacent pavements and flatwork.

Structural soil is 70 to 75 percent (by dry weight) crushed stone (typically 1 to 3 inches in diameter) and 25 to 29 percent clay loam (by dry weight). The clay loam is amended as needed to provide the required pH, percent organics, nitrogen, phosphorus, and potassium. Hydrogel is used to help the soil adhere to the crushed rock during transportation and placement, reducing segregation. The as-placed material should have a minimum infiltration rate of 0.75 inches per hour.

Typically, field tests result in a much greater infiltration rate. Considering the relatively high permeability, structural soil around parking lot planter areas could also be used to collect a portion of the stormwater runoff as a BMP mitigation measure.

The new system essentially forms a rigid, load-bearing stone lattice and partially fills the lattice voids with soil. Structural soil provides a continuous base course under pavements while providing a material for tree root growth. This shifts designing away from individual tree pits to an integrated, root penetrable, high strength pavement system.

This system consists of a four to six inch rigid pavement surface, with a pavement opening large enough to accommodate a forty-year or older tree. The opening could also consist of concentric rings of interlocking pavers designed for removal as the buttress roots meet them. Below that, a conventional base course could be installed and compacted with the material meeting normal regional pavement specifications for the traffic they are expected to experience. The base course would act as a root exclusion zone from the pavement surface.

Although field tests show that tree roots naturally tend to grow away from the pavement surface in structural soil. A geotextile could segregate the base course of the pavement from the structural soil. The gap-graded, structural soil material has been shown to allow root penetration when compacted. This material would be compacted to not less than 95% Proctor density (AASHTO T-99) and possess a California Bearing Ratio greater than 40 [Grabosky and Bassuk 1995,1996]. The structural soil thickness would minimally be 60-cm or a preferred depth of nearer 90-cm. The sub-grade should be excavated to parallel the finished grade. Under-drainage conforming to approved engineering standards for a given region should be provided beneath the structural soil material as insurance against waterlogging.

Although the structural soil itself is very well drained, the sub-grade below it may drain sufficiently well to avoid water backing up into the rooting zone.

The structural soil material is designed as follows. The three components of the structural soil are mixed in the following proportions by weight, crushed stone: 80; clay loam: 20; hydrogel: 0.03. Total moisture at mixing should be 10% (AASHTO T-99 optimum moisture).

Crushed stone (granite or limestone) should be narrowly graded from 1.5-3.5-cm, highly angular with no fines. The clay loam should conform to the USDA soil classification system (gravel<5%, sand 25-30%, silt 20-40%, clay 20-35%). Organic matter should range between 2% and 5%. The hydrogel, a potassium propenoate-propenamide copolymer is added in a small amount to act as a tackifier, preventing separation of the stone and soil during mixing and installation.

Mixing can be done on a paved surface using front-end loaders. Typically the stone is spread in a layer, the dry hydrogel or a slurry of hydrogel is added to the stone and screened moist loam is spread evenly on top. The entire pile is turned and mixed until a uniform blend is produced. The structural soil is then installed and compacted in 20-cm lifts.

In a street tree installation of such a structural soil, the potential rooting zone could extend from building face to curb, running the entire length of the street. This would ensure an adequate volume of soil to meet the long-term needs of the tree. Where this entire excavation is not feasible, a trench, running continuous and parallel to the curb, two to three meters wide and a meter deep would be adequate for continuous street tree planting.

Terry Mock, Executive Director of the Champion Tree Project, says that the CU-Structural Soil innovation is a significant technological advancement for landscape architecture. “It is a really cool urban forestry technology that is helping to resolve a long-term conflict between hardscape and greenscape. Cornell University has replaced the compacted soil that has been the norm for supporting hardscapes with a sustainable structural soil that allows for distribution of moisture and healthy growth”

CU-Structural Soil™ is produced and marketed by Amereq, Inc., through a network of qualified, licensed companies. According to Amereq’s Brian Kalter, there are currently 63 licensed producers throughout the United States, Canada, and Puerto Rico.

“We are able to virtually cover the entire country with licensed producers,” explains Kalter, “but we are continuously additional producers. Typically, a municipality or firm will determine a need for the Structured Soil and then look for a producer. If there isn’t already a producer in the area, they will assist us in identifying a company that may be capable.”

Kalter states that the type of organizations that are licensed producers ranges from high volume landscape contractors and suppliers to custom soil blending companies, including sand and gravel companies. He notes that in a couple of instances, municipalities have become licensed producers.

According to Barruk and Kalster, the need for patenting and licensing producers was simply a matter of protecting the technology from abuse and failure.

“As you can see, the ingredients needed for producing our structural soil are pretty common,” explains Dr. Barruk. “However, if it isn’t mixed properly and applied correctly, there is a possibility that it would not succeed in its design. It wouldn’t be long before people would be stating that structural soil does not work – even though they had not followed the prescribed process.”

To further illustrate the point, Kalster boasts that in hundreds of applications around the world they “have not had any failures of material that has been provided by a any of our licensed producers and has been installed according to specifications.”

Another advocate of CU-Structured Soil is Lowney Associates. Its first use in the San Francisco Bay area was beneath City of Palo Alto sidewalks in the fall of 1998, where Lowney Associates was the geotechnical engineer of record.

Since that first project, structural soil has been used at over 30 projects in cities around the Bay Area, of which Lowney Associates provided geotechnical services for eight projects. Structural soil is included in city master plan specifications for the City of Palo Alto and the City of Sunnyvale. Structural soil also has been used recently on public and private projects in Pasadena, Santa Monica, and Davis, California.

“Incorporating structural soil into development plans can satisfy the opposing needs of providing structurally stable subbase support for flatwork and pavements,” says Lowney engineer Laura Knutsen, “while providing a matrix for tree roots to grow laterally with access to moisture and oxygen. Structural soil improves urban tree growth and lifespan, and reduces long-term maintenance costs.”

As an important added bonus, Lowney has determined that structural soil can potentially be used as a stormwater runoff BMP measure, combining capitol expenses. SLDT

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