Urban trees and associated root problems: Part 3 — Managing root zone conditions for new plantings

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SPECIES SELECTION AND soil mitigation should be based on a thorough site analysis. Failure to identify and mitigate site and soil limitations will likely result in severe pavement damage, increased maintenance costs, and the reduced useful lifespan of newly planted trees.

Soil compaction is the most common limiting factor for trees growing in urban soils. Engineering requirements for pavement stability generally specify compaction levels above 85 percent (peak Proctor density). Such soil compaction precludes most root development and limits root growth to the backfill soil and interface between the pavement and compacted soil.

The need for soil compaction does not necessarily exclude developing a favorable root environment for trees. There are a number of cost-effective treatments that can be used to satisfy soil engineering needs, while allowing for reasonable root development. The cost of the treatments must be considered within the context of tree value, longevity, and long term maintenance cost.

Drain rock (large diameter) to prevent root intrusion under pavement

Smiley (2008) demonstrated that roots can be discouraged from developing immediately under pavement by

Soil compaction is the most common limiting factor for trees growing in urban soils.

(Left) Site analysis for the University Avenue median in Berkeley, CA identified highly compacted clay and clay loam soil. Because of the desire for a fairly dense planting of native California trees, a large volume of soil with favorable characteristics was required to accommodate the needs of the trees. Mitigation measures consisted of excavating the soil to a depth of five feet and amending with compost. The first 2.5 feet of soil was removed and placed in the roadway to the left. The lower 2.5 feet was then excavated and amended in place by the backhoe. As the backhoe mixed the material, the loader provided the compost. Soil was left uncompacted to settle naturally. There was some concern that methane gas would accumulate in the deeper layer as the compost degraded, thus inhibiting root growth. The consensus was that there would probably be adequate soil gas exchange to mitigate the potential for anaerobic conditions. (1996)

(Right) Landscape design arranged for the coast live oaks in the University Avenue median to be the long term trees in the planting. They were planted on 50-foot centers. The deciduous trees interplanted with the oaks will ultimately be removed. Photo shows the trees healthy and growing 15 years after planting. (2011)

applying a four- to six-inch layer of clean drain rock directly below the paved surface. The large voids within the drain rock greatly reduce water-holding capacity, and the lack of finer soil particles within the voids all but eliminates nutrient availability. Placing clean (no fines) drain rock on top of structural soil is recommended in irrigated sites.

Excavation of compacted soil

Trees cannot be expected to do well when soil conditions within their roots zones are heavily compacted. Over-excavation to loosen compacted layers is often required to provide the sufficient rootable soil volume. (Required soil volume depends on the needs of the species at maturity) Merely increasing the planting pit from 2x the size of the root ball to 4x the size will not mitigate the problem when all surrounding soil is compacted to a high bulk density. In areas where sufficient space is available, a backhoe or small excavator can be used to loosen compacted soils to the desired depth, or to break through impenetrable layers, e.g., hardpan, clay pans, and other layers that impede drainage. Amending loosened soil (particularly clay) with well-composted organic material will minimize re-compaction, increase pore space, and improve soil structure. It also helps to keep the soil voids open. It is critical that soil never be worked or amended when it is wet, as this will destroy structure and reduce soil pore space.

A continuous planting strip used in a parking lot.
(Photo Dr. Larry Costello)

Continuous planting strips

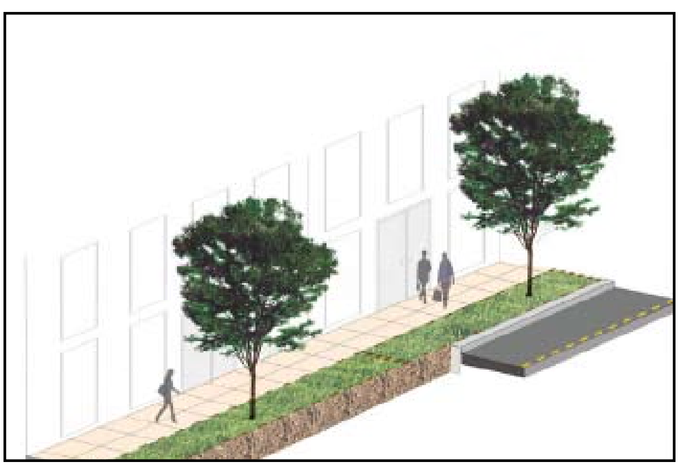
When trees are planted in rows along streets, rootable soil volume can be increased by planting in deep continuous trenches rather than individual pits. When severe soil limitations have been identified, it may be most practical and economical to replace the unsuitable soil. Providing a continuous volume of soil between the trees will simulate a more natural setting in which trees share soil resources. Trenches should be excavated to the full width of the parkway or median as is permitted by the engineers. Soil should be excavated and amended to a depth of 3-5 feet. After the soil is loosened and amended, it should be protected from excess compaction by applying mulch, or using raised concrete panels or grates. When turf is used as a groundcover in such areas, there is a potential for recompaction due to foot traffic when the soil is wet from irrigation and rainfall.

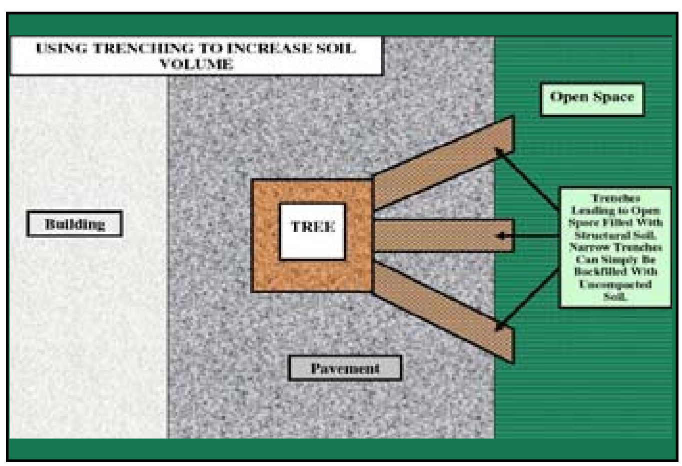
Trenching and bridging

To augment soil volume, tree roots surrounded by pavement can often be provided access to additional soil volume in a manner that is unlikely to displace pavement. Trenches (root channels) between a planting site and an adjacent area of favorable soil (less than 80 percent peak Proctor density) are excavated 8-12 inches wide and 2-5 feet deep. After excavation, the loosened soil, either amended or unamended, is replaced back into the trench and only lightly compacted. A sandy soil may also be used as backfill. In most cases, the addition of soil organic matter should not exceed 5 percent by volume to prevent excessive settling. Structural soil can be used as backfill when compaction for engineering requirements is required. Clean drain rock can be used for the top 6 inches. Tensile fabric is recommended on top of the entire trenched area to reduce infiltration of soil or cement into the drain rock and provide added support. The pavement is then installed.

(Left) Image: Casey Tree Washington, DC Copyright © 2008 Casey Trees

(Right) This graphic shows a low-cost solution when there is reasonably good soil available in close proximity to the planting site.





Horizontal auguring (coring)

This is most useful when surrounding pavement limits the application of other treatments. One to two-inch diameter holes can be augured or water-jetted into the sides of planting pits to provide root channels and some additional rootable soil volume. The holes can either remain open or filled with a mix of sand and compost.

Silva cell

The Silva Cell system, available through DEEPROOT Corp., can be used to provide adequate soil volume under pavement where high soil compaction would normally be required. The soil placed within the 'cellular' system does not need to be compacted to provide support for surface hardscape. The structural elements incorporated into the system provide ample support for pavement. Tree roots can then develop readily within un-compacted fill. We have seen this system successfully installed on a number of projects. Structural soil, by comparison, provides much less actual soil per cubic yard of backfill. In general, structural soil contains less than ⅓ cubic yard of soil per yard of mix. The Silva Cell is most appropriate for highly urbanized sites, where trees will be highly valued.

Structural (gap-graded) soil

Structural or gap-graded soil is a mixture of rock and soil. The rock, which is both angular and uniform in size, provides support for hardscape through stone-to-stone contact, while the soil within the voids provides water and mineral elements for root development. The diameter of the rock and the voids between the rock particles should be as uniform as possible. When properly mixed and installed, the soil within the voids, typically a good quality clay-loam, remains un-compacted after the mixture is compacted. Use of clay texture soil provides greater nutrient- and water-holding capacity in the mix. Structural soil provides rooting space under pavement, where roots typically develop poorly or not at all. Adding too much soil to the mix is one of the most serious mistakes when mixing structural soils. When this happens, soil within the voids compacts as the pressure is applied to the mix to meet the requisite bulk density.

CU Structural Soil, currently available through Cornell University, is a patented mix containing an amended clay-loam soil and a gel-polymer to act as a binder.

Structural soil is generally used when other options are too expensive or impractical to provide an adequate volume of favorable soil for root development. Structural soil can be used in deep excavations, under pavement, and to create a firm pedestal to properly support the root balls of new trees.

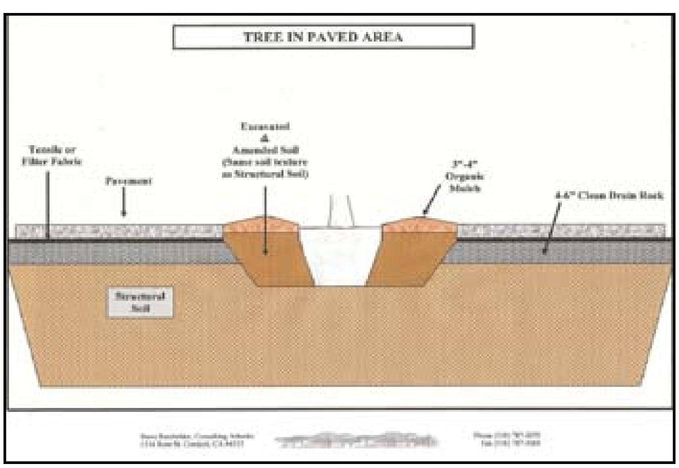
The main downside of structural soils is that they contain only 20-25 percent actual soil. Another problem is that the gel polymer, which increases water-holding capacity, can break down over time. Unless an adequate volume of structural soil is used, water and nutrient availability will be inadequate to sustain growth in the long term. Using clay soils in the mix helps to increase water- and nutrient-holding capacity as well.

Making your own gap-graded soil

An un-patented mix of structural soil can often be made on site from imported crushed rock and soil excavated from the site. The polymer used in the CU mix is not required under pavement, but the polyacrylamide (PAM) is used to control soil migration in areas where water infiltration

(Left) The components of a planting treatment for areas surrounded by hardscape. The backfill soil used around the tree root ball should be the same texture as that used in the structural soil.

(Right) Stanford University elected to preserve this native coast live oak (*Quercus agrifolia*). It would have been seriously impacted when Campus Drive was relocated within three feet of its base. Pre-stressed concrete was first considered but the price was excessive. Removal of soil around the existing roots to a depth of 2 feet, and backfilling with Cornell University (CU) structural soil mix was determined to be the best treatment. An air-spade was used to remove the soil and filter/tensile fabric was placed on top of the compacted structural soil before the pavement was installed.



(Left) This batch of structural soil was rejected due to an excess amount of soil in the mix. The mix should appear as though not enough soil has been added.

(Right) Piles of soil and rock used to make a structural soil mix for a project in San Francisco. The 6-inch cobbles proved too large to mix properly. 1-2 inch angular rock was substituted and the final mixture was installed. Structural soil using two-inch angular rock provides the best root anchoring due to better friction (personal communication with Claus Matteck).

will occur. Soil should be amended as necessary and screened if appropriate. As mentioned above, clay or clay loam soils are often used in this mix to increase water and nutrient availability.

The percentage of soil used in the mix is calculated to fill 80 percent of the void space determined by the water-filled method. Soil volume is based on an average bulk density of 65 percent ASTM. A tractor with a front bucket can be used to proportion and mix the amounts of rock and soil.

When the mixture is fairly uniform, it can be placed in the excavation in one-foot lifts each of which is compacted after each layer is added. If pockets of soil and rock are observed after the mix is placed, additional rock or soil can be added and mixed using a pick or mini excavator. Visual inspection is used to determine uniformity. If the mix looks like it has insufficient soil, there should be no problems; if it looks like there is too much soil, it will probably not perform as intended, as the soil within rock lattice is likely to compact. Uniformity in application can be determined through the use of a neutron probe.

Complete instructions for making your own structural/gap graded soil can be found on the Wallace Laboratories website: http://www.bettersoils.com/.

Providing adequate soil volume for plants where root space is limited.

Providing adequate soil volume for future root development will ensure reasonable tree health and long term survival. Furthermore, it is essential to sustain reasonable growth to the size that meets the design objective.

Determination of the volume of soil necessary for root system development should be based on species characteristics, eventual crown size, annual rainfall/water availability, and soil textural qualities which impact the water and nutrient storage capacity. Trees planted in sites that are hot and/or windy use more transpirational moisture and therefore require a more expansive root system, thus greater soil volume. Engineered solutions such as structural soils or suspended pavement should be considered and proposed when soil volume is sufficiently limited. Otherwise, the species should be selected based on the soil volume available. In general, soil volume should be in the range of 2 to 3 cubic feet of soil for each square foot of crown projection at tree maturity (dripline) Lindsey and Bassuk, 1991. This is more a starting point, rather than a goal.

Review

Sidewalk displacement is most likely when:

- a large stature tree is planted in a small pavement opening.
- soil within the root zone is clayey.
- soil compaction exceeds 80 percent peak Proctor density.
- soil directly below sidewalks is compacted clay or clay loam.
- sidewalks adjacent to parkway planting are bordered by areas of irrigated turf planted on slopes that drain toward the trees.

Best solution for new planting:

- Use a 6-inch layer of clean drain rock under pavement.

- Avoid compacting soil within the root zone to greater than 80 percent peak Proctor density.
- Use structural soil or Silva Cell when appropriate to provide adequate soil volume.
- Avoid frequent or excess irrigation and allow a sufficient dry down period.
- Assure that tree roots either have sufficient soil volume available or can be directed to areas where soil volume is available for healthy root development.

Trees that are provided insufficient soil volume are essentially confined to a pot. Matching the available soil volume with the needs of the tree will provide for trees that are healthier, long lived and less likely to cause displacment of adjacent hardscape.

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Home study for CEUs

You may receive one hour of Certified Arborist and/ or WCISA Certified Tree Worker continuing education units (CEUs) for reading the following article and completing the test questions. Copy the question page and use it to record your answers. Darken the correct letter choices and circle your choice for true and false or correct choice questions. Each question has only one correct answer. Passing score for this test is 14 correct answers (80%).

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Home study for CEUs:

Winter, December 15, 2011 — Expiration date for submitting answer sheet is October 1, 2012. The CEUs from this article can only be applied to the 3-year current certification period.

1. A 4-6 inch layer of sand placed directly under pavement has been shown to prevent the roots of adjacent trees from developing directly under the paved surface. **T or F**?
2. Large diameter gravel (drain rock) used as a base for paved surfaces favors root growth in the base material because the voids between the rocks improve soil aeration. **T or F?**
3. Root development of young trees planted in sidewalk cutouts can be greatly improved by mechanically loosening compacted soil surrounding the planting pit to increase volume of rootable soil. **T or F?**
4. Soil that has been loosened to reduce soil compaction should be amended with ____________ ____________________ to minimize or delay re-compaction.
5. Soil amendments are used to increase pore space, gradually improve soil structure and keep soil voids open. **T or F?**
6. One option to provide additional soil volume for rows of sidewalk trees is to create ______________________________ ______________________________. In this manner, the roots can then share the available space.
7. Root channels (narrow trenches) between a planting site with restrictive soil conditions to an adjacent area of favorable soil can serve to provide access to additional soil volume. **T or F?**
8. In most cases, the addition of soil organic matter should not exceed ____________ percent by volume to prevent excessive settling.
9. Cubic yard for cubic yard, structural soil provides about as much rootable soil volume as soil with a favorable bulk density. **T or F?**
10. The main advantage of using the Silva Cell system rather than structural soil in areas surrounded by pavement, which require severe soil compaction, is that it provides comparatively more soil volume than structural soil. **T or F?**
11. Structural soils use an angular, uniform and relatively large aggregate (rock) to support hardscape through stone-to-stone contact. **T or F?**
12. The soil held within the voids provides the space, water, and minerals needed for root development**. T or F?**
13. The texture of the soil mixed with or held within the large angular aggregate is largely unimportant. **T or F?**
14. When mixing a structural soil, the ratio of rock to soil is not particularly important because it is critical to completely fill the voids between the aggregate. **T or F?**
15. The volume of soil necessary for root development of most trees is about the same. **T or F?**
16. In general, soil volume should be in the range of __________ to__________ cubic feet of soil for each square foot of crown projection (dripline) at tree maturity.
17. Root growth is severely limited by soil compaction greater than ____________ percent (peak Proctor density).