Alternatives to Structural Soil for Urban Trees and Rain Water

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Compacted soils to support pavements and infrastructure increase the run off rate of rainwater. Only a small percentage of each rain event, even if the pavement is porous, can infiltrate compacted soil for aquifer regeneration and vegetation hydration. Soil compaction also stunts the growth of trees by restricting root penetration. Absorbing soils that are not compacted, placed under pavement can be a significant tool for rainwater management and improvement of the urban forest.

By using the BMP methods discussed below, paved city plazas, streetscapes, and town centers can become areas for rainwater mitigation. They can transform the urban forest into a rainwater mitigation asset. The strategies discussed will support roadways, parking lots and sidewalks while providing un-compacted soil volumes to absorb large amounts of water and enable large tree growth. These methods can contribute to sustainable designs in varying effectiveness for increases in water management with no loss of the paving's structural integrity.

Using trees and their required soil for rainwater management has additional advantages over other rainwater management strategies. The large healthy tree canopies created by large volumes of absorbing soil provide other benefits. The tree's canopy cools the air and paving which helps reduce urban heat island impacts and cools run off water temperature. A large canopy absorbs the initial 1/10th of an inch of the rain event and evapo-transpires large amounts of water increasing the effectiveness of the system. Healthy, long-lived trees also contribute to the social and economic health of urban communities.

SOIL VOLUME

The amount of absorbing soil required depends on the volume of water and the size of tree to be grown.

Trees: Trees need significant soil volumes of low compacted soil with suitable pore space, drainage and organic matter to provide for the long-term growth. The amount of soil required for trees of different sizes is depicted on Figure 1. As indicated on this table, a large tree needs more than 1,000 cubic feet of soil to reach the size where it becomes a significant contributor to a healthy urban ecosystem.

Large canopy trees are defined as trees that under normal conditions can support canopies 50 feet or more in height and width. The larger the tree at maturity, the greater will be the benefits, up to 15 times greater for an mature oak vs. a mature small tree such as a dogwood, according to the USDA Forest Service.

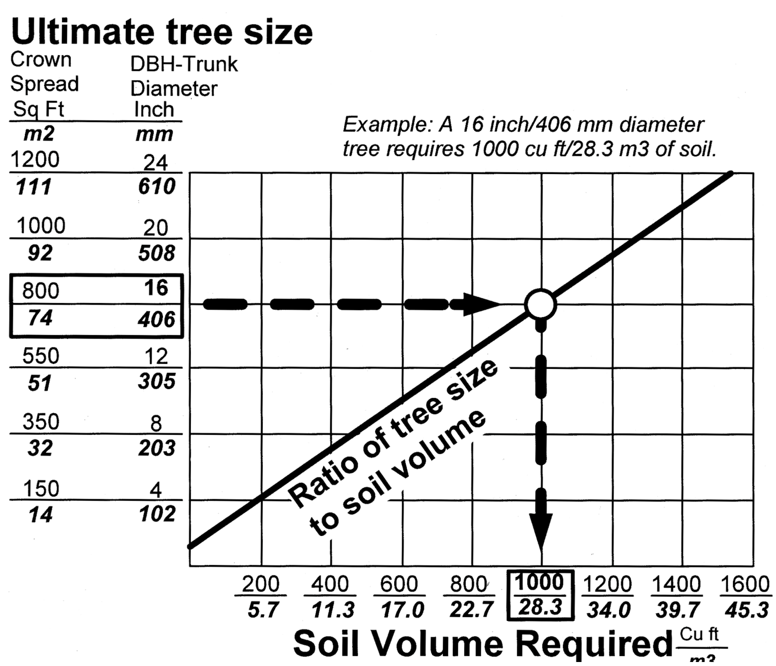

Figure 1 Soil volume and ultimate tree size relationships

Water: Approximately 25% of the total soil volume is usable as part of the water quality and quantity treatment train. Low compacted water absorbing soil is approximately 50% mineral and 50% void space. Approximately half of the void space is macro pores meaning that water fills these pores during a rain event and the water then drains slowly by gravity to a lower level. The other half of the voids are micro pores meaning the pores are so small that the water remains held against gravity by surface tension and capillary action. Much of this water is evapo-transpired by the tree back into the atmosphere. But the macropores release water so slowly that the water in the micro pores is normally not figured water storage calculations, as they will already be filled during periods of frequent rain events. Water in the micro pores, however, is an important part of long term water management strategy of the tree.

Water and trees: The soil needs of the tree and rainwater management goals require similar soil volume and similar soil types. The soil volume required to support a single mature tree, approximately 1200 cubic feet, can provide for the required rainwater management of an impervious area between 5,000 to 10,000 square feet. The size of the area depends on the regulation requirements, sub soil conditions, topography, depth of the outfall and the type of soil strategy employed.

Structural Soils

In the mid-1990s, Cornell University developed CU Structural Soil. Structural Soil is a mixture of stone aggregate and soil, with a small amount of polymer gel to hold the mix together. This soil mix can be compacted to 95% of dry density to support paving and still allow for tree root growth. The mix takes advantage of the fact that there are about 20% to 25% void spaces between pieces of compacted gravel, in which roots will grow. The approximate formula for structural soil is 20% clay loam soil, 80% 3/4-inch angular gravel with no fines, and 0.03% polymer gel. It is important that the aggregate be angular in shape and gravel pieces similar in size. The wider the range of the aggregate sizes, the less space for soil and roots. The clay loam soil should be approximately 25% to 35% clay, to maximize water-holding capacity.

In many regions of the United States, the most cost-effective crushed stone available is limestone. Limestone can raise the pH of the soil to as high as 8.0. A tree tolerant of high pH must be used with limestone aggregates. Non-limestone aggregates are usually available but are more expensive. In the Chicago region, for example, granite railroad ballast is being used in structural soil applications as a substitute for the local limestone aggregate.

The greatest limitation of the soil/aggregate formula is the small amount of soil in the mix. Only about 20% of the mix volume is actually used by the tree or can be included in the water treatment calculation. The rest of the volume is rock, whose primary function is to support the structure above.

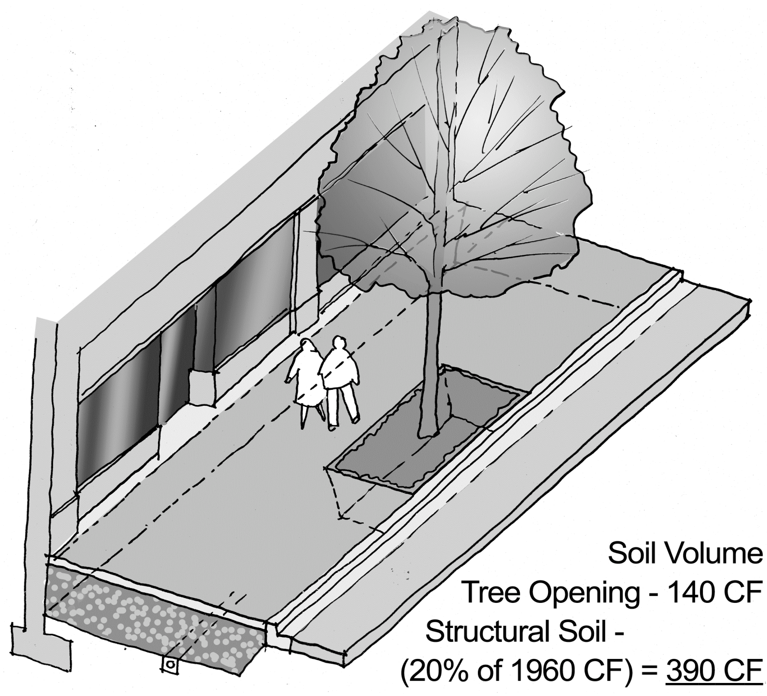

Figure 2 Diagram structural soil.

The macro pores in structural soil, which is the portion of the soil volume considered in rainwater management, may only be 6-8% of the total structural soil volume. This is due to the requirement that 80% of the total structural soil volume be gravel. For the same reason, structural soil is also limited in its ability to provide space for tree roots. Trees will not grow larger than the volume of loam soil in the mix**.** To create 1 cubic foot of usable soil under the sidewalk, approximately 5 cubic feet of structural soil must be installed. This requires significant space and large budgets to achieve the required soil volumes. Other options to provide absorbing soil under paved areas are more cost effective.

Suspended Pavements and Structural Cells

A different approach that suspends the sidewalk structure above the soil has been developed. This approach uses columns and beams to create a post-and-beam structure that supports a deck. The space within the system is available for low-compacted, absorbent soil, rainwater treatment and tree roots.

There have been a number of attempts to make suspended sidewalks. The City of Charlotte has made columns of poured-in-place concrete by digging holes in low-compacted soil and pouring a reinforced sidewalk over the tops of the columns. This system is labor intensive and would require site-specific engineering design to meet required loading standards. Arborists in Holland have tried filling plastic water-storage boxes with soil. They found the boxes difficult to fill and roots being girdled as they pass through the small holes in the sides of the boxes.

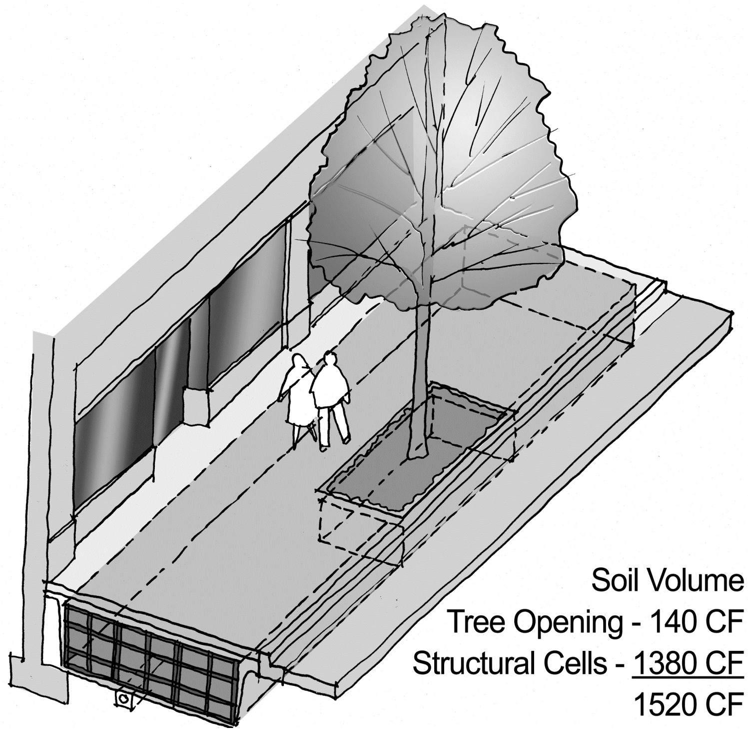

Figure 3 Diagram structural cells

A modular, pre-engineered cell system has been designed specifically to meet the needs of water management soil and tree roots. The system is designed to create large spaces under the pavement, and the pavement is supported and protected from root damage by the cell structure. The system's modular design fits irregular urban conditions. The size of the rooting area is limited only by the availability of space, utility conflicts, and the project budget. Approximately 95% of the space within the cells is available for tree-rooting soil, a huge increase in efficiency over previous systems.

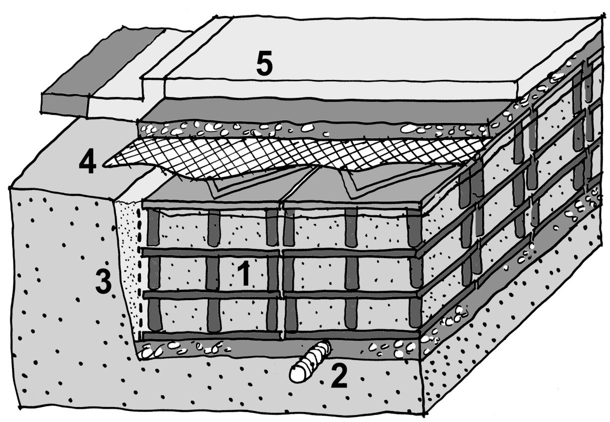

Figure 4 Structural cell detail

1. Absorbent soil in cells. 2. Drainage system, pipe can be raised to improve infiltration where soil conditions are suitable.
3. Compacted backfill. 4. Geotextile over deck. 5. Paving.

The deck is designed to exceed AASHTO H-20 loading when the paving system is installed to distribute the load over the deck. The system is compatible with concrete, asphalt, porous asphalt, and porous concrete paving, and modular brick and concrete pavers. Each paving type must include an appropriate base course between the paving and the deck from 4 inches for concrete to 12 inches for modular pavers.

An airspace, provided under the deck allows water to move under the pavement and pool above the soil, while keeping roots growing in the upper soil layers from lifting the sidewalk. The airspace can receive rainwater either from infiltration thru pervious pavers above the cells or by channeling surface water from inlets, drains and roof leaders into the air space.

The cell structures are set on a 4" gravel sub base. This sub base acts as the foundation for the cells and as a drainage course to remove water from the soil.

As an example, 8 foot wide by 45 inches deep layer of structural cells can absorb, filter and slowly release more than one inch of rain falling on the width of a 60' parking bay. The water is conveyed to the cell airspace through pervious pavers and a 12" thick layer of aggregate base course. Coarse material in the water is filtered by the pervious paver layer, while finer particles and chemical contaminants are filtered in the soil. Tree roots and their exudates in the root rhyzosphere, help support soil biology that decomposes contaminants in the water. During the growing season, evapo-transpiration through the tree further improves the water balance efficiency of the system.

Excess water and water in the macro pores slowly drains into the drainage layer below the cells to be conveyed to an outfall. In soil types that are suitable for infiltration into the base site soil, the design of the drainage system would be changed such that the pipe would be placed above the bottom of the drainage aggregate.

CONCLUSION

Increasing absorbent soil volumes under pavements has substantial value to the environments and communities. Larger and healthier trees, increased water storage capacity, pollutant removal rates, structural stability, and excellent hydrologic performance of these systems restore natural soil water and forest ecology relationships to urban areas. Systems than provide absorbent soil under pavement can be designed to measurable quantity standards for that can meet the requirements of existing rain water management regulations.

Figure 5 Installing absorbent soil in cells

Figure 6 Installing cell decks

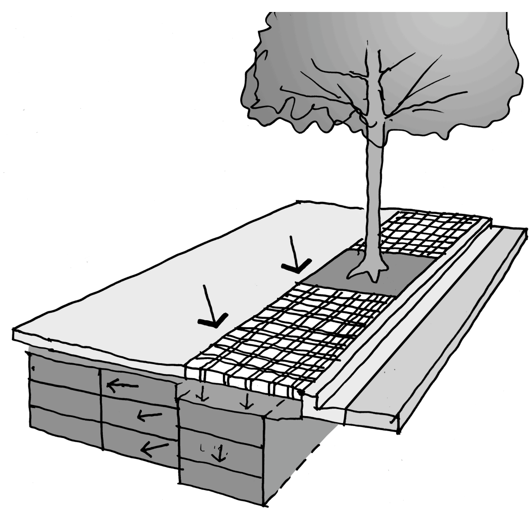

Figure 7 Water moving from impervious paving to pervious pavers and into cell system