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GROWING Points

The Design of Structural Soil Mixes for Trees in Urban Areas - Part II

There is no one perfect compaction resistant, aggregate-based tree soil mix. A range of mixes can be designed that meet basic requirements for tree root growth following compaction and that also utilize regionally available materials. What is required from the professional however, is a methodical and multi-disciplinary approach to testing, evaluating and specifying such a mix. This article will outline an approach, discuss the preliminary results of research on soil mixes at UC Davis, and take a look at a large urban park project where such a mix was used.

Remember from the previous discussion that these mixes are composed of a base material (large size aggregate) that provides the structural component, and a filler material (topsoil) that provides most of the important horticultural properties. It is important to note that each mix potentially will be different, depending on the type of base and filler material selected and because the ratio of the materials used will vary according to the properties of the base material.

On what criteria does one begin to select a base material? The base material should be of a particle size distribution such that it produces a mean pore size large enough to accommodate root growth. In Table 1 on the following page, it can be seen that the largest class of roots for a given tree, 81%, are of medium diameter, 5-10 millimeters (where 25 mm = 1 inch). To accommodate a 5 mm diameter root, the base material would have to have a particle size of 25 mm, or 1 inch. For a 10 mm diameter root, the base material would be 50 mm in diameter, or 2 inches. Fifty milliliter diameter aggregates for the base would be ideal, although there would be the distinct possibility of significant sorting out and separation of the base and filler materials during mixing and installation due to the extreme particle size differences of the two.

To examine this further, tests were run on a series of commonly available base materials: 1-1/2" river rock, 3/4" gravel and 3/4" expanded shale. Table 2, page 2, shows the approximate particle size distribution of these materials. The first step was to compact these materials according to ASTM-698 (Moisture-Density Relations of Soils Using 5.5lb Rammer and 12-In. Drop) and calculate the total % void space within each of these materials following compaction. The formula for calculating the % voids requires knowledge of the dry

continued on page 2............

Clinton and the Environment

In a recent White House press release, President Clinton sought to bring Federal properties in compliance with current thinking on environmentally sound and sustainable landscaping practices. It is remarkable to have that level of governmental support and acknowledgment for practices that have been in force in California for some time now. The five major directives that were issued are listed below. Seem familiar?

Use regionally native plants for landscaping.

Design, use, or promote construction practices that minimize adverse effects on the natural habitat.

Prevent pollution- reduce the use of fertilizers and pesticides, use integrated pest management techniques, and recycle green wastes.

Implement water efficient practices such as mulching, irrigation audits, the use of recycled water, appropriate plant selection for low water usage, and plant placement in the landscape to reduce energy consumption.

Create outdoor demonstration gardens incorporating the directives above.

CONTENTS

Summary of Important Determinations

Selection of a base material.

A base material for the large particle aggregate should be selected that is of sufficient strength to withstand standard compactive effort without excessive crushing and the production of fine material. While this is not a problem with gravel, some of the expanded shale materials, depending on the source, can be brittle.

Selection of a particle size gradation for the base material.

The particle sizes of the base material should be sufficient to provide enough total volume of pore space and average pore size to accommodate an adequate quantity and size of roots. As a helpful rule of thumb, the pore size produced by an aggregate is 1/5 of the particle diameter.

Calculating the %void space of the base material.

This is necessary in order to know how much filler material can be added to the base material without compromising the structural integrity of the material. The only value that must be determined is the compact unit dry weight.

Selection of a filler material.

The particle size gradation must be sufficient to provide an acceptable balance between levels of aeration and water retention. The largest size of the filler material must be smaller than the smallest pore size found in the base material to prevent the larger particles from being pushed apart.

Determination of the ratio of base to filler material.

It is important not to overfill the voids in the base material, but fill only up to 95 to 100% of the total voids.

Soil Mixes, cont.

bulk specific gravity, the density of water, and the unit dry weight of the soil.

$$\frac{\text{specific gravity x density of water - dry weight}}{\text{specific gravity x density of water}} \times 100$$

Using this formula, following compaction the river rock had 36% voids, gravel had 37.1% and the shale had 38.4%. This is also the point at which one can determine if significant crushing of the material will occur during compaction, by analyzing the particle size distribution of the material before and after compaction for a decrease in particle size and an increase in fine material.

The next step is to select an appropriate filler material. A locally available sandy loam topsoil (see Specifications column on page 4), was tested for various horticultural properties, alone, and in combination with various amounts of peat, ranging from 10 to 30%. Soil bulk density, total porosity, air-filled porosity, and capillary porosity were subsequently evaluated. For this topsoil, the addition of 10% peat was sufficient to increase the total porosity from 47.6% to 53.2% and increase the capillary porosity, or water retention at field capacity from 19% to 24.5%.

A normal mineral soil may have an air-filled porosity as low as 10% and still support root growth. The filler material for this kind of soil mix needs to hold in excess of this however, since it represents only a fraction of the total volume of soil. If a minimum of 10% is not achieved for the mixed soil, then changes must be made to the filler ma-

Particle size needed to accomodate root size class (mm)	Tree Root Diameter[1] (mm)	Root Class[2]	Belowground Biomass[3]	Particle Size Classification USDA (mm)
<2.8	<0.5	very fine	14%	<0.002 clay 0.05-0.002 silt 0.10-0.05 very fine sand 0.25-0.10 fine sand
10	0.5-2	fine		0.5-0.25 medium sand 1.0-0.5 coarse sand 2.0-1.0 coarse sand
25	2-5	small	5%	>2.0 fine gravel
50	5-10	medium	81%	2.4-3.4 coarse gravel
100	10-20	large		cobbles
>100	>20	very large		

[1] and [2] (Bohm, 1979; Jackson and Chittenden, 1981)

[3] (Landsberg, 1986)

Table 1. Minimum soil particle sizes needed to accomodate different root size classes.

Sieve Designation	%Passing
LIGHTWEIGHT AGGREGATE	
3/4"	100
1/2"	93
3/8"	53
5/6"	20
1/4"	5
NO.4	1
RIVER ROCK	
2"	100
1-1/2"	71.3
1"	15.2
3/4"	0.2
GRAVEL	
3/4"	99.3
1/2"	57.3
3/8"	20.8
NO.10	0.2

Table 2. Particle size distribution curves for the base materials.

Soil Mixes, cont.

terial, or compensatory irrigation added.

The next to the last step is the determination of the ratio of the base material to filler material. This ratio is dependent on the % void space of the base material. For the 1-1/2" river rock with 36% voids, the ratio, on a volume basis, would be 2.7:1 rock to filler; for the 3/4" gravel with 37.1% voids it would also be 2.7:1; and for the 1/2" shale with 38.4% voids, it would be 2.6:1. This ratio guarantees a solid structural base of aggregate, with the inner voids 100% filled. Many of the mixes currently being designed and installed have not met these basic structural requirements.

The final step is the mixing, testing and evaluation of the soil mix, following a standardized compaction protocol. The compaction curve generated should be relatively flat, i.e. density should be moisture independent. The mix must meet previously established horticultural performance criteria for the specified level of compaction, usually 90-95% of maximum density. If a mix does not meet the criteria, it may be possible to adjust both the amount and the nature of the filler material, compact and retest.

Preliminary results are promising. The greatest challenge is achieving a balance between air and water within the soil. The following values were calculated using a sandy loam filler with 10% peat added on a volume basis and evaluated at 100 cm of tension (to a soil depth of over 3'). The total porosities for the three base materials with 100% voids filled are river rock 25.5%, gravel 27.8% and shale 21.3%. Air-filled porosity for the river rock is 17.6%, capillary porosity 7.9%. Air-filled porosity for the gravel is 19.7%, capillary porosity 15.9%. Infiltration data is being collected now, and trees will be grown in these mixes for the next several years.

It is important to note, that these kinds of soils can not be compacted directly up to the base of a tree. Figure 1 on page 3 shows the approximate root size distribution for a forest tree. Note that most major roots occur within 1 to 3 feet of the trunk. The use of any of these soil mixes then will always require some area immediately adjacent to the trunk to be unpaved and uncompacted to allow for large structural root development and trunk expansion.

Pershing Square, in Los Angeles, is an example of an urban plaza where an expanded shale mix was installed last year in a redesign of the park by Hanna/Olin, Ltd. Comprising a city block of park over a parking garage, the intent was to create an 18" layer of structural soil mix across the entire site. While tree pits would be of normal depth, this band of soil could essentially make the entire park one large tree pit. The soil mix had to be both lightweight and able to meet compaction levels of 95% of maximum density. The soil mix used, after extensive testing and communication between all the professionals involved, was a 2.8:1 shale to topsoil mix. Apparently some particle segregation did occur during installation, indicating that it is important to wet the material beforehand.

Once again, there is no one soil mix for this purpose. The mix that is ultimately specified will be a reflection of the materials being used. In the research program here, we hope to eventually provide good guidelines based on access to a range of materials.

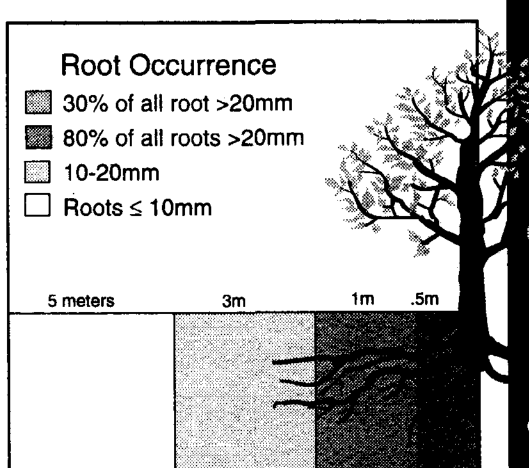

Figure 1. Root diameter distribution laterally for a composite tree in a forest with an 8" diameter trunk.

Soil Specifications

LIGHTWEIGHT AGGREGATE

A. Rotary kiln expanded shale, ASTM C-330-89. No by-product slag or cinders permitted.

B. Noncorrosive with less than 100 ppm chloride.

C. Size: 3/4" - # No. 4

RIVER ROCK

A. Coarse water washed rock with no fine particles.

B. Size: 2" - 3/4".

GRAVEL

A. Crushed open gravel with no fine particles.

B. Size: 3/4" - No. 10.

TOPSOIL

A. Fertile, friable, loamy soil containing 2-5% by weight organic matter; free from refuse, heavy clay, noxious seeds. The pH value shall be between 5.5 and 6.5.

B. Soil texture: a sandy loam soil with the following particle size distribution.

Medium sand	5-10%
Fine sand	80-85%
Silt and clay	<7%

Cited References:

Bohm, W. 1979. *Methods of Studying Root Systems.* Springer-Verlag. New York 189 pp.

Jackson, D.S. and Chittenden, J. (1981). Estimation of dry matter in *Pinus radiata* root systems: I. individual trees. N.Z. J. For. Sci. 11, 164-182.

Landsberg, J. 1986. *Physiological Ecology of Forest Production.* Academic Press, New York. 198 pp.

New Publications

The Landscape Below Ground

This is the proceedings of an international workshop on tree root development in urban soils, held at the Morton Arboretum in Illinois, in the fall of 1993. Sponsored by the Arboretum, this workshop was organized to address one of the more important factors determining the successful establishment of in the landscape: the root-soil environment. Researchers in this area presented the results of their studies.

The resulting 24 papers are divided into two major areas- tree planting and establishment, and managing root systems and soil environments of established trees. Research topics include the elimination of circling roots during nursery production, street tree establishment, an assessment of soil compaction and site construction, the effect of lightweight aggregates as a soil amendment, strategies to minimize damage to asphalt pavement by tree roots, and a buyer's technical guide to root barriers.

The book is available from the International Society of Arboriculture, P.O. box GG, Savoy, Illinois 61874. The price is $25 for members, $35 for non-members.

Pests of Landscape Trees and Shrubs

With over 300 superb color photographs and 330 pages of text, this publication provides a way for the professional to identify insects, diseases and abiotic problems, learn what specific plants are affected, and what integrated pest management strategies are most effective in preventing or treating these problems. Site analysis, design, plant selection, and proper transplanting techniques are just some of the strategies covered.

This book, priced at $32.00, may be ordered from ANR Publications, University of California, 6701 Pablo Ave., Oakland, CA 94608-1239, (510) 643-5470.

Next Issue

The use of recycled water in landscape irrigation. A look at research projects in both southern and northern California which are testing individual ornamental species susceptibility, and gauging the effect of recycled water on soil chemical and physical properties.

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