Sydney Environmental & Soil Laboratory

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Structural Soils – Some Technical Aspects

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Structural soils, some technical aspects

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For street trees, or other trees in hard surfaced areas, the major conflict is the maximisation of soil volume for tree rooting, whilst also providing a stable base onto which roads and pavements can be laid. In asphalted paving, the relatively high aeration and moisture content of the soil directly beneath the pavement attracts roots and accelerates pavement damage by heaving (Kopinga, 1994). By providing a hospitable rooting medium down the entire depth of the profile, roots are drawn deeper into the soil profile creating gentle bulges in the surface, rather than sharp up wellings, which causes tripping hazards.

Structural soils, possible better described as Gap Graded or Bimodal Support soils are a growing medium that allows for the needs of both the landscape architect and engineer to be met.

Various approaches to providing sufficient rooting volume for urban street trees have been tried. The "rule of thumb" provided by Grabosky, Bassuk, & Trowbridge (1999) is as good as any and has worked in practice. This rule says (in the metric version) that for every one square metre of crown projection a root volume of two cubic metres should be provided. Thus a tree with an expected crown spread of diameter say 10m needs: -

$2 \times 3.14 (5)^2 = 157$ cubic metres.

It is not difficult to see that the common use of a 2 x 2m tree planting pit provides nowhere near that volume. It can be taken for granted that the average soil under pavement and roadways in heavily built up areas cannot be exploited by the tree as the "Procter or peak compaction" requirement for supporting such pavement dictates that the density will be in excess of 1.7g/cc a density above which roots simply cannot penetrate. The result of this inadequate root volume is greatly shortened longevity and poor structural stability.

The concept of structural soils grew out of a consideration that a large volume of exploitable soil should be possible under the surrounding pavements, but whatever is placed under a pavement or bearing surface must be compacted to a nominal 95% peak density.

Aside: Peak density does not imply no pore space, it simply implies the maximum possible density that can be obtained by heavy compaction therefore 95% peak density is that density achieving 95% of the peak density.

It has been well known for many years that angular single size aggregates (i.e. a mixture of angular stones of one particle size range) compacted to peak density still retains about 40% pore space. Round stones however, achieve only 33% pore space when close packed and compacted. In such materials, the bearing strength can be very high. This is assessed using the California Bearing Ratio (CBR) which compares the material to another standard material known to give adequate bearing strength. For most commercial aggregates a CBR of well over 50 is obtained, more than adequate for pavements. Using high strength basalt or granitic aggregates a CBR adequate for pavement purpose can be obtained.

The sizes of the pore spaces obviously dictates the size of roots than can grow through them without heaving the rocks aside. Pores have both a "body" and a "neck". It is the size of the neck that must admit the root that is important. The general relationship is that the radius of a pore "neck" is about 1/5th of the radius of the particles. Thus stones 100mm diameter will admit roots 20mm in diameter before heaving occurs.

These considerations of high strength and large pore sizes in the fully compacted material lead to a conclusion that such coarse rock material might be a good substrate for use under pavements if root growth is to be allowed. Rock, of course, has very poor water and nutrient holding ability and the addition of some kind of material more akin to natural soil will be needed. If the "neck" of a pore is what limits root size then the larger diameter and hence volume of the pore "body" can be used to provide space for this soil.

How much soil should we add? Obviously there is a trade off between providing air filled pore space, water and nutrient holding soil volume, and room for roots to grow without heaving. Compaction analysis shows (Grabosky, Bassuk, & Trowbridge 1999) that if any more than 65% of the total pore volume is added the ability to fully compact the material is compromised. For this and other reasons it is not sensible to entirely fill the measured pore space with "filler" soil.

At the Sydney Olympics site we worked on adding 50% of the pore volume. In an aggregate with 40% pore space fully compacted this results in a mixing ratio of 80% aggregate and 20% filler soil <u>by volume</u>.

The properties of the filler soil are also important. In our view they should have:-
- High stability and longevity
- High cation exchange capacity
- High water holding ability
- Low potential for downward migration
- High pH buffer capacity.

These considerations lead to the conclusion that high charge clay materials are the filler soil of choice. Organic matter will decay too rapidly, sandy loams have low CEC and buffer capacity as well as low water and nutrient holding ability. For the Sydney Olympics site we used a product called decomposed dolerite, which had a moderately large CEC and clay content. This product was improved with some organic matter, fertiliser, and pH adjustment additives.

Other suitable products would be-
- "Black Soil" or high charge cracking clay.
- Artificial mixes with products such as bentonite and zeolite to improve CEC.
- Silty type "peat" materials.

The originators of the concept in the key paper in this area is that of Grabosky and Bassuk (1995) and the later discussion paper of Grabosky, Bassuk & Trowbridge (1999) recommend the use of "tackifiers" being gooey polymers that stick the soil to the rocks to avoid separation in transit and mixing. We have found quite satisfactory results if clayey type filler soils are used and some water is added to make the clays themselves "tacky". No polymers were used in the Olympics job and perfectly satisfactory mixing was achieved.

Structural soils can be mixed on a volume or weight ratio if the loose packed density conversion data is available (i.e. the loose density of filler soil and aggregate is known).

Other requirements in an installation are:-
• Subsoil drainage
• Road base under the pavement separated from the structural soil by geotextile to discourage root growth into the road base. Bedding is preferably a 2-5 mm aggregate with no fines which would cause an interference with downward water movement.
• Passive aeration tubing installed in the pavement opening that also doubles as feeding and irrigation route.
• A planting pit of normal sandy loam type soil in the area immediately surrounding the tree to allow for the zone of rapid taper development (buttress roots).

Initial feelings are that trees for structural soil plantings should be tolerant of drought and alkaline soils. It is highly likely that the structural soil will become alkaline in an urban context given the proximity of concrete products such as pavers.

The process of design should follow the following essential steps:-
1. Choice of aggregate for size and known stability to weathering
2. Precise measurement of total pore volume in compacted material
3. Choice and design of filler soil using highest quality materials available
4. Addition of the calculated filler soil volume ratios (and probably a couple either side as well)
5. Submission of samples for Procter compaction and CBR testing for certification by an engineer as acceptable in the design situation.
6. Careful specification to suppliers with a requirement to show proof of meeting the engineers requirements.
7. Careful supervision of installation to ensure correct mixing ratios and achievement of compaction requirements.

An excellent summary of Cornell University's specification and QA/QC detail for CU Soils is given in of Grabosky, Bassuk, & Trowbridge (1999), highly recommended reading.

This structural soil approach possibly represents the most scientifically credible and cost effective way to provide for the needs of the engineer and the tree and to bring larger rooting volumes and hence improved longevity to the urban street tree while reducing the incidence of heaving and damage to structures. Initial results are very encouraging.

References

Grabosky, J. and N. Bassuk (1995). *A New Urban Street Tree Soil to Safely Increase Rooting Volumes under Sidewalks*. Jnl Arboriculture 21(4): July 1995.

Grabosky, J., Bassuk N., and P Trowbridge (1999) *Structural Soil: A New Medium to Allow Urban Trees to grow in Pavement. Landscape Architecture*. Technical Information Series . Todd A. Steadman

Kopinga, J. (1994) *Aspects of Damage to Asphalt Road Pavings Caused by Tree Roots in the Landscape below the Ground*, conference proceedings, Eds. Watson G and Neely D. International Society of Arboriculture