Below the Surface: In-depth Investigation of Tree Development, Root Growth, and Soil Conditions in Structural Soils in Copenhagen, Denmark

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Extended abstract:

Since the early 1990'ies, structural soils have become increasingly important in the tool kit of Danish Landscape architects and other professionals involved in the planning of urban tree planting. Based on research mainly from USA and Denmark (e.g. Grabosky & Bassuk 1996 and Kristoffersen 1999), structural soils are installed in order to extend root growth to soil volumes beneath pavements, providing favorable root growth conditions while satisfying load bearing requirements for 'light traffic', i.e. pedestrians, bicycles or even automobiles. Structural soils were thus designed to provide the opportunity for tree growth on locations where paving is required and unavoidable; and the use of conventional open tree planting substrates therefore is unadvisable.
Structural soil is basically a mixture of gravel or stones and soil and should meet two requirements: The gravel/stone fraction provides a skeletal structure that transfers loads from paved surfaces to the subsoil, and the uncompacted soil fraction in the voids between the stones provides the possibility of root growth.

In Denmark, container growth tests with different mixtures revealed that roots actually grow into structural soils and result in total tree growth rates comparable to the sole use of top soil (Kristoffersen 1999). A subsequent survey in the capital of Denmark, Copenhagen, established that trees planted using structural soils have comparable above ground growth rates to trees established in conventional open planting pits, inferior only to trees established in large open planting pits with at least 12 m^2 permeable surface area (Bühler, 2007).

Until now, however, it had not been attempted to investigate tree growth below ground on a 'real' urban tree planting (i.e. not established for research purposes). This opportunity arose with the construction of new subway-lines in Copenhagen, Denmark. A planting of altogether 80 *Tilia* X *europaea* 'Pallida' established in two concentric circles of continuous structural soil stripes on a central square in Copenhagen had to be removed in November 2011 to make way for a construction site. The structural soil stripes were installed 170 cm wide and 60 cm deep.
The removal of these trees provided a unique opportunity to investigate and evaluate root development and soil conditions on a real urban tree planting in structural soil. Ten tree sites were investigated in regard to chemical and physical soil conditions. Tree growth above ground was investigated by measurements of height and stem circumference as well as year ring analysis. For the quantification of root distribution and soil sampling, soil profiles were established in three distances from each tree (1, 2 and 3 m) from two sides (figure 1).

The main findings of the study were as follows:

Tree growth below ground:

- Constructed according to correct specifications structural soil facilitated root growth through the entire profile area at all distances from the stem. Both coarse and fine roots where found at all distances from the stem, with decreasing density with increasing distance from the stem.
- A severe construction defect resulted in one of the concentric circles resulted in a highly compacted soil layer in the middle of one of the circles, resulting in significantly ($p>0.05$) reduced tree growth.
- Coarse roots also in the deeper layers of the structural soil profile indicate that no long-term anaerobic conditions occur.
- Coarse roots are noticeably affected by the stone matrix.
- Roots tend to grow particularly along drainage and aeration pipes and along the sides of the profile where remains of the root systems of long removed elm trees were found.

Tree growth above ground:

- The year ring analysis emphasized the importance of water for tree growth. In years with low precipitation and generally dry growth periods, the year ring was significantly smaller.

Soil characteristics:

- pH ($CaCl_2$) averaged at 7.3, indicating rather alkaline soil reaction. This may affect the plant availability of micronutrients (in particular Mn).
- No anaerobic conditions were observed

Tree nutritional status:

- Based on leaf analysis, no deficiencies of N, P, Ca, Mg, Fe, Zn or S could be determined.
- Leaf tissue concentrations of K and Mn indicate deficiency. However, no apparent deficiency symptoms could be observed.

The study contributes thus to the by now substantial body of evidence that structural soils facilitate establishment of trees in paved areas. However, it is also emphasized that careful planning and construction is critical for the success of tree plantings in structural soils.

Figure 1: Example of a structural soil profile. For increased visibility, roots have been spray painted.

References:

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