Urban trees and associated root problems: Part 1

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THE FOLLOWING DISCUSSION COVERS SOME of the more common causes of sidewalk, curbing and pavement damage associated with tree roots. A number of possible treatments for existing root/hardscape conflicts are provided as well as some approaches to reduce the potential for problems through improved site preparation.

Featured topics:

1. economic impact of root-hardscape conflicts
2. requirements for healthy root development
3. common conditions that contribute to root-hardscape conflicts
4. site analysis and soil volume calculations
5. treatments to mitigate existing root-hardscape conflicts
6. site preparation treatments that can reduce the potential for root conflicts and extend useful lifespan

This photo illustrates what can happen when there is a poor match between the size of the tree species at maturity and site constraints. This silk oak (*Grevillea robusta*) is simply too large a tree for planting in a narrow parkway. A more systematic approach to tree selection could have prevented or greatly reduced the resulting hardscape damage.

Restrictive site conditions surrounding this *Liquidambar* tree are contributing to the pavement damage. Irrigation water from the lawn nearby drains toward the tree and has encouraged root development under the sidewalk. Sidewalk, driveway apron, curb and gutter, as well as the street pavement have all been impacted. Deciding what can and/or should be done at this point often involves difficult and time-consuming decisions involving city staff, adjacent residents, and city commissions. The city opted to retain the tree because it contributes significantly to canopy cover. If a more prudent decision had been made at the time of planting, long-term maintenance costs would have been greatly reduced.

Replacing the curb and gutter would have caused excess root damage to this valuable tree. It was decided to hand compact asphalt around the root ball and thereby minimize damage. Water flow lines were restored and ponding eliminated to reduce mosquitos and threat of West Nile Virus. Asphalt was also used to patch the differential in the sidewalk. This treatment was less expensive than replacing the sidewalk but also temporary, as the asphalt is expected to break apart in time as the sidewalk continues to lift. Another option would have been to shift the sidewalk several feet away from the tree to minimize root damage.

Cost of root-hardscape conflicts

Infrastructure and hardscape damage caused by tree roots is a major city expense nationwide. Approximately $70 million is spent annually in California on conflicts between street tree root growth and hardscape (McPherson 2000). And it is not just the repairs that prove expensive. The damage inflicted to trees, which often times results in decline or tree mortality, can result in increased maintenance costs. An additional consideration is the liability issue associated with root pruning close to the trunk. Failures stemming from root loss may occur within a year or two years due to reduced root support, or years later as a result of developing decay in the buttress roots and trunk base from root injury.

Most cities budget more to repair hardscape damaged by tree roots, than they do for pruning and care of trees. Unfortunately, the budgeting process for tree programs is "more closely tied to controlling management costs" than it is to "providing incentives for expanding a city's tree canopy" (McPherson 2000). This has resulted in the net loss of tree canopy cover in most urban forests.

Past attempts to reduce hardscape damage include: root barriers, deep watering tubes, planting below grade and the use of deep liners for growing planting stock. All have been shown to be largely ineffective and sometimes counter-productive. This is because such 'solutions' do not address the fundamental reason for root growth into areas where hardscape displacement can occur.

What tree roots require

Root system health is linked to the soil environment. Aside from serving as a substrate for anchorage, soil provides water, minerals, and oxygen, essential for root development. In soils where these resources are limited, root function and development can be severely impaired.

The four primary soil qualities necessary for root development are: 1) porosity for good soil-gas exchange (oxygen availability), 2) sufficient but not excess soil moisture, 3) sufficient but not excess mineral availability, and lack of toxic ions or other chemicals, and 4) ease of root penetration. Limitations in any of the above should be mitigated as needed.

Costello and Jones (2003) in a test survey of trees in the San Francisco bay area, found that the average diameter of sweetgums (*Liquidambar styraciflua*), measured at ground level (DGL), was 55.6 inches. The average diameter of the trunk above the flare or root buttress (DAFB) was 21 inches. The ratio of the DGL to the DAFB was then calculated to be 2.64. This ratio is high when compared to other species. For example, red ironbark (*Eucalyptus sideroxylon*) is 1.26. Its root flare is much less pronounced. The liquidambar pictured here is not yet mature, but has already caused significant hardscape damage because the species' trunk flare was not considered.

Common causes of root- hardscape conflicts

Ultimate size of tree in relation to the planting site: The size of the tree species at maturity determines the volume of soil needed to sustain that species into maturity. Research accomplished by Pat Lindsey and Nina Bassuk at Cornell's Urban Horticulture Institute found that "for much of the United States a soil volume of 2 cubic feet for every square foot of canopy crown projection is a good place to start" (Trowbridge and Bassuk 2004). This would indicate that the volume of rootable soil required by a large tree with a 50 foot crown spread is in the ballpark of 4,000 cubic feet. Such abundant soil volumes are generally only found in non-urban settings. And it should be understood that soil texture, climate and management practices also affect soil volume requirements. Early root pruning to generate a more diffuse root system can be useful to better utilize limited resources when available soil volume is restrictive. Nevertheless, when a tree is provided insufficient soil volume, it is essentially confined to a 'pot'. Once the available soil volume has been fully exploited, the roots will either begin to decline or explore avenues to break out of the pot.

Inadequate space for root flare: The diameter of mature trees at ground level (DGL) must be considered when selecting a species for planting in parkways or sidewalk cutouts. "By knowing the average DGL for the species in a location, planting spaces that are sufficiently large can be specified, or appropriate sized species can be selected for established spaces" (Costello, Jones 2003).

Compaction and clay soils: Moderate to high soil compaction within the root zones of trees limits available soil volume by decreasing soil aeration, restricting air and water movement, limiting water-holding capacity, and impeding root

Bulk density of soils at 70-95% relative compaction					
	Landscape	Vehicular paving	Pedestrian paving		
Soil type	70%	85%	90%	95%	Critical B.D.
Loamy sand (WG)	1.52	1.85	1.96	2.07	1.75
Sandy loam (WG)	1.43	1.74	1.85	1.95	1.70
Sandy loam (MG)	1.35	1.64	1.74	1.83	1.70
Sandy silty clay	1.29	1.56	1.66	1.75	1.50
Silt	1.19	1.45	1.53	1.62	1.40
Silty clay	1.22	1.49	1.58	1.66	1.40
Clay	1.15	1.40	1.49	1.57	1.40

This chart provides information on the critical bulk density for soils of differing textures. Critical bulk density is the level of compaction at which roots are no longer able to penetrate soil. Bulk densities are based on the Proctor Compaction Test (ASTM D698/ AASHTO T99). Units are given as dry bulk density in grams per cubic centimeter (gm/cc). WG is with gravel; MG is minus gravel. (Lindsey, Barlow 1994)

penetration. Fine textured (clayey) soils are more affected by soil compaction. Engineering standards generally require a minimum of 85 percent ASTM compaction under sidewalks. For most soils, 85 percent is the 'critical bulk density' that inhibits root penetration. Such levels of compaction generally force roots to grow at the interface between the pavement and soil where oxygen and moisture are more available.

Excess soil moisture: The ideal planting soil is composed of 50 percent solids (mineral particles and organic matter) and 50 percent pore space holding (25 percent water and 25 percent air). When soil saturation occurs, water occupies the pore space within the soil, displacing the air. In excessively irrigated landscapes and poorly drained sites, soil aeration within the root zone generally becomes more restrictive as soil depth increases. Such conditions, which encourage shallow or surface rooting, also favor the development of root pathogens. Thus, affected trees are less stable and more subject to decline, and failure. Surface rooting is more likely to develop when trees are planted in turf, particularly when drainage is restricted and/or irrigation is excessively or applied too frequently.

Site analysis

Many of the problems associated with trees in urban plantings can be avoided or minimized when unfavorable conditions and site constraints are identified and mitigated or addressed prior to planting. Site analysis is the process of assessing limitations in soil conditions and other site constraints, e.g., shade, limited space, etc. Data is collected in three primary areas: site conditions assessment, soil profile examination and laboratory soil analysis. Results can then be utilized in species selection and in determining the level of site preparation required.

Site conditions assessment:

- topography and drainage patterns
- available surface area (unpaved) surrounding the tree
- available space for ultimate height and spread
- distance to pavement
- presence of turf, ground covers and adjacent plants
- other constraints, e.g., traffic signs, underground utilities, etc.
- sun and wind exposure
- irrigation and surface moisture conditions
- site quality determined by observing plants nearby.

Soil and profile examination:

- different soil strata to a minimum 5 feet deep
- color and smell
- presence of soil compaction and impermeable layers (hardpans, plow pans, rock, textural changes, etc., that can impede drainage)
- retaining walls, obstacles, etc., that restrict drainage or cause water to impound in the root zone
- depth to impenetrable or impervious layers
- water-table depth
- cuts (grade change) or fills
- soil moisture: water infiltration (entry of water into the soil) and permeability (drainage or movement of water through the soil profile)

Laboratory soil analysis:

- texture
- structure (bulk density)
- organic matter levels
- fertility (CEC)
- soil reaction (pH)
- total soluble salts
- electrical conductivity (salinity)
- sodium absorption ratio (SAR) for suspected sodic soil conditions
- toxic ions

Site analysis determines:

- appropriate size, shape and environmental tolerances required for the tree species for long-term success.
- soil conditions that may need to be mitigated, e.g., disruption of compacted soil or impervious layers, incorporation of amendments, fertilization, etc., (as determined by soil analysis)
- approximate volume of soil needed for root development
- the maximum surface area and depth that can be excavated

The roots of this New Zealand Christmas tree (*Metrosideros excelsa*) caused the adjacent pavement to buckle. Soil under the sidewalk was highly compacted and the lawn nearby heavily irrigated. The roots developed deeper in the turf area because the soil there was sandy, and only moderately compacted.

Careful site analysis will help determine the type and level of site mitigation required to provide favorable root zone conditions to sustain tree growth and minimize the potential for pavement damage. Useful life-span is reduced and maintenance costs increase when restrictive soil conditions or physical site constraints are not addressed. Planting trees with little regard to site conditions and constraints is expensive and counterproductive. It is more prudent to do thorough site assessment and adequate site preparation, even if it means planting fewer trees. Funding for urban forestry programs has been slashed due to current economic conditions, so it is in the interest of municipalities to look for ways to reduce maintenance costs, while trying to maintain the present urban forest canopy cover.

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As typically required by municipal building codes, the soil below this sidewalks was compacted to over 85 percent bulk density. Irrigation of the adjacent lawn was so excessive, these large carob *(Ceratonia siliqua)* roots were precluded from growing toward the lawn. The tree was recommended for removal and replacement because it was unhealthy and an undesirable species. Furthermore, returning the sidewalk to grade would have caused severe root injury. A number of site modifications were specified to improve root zone conditions for the replacement tree. Educating homeowners and landscape professionals about proper water management is necessary to avoid similar mistakes.