Reducing Tree Root Damage to Sidewalks in California Cities: A Collaborative Study

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We proposed conducting a collaborative, broad-spectrum research project focused on collecting key information that cities and residents can use to develop effective programs aimed at reducing damage caused by tree-sidewalk conflicts. The long-term goal of this work is to effectively reduce damage caused by tree-sidewalk conflicts in California cities (Figure 1). To accomplish this goal we identified three short-term objectives that will provide critical information needed to achieve our long-term goal: 1) a literature review of root-sidewalk research to date, 2) a field survey of factors contributing to sidewalk damage, and 3) an economic analysis of 50-year benefits and costs for alternative street tree planting configurations and species selection.

Objective 1. Comprehensive Literature Review. We proposed to conduct a detailed literature review to provide arborists and scientists with a single, comprehensive bibliography and review of all root-sidewalk publications to date. This work was not accomplished because $3,000 originally budgeted for it was not funded by the grant. However, Drs. Burger and McPherson will offer a seminar course during winter quarter at UC Davis that will result in a compilation of relevant literature.

Objective 2. Field Survey of Factors Contributing to Damage of Sidewalks. Establish a field-validated ranking of key factors which contribute to sidewalk damage by tree roots in California. This work is reported below.

Objective 3. Quantify Benefits and Costs for Alternative Street Tree Planting Configurations and Species Selection. Produce descriptive and quantitative information that can be used by planners, municipal foresters, street tree commissioners, non-profit tree groups, and interested citizens to evaluate pros and cons of alternative street tree planting configurations and species selection. The scope of this work changed once we examined sidewalk repair data and found that developing damage profiles for different species in

Figure 1. Sidewalk damage caused by tree roots is commonly found in California. Annual repair costs are substantial.

different right-of-way configurations was confounded because of differences among 1) tree planting sites (e.g., yard, lawn, tree well), 2) soils, 3) sidewalk age and construction, 4) tree species characteristics (e.g., trunk flare, root stock), and 5) sidewalk repair procedures. Because all these factors can influence the extent of sidewalk damage and our database contained limited information on these factors and their role in tree root-sidewalk conflicts, our original work plan seemed untenable. Data simply do not exist and could not be readily obtained within the budget for this objective to develop reliable damage profiles for different species in different right-of-way configurations.

Now our objective is to develop benefit-cost ratios (BCRs) for ten of the most important street tree species in Modesto. The BCRs will reflect the distribution of planting sites, soils, trees, and management practices in Modesto, and will be based on work records and tree managers' observations concerning maintenance activities associated with the 50-year growth of each species. Root pruning, sidewalk repair, and replacement data are part of a comprehensive database we have obtained for this analysis. The database includes the time required for every maintenance activity performed by Modesto tree crews during a 3-year period (1996-98). We have not been able to complete the analysis in time for this report, but will produce a final report for the Slosson Fund on this work by Spring 2000.

Field Assessment of Soil Factors Contributing to Sidewalk Damage by Tree Roots

Restrictive soil conditions are frequently cited as a key factor contributing to sidewalk damage by tree roots. Soils with hardpans (duripans), poor structure, fine texture, or perched water tables are thought to limit root development to a shallow zone near the soil surface. As a result, roots have a higher potential to contact and damage sidewalks. Conversely, in soils with no apparent physical limitations, root development is thought to occur deeper in the soil and the potential for sidewalk damage is less.

The objective of this study was to assess whether there is an association between soil physical conditions and tree root damage to sidewalks. We hypothesized that in areas where sidewalk damage is present, a physical limitation to root development could be found. Reciprocally, in areas where no damage is found, physical limitations to root development would not be present.

Methods and Materials

The city of Modesto was selected as the study site for this project. This selection was based on the following: 1) Modesto has an up-to-date tree inventory, 2) it has complete records of sidewalk damage on a city-wide basis, 3) it has both mature and newly-planted trees, 4) the land area is sufficiently large to possess some variation in soil conditions, and 5) it has urban forestry and sidewalk-repair staff who were willing to cooperate in this study.

In order to survey sites with sidewalk damage, Modesto's tree inventory and sidewalk repair data were used. The computerized tree inventory was overlain on a city-wide street grid (prepared by McPherson, *et al.*, USFS Center for Urban Forestry Research and Education, UCD) and repair records were plotted as an additional overlay. This provided an opportunity to examine the distribution of sidewalk damage and identify potential links to tree species, age, and size data. In addition, a generalized soil map (Stanislaus County) was digitized and used as another overlay to investigate links among trees, repairs, and soils.

Although this data gave a general assessment of sidewalk damage distribution, no notable associations with tree species, age, size, or soil type were found from maps alone. For example, we could not link areas with particularly high numbers of sidewalk repairs with a specific soil type or with trees of a certain species or age. Distribution patterns were variable across the city for these factors. As a result, the use of maps and inventory data was not considered to be a singularly reliable method of identifying tree-soil-sidewalk damage associations or trends.

In addition to maps and inventories, therefore, further information was collected via interviews with Modesto Urban Forestry staff and sidewalk repair staff. We noted their observations and assessments of areas where damage was most and least severe, and the tree species they thought were most and least troublesome. Following these interviews, we identified and visited several neighborhoods where trees of the same species and size were found, yet where damage was found to

Table 1. Summary of laboratory analyses of soils from 9 locations and at 3 depths.

Soil Characteristic	Most Readings	Range
Sand (%)	~70	53 - 84
Silt (%)	~23	12 - 35
Clay (%)	~7	4 - 15
pH	~6.5	5.6 - 7.2
Electrical Conductivity (mmhos/cm)	< 0.5	0.2 - 1.38
Cation Exchange Capacity (meq/100 g)	< 10	3.5 - 13.7
Organic Matter (%)	< 0.8	0.24 - 1.55
Total Nitrogen (%)	< 0.55	0.016 - 0.065

Table 2. Summary of tree, sidewalk, and soil conditions at each of 9 sample sites.

Site	Tree DBH (in)	Sidewalk Damage	Soil Textural Class	Soil Depth to Hardpan (in)	Root Distribution in Profile	Comments
1	13	yes	sandy loam	58	small dia. roots to 58 inches	profile constraints in upper 40 in.
2	14	yes	sandy loam	52	concentrated at 2 depths	no irrigation
3	14	no	sandy loam	60	small dia. roots to 60 inches	
4	17	yes	sandy loam	60	small dia. roots to 60 inches	root crown lifted above ground level
5	13	yes	sand/silt loam	62	small dia. roots to 62 inches	duripan at 62 inches
6	24	no	sandy loam	restriction at 48, hardpan at 62	small dia. roots to 62 inches	iron masses at 48 inches
7	20	yes	sandy loam	58	small roots to 58 inches	root crown raised above ground level
8	12	yes	sand/silt loam	56	small roots to 56 inches	
9	16	no	sandy loam	compacted zone at 6, hardpan at 58	small roots to 58 inches	

range from substantial to none. For instance, in one area, ash and hackberry were found to have been growing for 35 years without breaking sidewalks, while in a nearby area, trees of both species were causing damage after 15 years. In both cases, the trees were growing in similar conditions: approximately 3 feet from sidewalks in irrigated front lawns.

Using these observations, ash trees (*Fraxinus spp*.) of equivalent size (11 to 24 inch DBH or diameter at breast height) were selected in 9 areas. In six areas, sidewalks adjacent to the trees were damaged, while in 3 areas no sidewalk damage was found. In all cases, trees were located in front lawns, approximately 3 feet from the sidewalk. Sidewalk materials, engineering, and construction were the same at all locations, and sidewalks and curbs were contiguous.

At each location, soil within the dripline of the tree (approximately 5 feet from the trunk) was sampled using an augering tool which excavated a hole 4 inches in diameter and 6 feet in depth (Figure 2). In the field, evaluations of soil texture, moisture content, color, and root content were made approximately every 10 inches in depth. In addition, depth-to-hardpan was assessed at each location. Soil samples were separated on a tarp as they were removed from augered holes and notes regarding soil qualities were made. Samples then were collected at 6, 18, and 36 inches and submitted to the DANR Laboratory (UC Davis) for analysis of pH, salts, texture, organic matter, and total nitrogen. Photos of trees and sidewalks at all locations were taken.

Results

A. Soils. Laboratory analysis indicated that soils were generally uniform among the 9 locations and in depth at each location. Texture, pH, organic matter content, salt content, cation exchange capacity, and total nitrogen showed little variation (Table 1).

Most soils were classified as being in the sandy loam textural class. In one location, loamy sands were found, while in another loam/silt loam was found. All soils were low in salt content (electrical conductivity), and pH was in a range suitable for most plants. As found in many California soils, organic matter content was low (< 1%). Collectively, all soil chemical and physical properties evaluated were not considered to represent appreciable limitations to root development.

B. Sidewalk Damage, Tree Size, and Soils. Sites were selected using an assessment of sidewalk damage (+ or -), tree size (DBH), and tree species (*Fraxinus spp*). For trees of similar size and species, and using soil sampling information, an assessment of the role of soils as a factor contributing to sidewalk damage was made. Table 2 summarizes findings for each of the 9 sites.

Discussion

As noted from Table 2, sidewalk damage was found in 6 locations (sites 1, 2, 4, 5, 7 and 8), while no sidewalk damage was found in 3 locations (sites 3, 6 and 9). In all of these locations, soil physical and chemical properties were quite similar. Restrictions to root development were not found in the sites where sidewalk damage was noted.

Based on these findings, assessments of soil conditions alone (at the study sites) did not provide an assessment of potential for sidewalk damage. Soil certainly plays a role in root distribution, but we were unable to identify any soil condition which would serve as an indicator for sidewalk damage potential. Duripans (hardpans) were found below the soil surface, but they were sufficiently deep in all cases (50 to 62 inches) to seriously diminish their potential to contribute to surface root development. Soil texture, structure, and moisture content were similar in sites with and without sidewalk damage.

Figure 2. Soil was analyzed at sites where ash trees were growing next to sidewalks in irrigated turf. Sites with sidewalk damage were compared to sites without sidewalk damage.

Figure 3. Various rootstocks are used for ash propagation. Certain rootstocks may have a high potential for sidewalk breakage.

Surprisingly, no sidewalk damage was found next to the largest tree in the study (site 6), while smaller trees were linked to damage. In fact, the 3 smallest trees (12 - 13 inch DBH), were all associated with damaged sidewalks. This finding suggests that factors other than tree size and soil characteristics contributed to sidewalk damage. Since other factors were uniform across the sites (sidewalk configuration and construction, proximity of the tree to the sidewalk, and tree in irrigated turf), it was thought that rootstock variation may be an important factor.

An investigation of rootstocks used for ash in Modesto found that species varied. Trees purchased from a local wholesale nursery were grown on green ash rootstock, while those grown in the City of Modesto nursery were grown on *F. oxycarpa* roots, and Marshall ash were grown on Arizona ash rootstock. Although differences in rootstock were observed, we were not able to accurately identify rootstock species in the field (Figure 3). This may be a productive area for future research.

Although soil conditions which may limit root development and contribute to sidewalk damage were not found in this study, it should be emphasized that soils of other textural classes (e.g., clays and clay loams) may play a major role in sidewalk damage. In addition, soils with poor structure or with restrictive layers (duripans) close to the surface will likely increase the potential for sidewalk damage from tree roots. Finally, sites with no apparent restrictions to root development (e.g., sands), yet where tree root damage to sidewalks is found, may offer a contrast to sites where soil plays a major role in sidewalk damage. Sites with trees of the same species and of similar size planted next to sidewalks and with these soil conditions (e.g., Stockton, Davis, and San Francisco) would be promising locations for future studies to further identify the role of soils in root and sidewalk conflicts.

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