

TREE ROOT DAMAGE TO SIDEWALKS AND CURBS

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Tree roots cause enormous damage to sidewalks and curbs each year, and repair of this damage has been a major cost to cities. In 1975, for example, Hamilton et al. (4) found the annual cost of repairing root-damaged sidewalks to be approximately \$27,000 per city for 22 northern California cities. Sidewalk damage is especially serious because cities may be liable if citizens injure themselves on root-damaged sidewalks (3,5).

To explore how damage to sidewalks and curbs is related to tree species, tree size, planting-strip width, and soil texture, we studied street trees in cities along the eastern shore of San Francisco Bay in California. These cities have a nearly frost-free Mediterranean climate with annual precipitation of 16 to 20 inches, which falls mostly from October through April. All trees studied were located in street rights-of-way between curbs and sidewalks. The soils consisted mostly of clays and clay loams except for sands in two areas.

Methods

In 1980 we studied 10 of the tree species most commonly grown in the San Francisco Bay Area, with species and numbers sampled as follows:

| Species | Number |
|---|--------|
| Sweetgum (<i>Liquidambar styraciflua</i>) | 118 |
| Planetree (<i>Platanus acerifolia</i>) | 113 |
| Modesto ash (<i>Fraxinus velutina</i> 'Modesto') | 98 |
| Flowering plum (<i>Prunus spp.</i>) | 86 |
| Myoporum (<i>Myoporum laetum</i>) | 79 |
| Glossy privet (<i>Ligustrum lucidum</i>) | 59 |
| Evergreen elm (<i>Ulmus parvifolia</i>) | 57 |
| Shamel ash (<i>Fraxinus uhdei</i>) | 49 |
| Fruitless mulberry (<i>Morus alba</i>) | 54 |
| Southern magnolia (<i>Magnolia grandiflora</i>) | 50 |
| Total | 763 |

On the basis of preliminary measurements and analyses for several hundred trees made in 1979, we knew we had to avoid strong correlations among soil texture, planting strip widths, tree species, and tree size. Therefore, for each of four

soil classes, we located planting strips 2 feet wide, 2 to 4 feet wide, and 4 feet wide. For each soil and strip-width class we then sought (but could not always find) trees of each species in diameter classes of 4 to 8 inches, 8 to 12 inches, 12 to 18 inches, and > 18 inches. For each species, we defined all possible combinations of soil, strip-width, and diameter classes, and attempted to sample approximately the same number of trees for each combination. When a choice existed among several trees at a location, it was made by rolling a die.

For each tree sampled, we rated damage to sidewalks and curbs on the basis of how much the concrete was displaced, as follows: 0 = none, 1 = less than 1 inch, 2 = 1 to 2 inches, and 3 = more than 2 inches. Sidewalks or curbs that had been replaced because of apparent root damage were also rated as 3. If we had any doubt concerning why concrete had been replaced, we rejected the tree. Tree diameter was measured with a diameter tape to the nearest tenth of an inch 4.5 feet above the ground. Planting strip width was measured from sidewalk to curb to the nearest tenth of a foot. Soil texture at a depth of 3 inches was classified by working a moistened soil sample between the fingers and comparing it with soils of known texture: (We chose these classes after consulting Dr. Esther Perry, former Soils Specialist, Department of Soil and Plant Nutrition, University of California, Berkeley.)

Soil 1 — sand, loamy sand, sandy loam and loam

Soil 2 — sandy clay loam and clay loam having less than 35 percent clay

Soil 3 — sandy clay and clay loam with 35 to 40 percent clay

Soil 4 — clay and sandy clay with more than 40 percent clay.

The soils within a class were judged to affect tree roots in generally similar ways.

Preliminary measurements and analyses from 1979 indicated that more detailed soil measurements, including texture at several

depths and marked discontinuities, would provide little advantage in explaining how much sidewalks and curbs were displaced.

We determined approximate relationships between displacement of concrete (sidewalks and curbs) and tree species, tree diameter, width of planting strip, and soil texture through regression and discriminant analyses.

Results

Our regression analysis for sidewalks accounted for only 38 percent of the total variation in damage. More than half of this (22 percent) was associated with tree diameter, followed by tree species (10 percent), planting strip width (4 percent), and soil texture (2 percent). The regression for curbs accounted for only 25 percent of the total variation in damage, with slightly less than half (11 percent) associated with tree species, followed by diameter (8 percent), planting strip width (3 percent), and soil texture (3 percent).

As expected, more large trees caused damage than did small trees (Fig. 1). After the effects of size, soil texture, and planting-strip width had been accounted for by regression analysis, the 10 species studied were ranked from most to least damaging as follows: sweetgum, fruitless

mulberry, Shamel ash, Modesto ash, evergreen elm, southern magnolia, planetree, glossy privet, myoporum, and flowering plum (Fig. 2). Although the ranking is approximate, it indicates which species are likely to cause damage substantially above or below average. The average difference between the most and least damaging species on a scale of 0 to 3 was 0.85 for sidewalks and 0.45 for curbs.

We estimated the average effects of tree diameter, planting strip width, and soil texture, using regression analysis to correct for other variables. The severity of damage increased with tree diameter (Fig. 3) and averaged greatest in the narrowest planting strips (Fig. 4). Sidewalk damage averaged somewhat less in the lightest soil class (soil 1) than in the other classes (Fig. 5).

We were especially interested in the possibility that soil texture and tree species would interact to cause particularly damaging or nondamaging combinations. We did find limited evidence of differences in the ways different species respond to texture. Myoporum did far more damage on soils 1 and 2 (having less than 35 percent clay) than on soils 3 and 4 (with 35 or more percent clay). Discriminant analyses for sweetgum (Table 1) and planetree showed the division between less

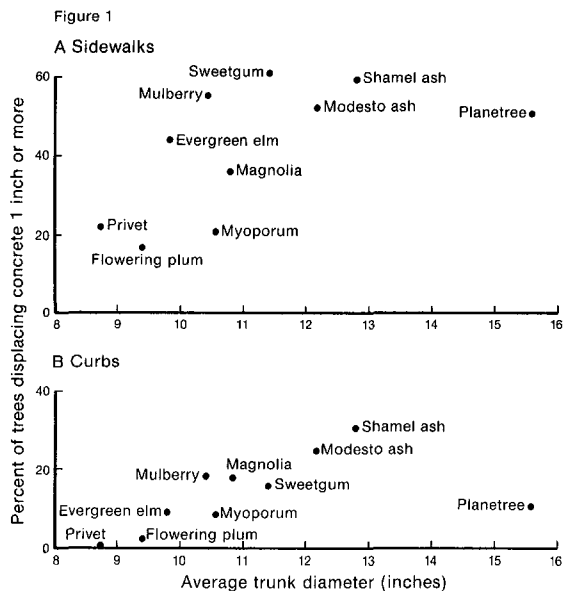


Figure 1. Relation of average diameter of tree species to (A) percentage of trees that damaged sidewalks and (B) percentage of trees that damaged curbs.

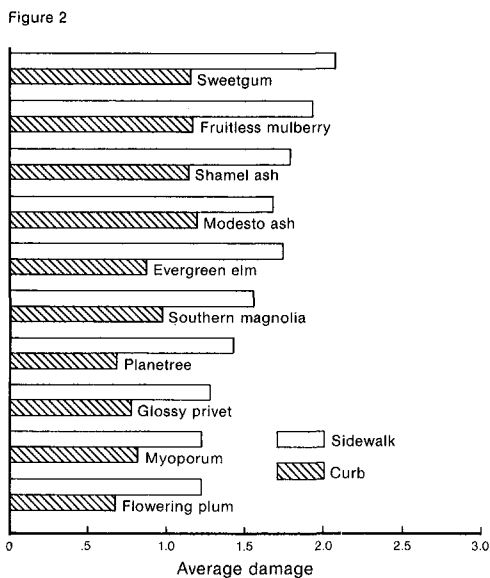


Figure 2. Ranking of tree species by amount of damage to sidewalks and curbs (scale: 0 = no damage to 3 = concrete displaced more than 2 inches.).

and more damaging trees to occur at smaller diameter classes on heavy clay soils than on soils with lower clay content. Even for these three species, however, damage among trees of similar sizes varied so much within the same soil texture class that matching species to soil texture shows only limited promise for reducing sidewalk damage.

Contrary to experience in some regions, the urban soils we examined showed little evidence of major disturbance, probably because sampling was in residential areas where very few houses have basements.

Discussion

For the area and species studied, tree root damage to sidewalks and curbs depended more on geometry (i.e., tree size and planting strip width) and on species than on soil texture. Predic-

tably, large trunk diameters and narrow planting strips were both associated with substantial damage. To avoid narrow planting strips, many cities now specify contiguous curbs and sidewalks for new subdivisions (1).

Among the species studied, the most damaging are also some of the most frequently planted. A cycle seems to have developed in which cities buy trees from the lowest bidder, unintentionally encouraging nurseries to emphasize species that grow quickly to saleable size. But such vigorous, fast-growing species are also those apt to create costly problems the soonest. However, some of the less damaging species we studied have other problems. Myoporum's abundant fruit, for example, leaves sidewalks messy with fruit stains and bird droppings. Planetree may have disfiguring anthracnose and mildew, and it drops leaves and bark throughout the summer.

In all cases, damage to curbs averaged less than damage to sidewalks, suggesting advantages for thicker concrete extending to greater depths.

Soil texture appeared to affect the likelihood of damage by myoporum and, to a lesser extent, by sweetgum and planetree. Actual relationships were not identified and may be somewhat complex. Garin (2), for example, found that tree roots

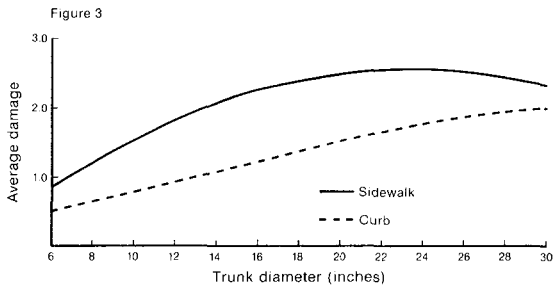


Figure 3. Approximate effect of trunk diameter on damage to sidewalks and curbs as determined by using regression equations to adjust estimated damage for planting strip width, tree species, and soil texture. (Damage scale: 0 = no damage to 3 = concrete displaced more than 2 inches).

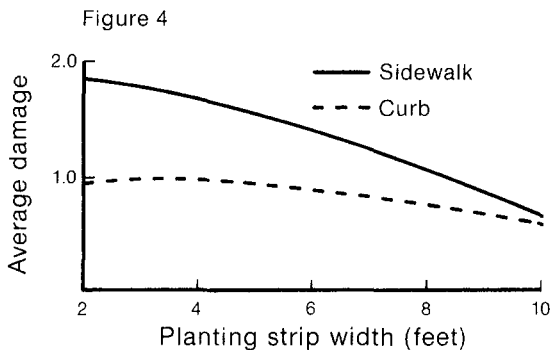


Figure 4. Approximate effect of planting strip width on damage to sidewalks and curbs as determined by using regression equations to adjust estimated damage for trunk diameter, tree species, and soil texture. (Damage scale: 0 = no damage to 3 = concrete displaced more than 2 inches).

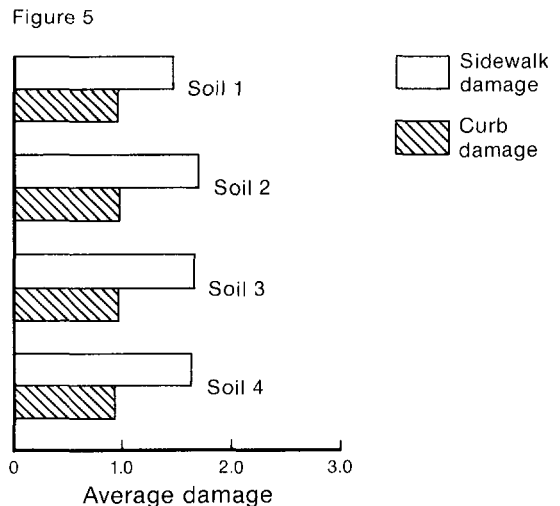


Figure 5. Approximate effect of soil texture on damage to sidewalks and curbs as determined by using regression equations to adjust estimated damage for trunk diameter, planting strip width, and tree species. (Damage scale: 0 = no damage to 3 = concrete displaced more than 2 inches; soil 1 had most sand, soil 4 had most clay).

in poor soils extend farther and branch less than roots in rich soils. The greater damage by myoporum growing in sands as compared with that growing in clays may be because its roots branch less in sands and are therefore larger.

On the other hand, differences in damage may result from the way moisture affects the mechanical strength of sands and clays. Wet sand is generally firmer than dry sand, whereas wet

clay is much more plastic than dry clay. Myoporum is an evergreen species of Mediterranean climates that may do much of its growing during the rainy season, when clay soils—but not sands—may be plastic enough to squeeze out of the way as roots grow in diameter. The roots of such deciduous trees as sweetgum and planetree, however, probably grow primarily during the summer when clay soils would be drier,

Table 1. Relations between amount of sidewalk damage and tree size, soil texture, and planting strip width for 118 sweetgum trees.¹

| Width (feet) | Diameter (inches) | | | | | | | | | | | | | |
|---------------------------|-------------------|----|----|----|-----|-----|----|----|----|----|----|----|----|----|
| | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| <u>Soil 1 (most sand)</u> | | | | | | | | | | | | | | |
| 0.5 to 3.0 | | oo | | oo | xx | xx | x | | •• | | | | | |
| | | ox | | xx | x | x | | | • | | | | | |
| 3.1 to 5.0 | o | o | o | xx | | | | | • | | | x | | x |
| | | | | x | | | | | | | | | | |
| 5.1 to 7.0 | | | o | ox | ox | | | | | xx | | | | |
| 7.1 to 9.0 | | | | | | | | x | | | | | | |
| <u>Soil 2</u> | | | | | | | | | | | | | | |
| 0.5 to 3.0 | | oo | | xx | x | | | | | | x | | | |
| | | x | | | | | | | | | | | | |
| 3.1 to 5.0 | | oo | | xx | x | | | | | | x | | | |
| | | | xx | x | | | | | | | | | | |
| 5.1 to 7.0 | | oo | | o | | | | | | | | | | |
| | | x | | | | | | | | | | | | |
| 7.1 to 9.0 | | o | o | | | | | | | | | | | |
| <u>Soil 3</u> | | | | | | | | | | | | | | |
| 0.5 to 3.0 | | | | x | | | | | | | | | | |
| 3.1 to 5.0 | | | ox | ox | xx | •xx | xx | •x | x | xx | | | | |
| | | | x | xx | xxx | xxx | xx | xx | | | | | | |
| 5.1 to 7.0 | | | oo | x | | x | | | | | | | | |
| 7.1 to 9.0 | oo | oo | x | | | | | | | | | | | |
| <u>Soil 4 (most clay)</u> | | | | | | | | | | | | | | |
| 0.5 to 3.0 | | x | x | | | | | | | | | | | |
| 3.1 to 5.0 | | ox | o | ox | xx | x | x | | | | | | | |
| | | | | | x | | | | | | | | | |
| 5.1 to 7.0 | o | oo | oo | x | | | | x | x | | | | | |
| | | | ox | | | | | | | | | | | |
| 7.1 to 9.0 | | o | o | | x | | | | | | | | | |

¹x = tree that displaced sidewalk 1 inch or more; o and • = trees that displaced sidewalk less than 1 inch; • = possible source of less damaging cultivar. Trees to left and right of dotted lines were predicted by discriminant analysis to move sidewalks less than 1 inch and 1 inch or more, respectively.

less plastic, and less yielding. If soils will not yield beneath a growing root, it may move the concrete above it. Keeping clay soils well watered during late summer and fall might reduce damage to concrete by species whose roots expand at such times.

Soil texture may also affect the depth of rooting. Clays may cause shallow rooting by holding moisture near the surface and by being dense enough to reduce aeration in deeper layers. Sands may encourage deeper rooting of some species by providing good drainage and aeration.

Our analyses accounted for well under half of the total variation in the effects of trees on concrete. Sources of unmeasured variability probably include genetic differences within species, the directions major roots were pointing when trees were planted, amounts and depths to which different trees were watered, and perhaps such differences as the thickness of sidewalks and whether the soil over which they were poured was compacted. Some variability undoubtedly resulted from misclassification of damage. Damage to concrete that had been replaced was classified as "3" (displacement of more than 2 inches), but actual displacement may have been less. In a few cases, replacement due to utility repairs may have been mistaken for replacement due to root damage.

Although variability creates problems for analysis, the variability due to genetic differences within a species offers an opportunity. Some of the trees we studied did far less damage than others of the same size and species, in similar soils, and in planting strips of similar width. It may be possible to reduce root damage to sidewalks by selecting trees or rootstocks within a species that do little damage.

Conclusion

Although damage to concrete might be reduced by avoiding some combinations of species and soils, more effective short-term approaches for reducing such damage appear to be (1) planting less damaging (often smaller and slower-growing) species and (2) devoting more space to trees. Differences in damage among trees of the same species, size, and apparent environment suggest, for a somewhat longer time frame, that damage to concrete can be further avoided by the propagation and commercial production of trees and rootstocks selected for unusually low levels of damage.

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