CHAPTER 6

URBAN DESIGN FOR A WIND RESISTANT URBAN FOREST

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Introduction

Researchers who visited post-hurricane sites found that many incidents of tree failure could have been prevented with appropriate design and management. Many trees that grow to a large size had been placed too close to curbs, sidewalks, foundations, and pavement. Roots on mature trees had been deflected, decayed or been cut close to the trunk. These conditions resulted in trees toppling in high winds.

A strong root system is one of the most critical factors that allow trees to withstand hurricane-force winds in urban landscapes, where space for root growth is often limited. Limited rooting space presents a challenge to creating sustainable landscapes. Strategies for developing strong root systems on newly planted trees and preserving the roots of existing trees will be discussed in this document. Other elements of wind-resistant design such as tree grouping and species selection will also be introduced.

Research shows that the more rooting space trees have, the less likely they are to fall. Root systems that grow without being deflected by curbs, sidewalks, pavement and other urban soil structures have a chance to develop a strong supporting base for the tree. Main roots close to the trunk should be straight.If these roots are deflected or cut during construction, then risk of failure increases significantly. Trees growing in groups have a higher rate of survival than trees that stand individually. Groups of trees also divert wind so they offer more protection for nearby buildings compared to isolated trees. See *Chapter 5—Wind and Trees: Lessons Learned from Hurricanes* for more details on the design factors that have affected tree failure in past hurricanes, based on the research and observations of experienced professionals.

Good design means designing the underground soil space to support trees and selecting the right tree. However, many landscapes are already established. So it is important to first address design solutions for existing situations where trees are in conflict with the landscape.

Existing Design Situations

Every day people pass by trees that are growing in conflict with the existing landscape: the parking lot of the grocery store, the sidewalks downtown, the front yards of their homes, and so on. In each of these situations, when trees have a limited space to grow, pavement begins to interfere with root expansion 10 to 20 years after planting (Figure 1). The problem can begin as a crack in the surface of the pavement, which attracts growing roots and eventually results in an entire section being lifted. This can present a trip hazard to pedestrians passing by. Large maturing trees grown in small spaces will do one of two things: grow and disturb the hardscape, or decline and eventually die. The latter outcome is wasteful and impractical because the cost of planting a tree in an urban area can range from five hundred to thousands of dollars. Tree removal and replanting is yet another expense, and still the design objective is not fulfilled. In the former scenario, in which the tree continues to grow in conflict with the hardscape, often the large anchoring roots are cut when the hardscape is repaired (Figure 2). Many urban tree managers have learned from experience that cutting roots is a poor decision because it makes the tree unstable. Trees with cut roots have fallen over and damaged homes and vehicles. They have even killed people. It should be clear that for the sake of wind resistance, cutting or damaging the root system that anchors the tree is not an option! Trees that lack their main support roots are hazards in the landscape.

When root pruning is necessary, the general guideline is to preserve all roots within an area about five times the trunk diameter. For example, if the trunk diameter is two feet, than do not prune roots within ten feet of the trunk. Although this will not guarantee that tree will remain erect, it is better than cutting closer to the trunk.

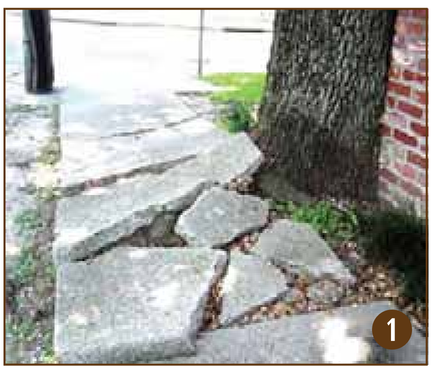

Figure 1

Sidewalk located too close to the root flare of a large tree.

Figure 2

Main supporting roots were cut. These trees, once of value to the landscape, are now at high risk for failure and should be removed before they fall over.

Design solutions for situations where roots are in conflict with the landscape

Rather than cutting the roots, there are many different techniques that have been used that do not interfere with the root system of the tree. Several of these are discussed below. Look for more detailed information on our Web site: http://treesandhurricanes.ifas.ufl.edu/.

Install different surface material

Materials other than concrete can be used as a wearing surface for sidewalks. Some examples are crushed granite, gravel, wood decking, brick-in-sand and asphalt. Porous pavers and porous asphalt have been used for parking lots with success. A potential benefit to these alternate surface materials is that they provide some aeration to the soil beneath, versus concrete, which traps moisture and can encourage roots to grow directly under and break the pavement. Most of these materials are flexible, so they are less likely to crack from root growth than a rigid surface like concrete. Repairing these alternate surface materials can also be less expensive than traditional hard surfaces.

Stone dust

Surface materials like gravel, limestone, or stone dust allow continued root growth and expansion (Figure 3). The surface can be easily repaired as roots continue to expand in diameter. Crushed rock is inexpensive and easy to install, and the surface is porous. It is best used on fairly flat surfaces because rain can cause erosion on sloping ground. The use of brick pavers, shown in the picture, provides a route for pedestrians walking from the parking lot to the other side of the street. Displaced stones will need to be replaced occasionally, and may be a nuisance when using equipment such as a leaf blower (Gibbons, 1999).

photo courtesy of Scott Wheeler

Figure 3

Stone dust is placed around the root flare of the tree in cutouts along this brick sidewalk. This technique is attractive and allows for easy repair as roots expand in diameter.

Porous pavers

This solution is most commonly used for paved areas such as parking lots (Figure 4). Porous surfaces are a good idea for areas prone to flooding because they allow some water to permeate for more even distribution, and can help reduce runoff problems. This is an especially important design detail for Florida and the Gulf coast, which is prone to heavy tropical rains.

Soil should be added around the roots to prepare a base for the pavers. Coarse sand works nicely as a sub-base for the porous pavers because it compacts, yet allows enough air space between particles for air movement. Be sure that the soil grade is not lowered during the construction process, because this will damage roots.

Fill and re-pour sidewalk

Like many of the other solutions, this can be a short-term solution that often requires repair in the future. Perhaps using an alternate sub-base material like gravel or rubber chips (instead of soil) and then re-pouring will prevent roots from growing directly under the pavement and lifting it. Reinforcing the concrete with rebar can extend the life of the sidewalk or driveway by forcing the expanding roots to lift the entire slab. This can prevent cracking because the root can deform and become flattened under the slab instead of lifting it.

Figure 4

Porous pavers can be installed around existing trees where roots have lifted the pavement or sidewalk. This makes it easy to repair damage in the future and can potentially reduce water runoff.

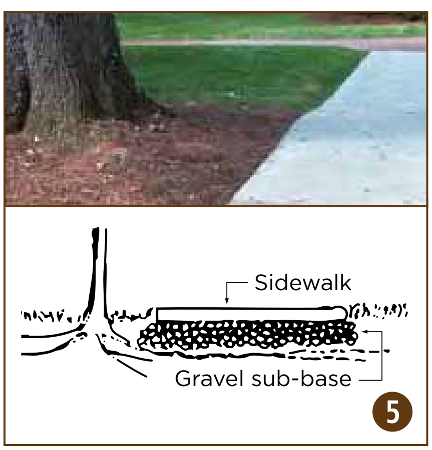

Figure 5

After adding soil over the roots that are causing the walk to lift, re-pour the sidewalk. Use a sub-base material like gravel, or reinforce the concrete with rebar to deter roots from lifting the pavement.

Bridging

Surface materials such as interlocking concrete pavers, wood decking, rubber sidewalks, or metal (Figure 6) can be used to bridge over roots.

Reroute

Where possible, redirecting the sidewalk is a great option if there is space (Figure 7). This solution is used for many trees in urban areas. Be sure to put a mechanism in place that prevents contractors from damaging the main support roots during sidewalk repair.

Figure 6

Materials such as metal can be used to bridge over roots that are lifting an existing sidewalk. The tree can be seen at the extreme top of photo.

Figure 7

When there is space available, re-routing the sidewalk is the recommended option.

New Design/Construction: Designing the Right Place

A good design should provide enough soil space to support root growth of the tree. The volume of soil required depends on the expected size of the tree. Unfortunately, many trees are squeezed into soil spaces that are large enough for the root ball at planting but way too small for future root growth. This is a main reason for poor growth and instability of trees in hurricanes. Current design practices will have to change significantly in order to give trees the appropriate amount of soil space. A typical design specification can call for a volume of 200 cubic feet of soil for trees, whereas 2,000 to 3,000 cubic feet would be an ideal amount. This is a drastic difference! The table and design solutions presented here attempt to strike a compromise between these two extremes.

Soil requirements

For situations where the planting area is surrounded by paved surfaces, Table 1 provides guidelines for the minimum amount of soil to provide based on tree size at maturity. There are two components to soil space: 1) the total soil volume needed to sustain a tree for a reasonable period of time, and 2) the open soil area needed immediately surrounding the trunk to accommodate trunk flare growth. *Open soil space* is soil that is not covered by a solid hard surface such as a sidewalk, pavement, or a building.

Table 1. Soil requirements for trees based on their size at maturity.

TREE SIZE AT MATURITY	TOTAL SOIL AREA*	DISTANCE FROM PAVED SURFACE
SMALL Height: shorter than 30 ft	10 ft x 10 ft	2 ft
MEDIUM Height or spread: lesser than 50 ft	20 ft x 20 ft	6 ft
LARGE Height or spread: greater than 50 ft	30 ft x 30 ft	10 ft

* Measurements for when rootable soil depth is 3 feet or greater. For soil less than 3 feet deep, smaller maturing trees are recommended.

The soil guidelines in Table 1 are minimum recommendations intended for good quality, well-drained soils. When the soil has limitations such as compaction, high water table, poor drainage, etc., either provide more space, or choose small maturing trees. Although these recommendations are significantly different from a typical specification, much more rooting space is necessary for trees to be more stable in the landscape and to be appropriately considered a wind resistant design.

Design solutions for urban situations where space is limited

There are many options for increasing soil area for trees in downtown landscapes, malls, and other urban situations where pavement is in very close proximity to the trunk. This section will list options for increasing soil area in this type of environment, or making better use of existing site soil.

Step 1—Plant trees in the open space available.

Study Figure 8 carefully—notice the large space provided for turf. Compare this to the limited size of the sidewalk cutouts that the trees are planted in. If planted in the open lawn, the trees have a better chance to become large, to provide shade for people using the space, and reduce cooling costs for nearby buildings. Instead, they will have a shorter lifespan due to the limited growing space. The tree grates shown in Figure 8 cause more harm than good. Don't use them, pavers are a better option.

Figure 8

Locate trees on the site so they have access to the most soil space. These trees would thrive better if planted in the open space on the right. Root paths or suspended sidewalks could increase access to rootable soil.

We are accustomed to seeing trees planted in a thin strip of lawn between the sidewalk and street (Figure 9). Sidewalks often become displaced and broken as roots expand in diameter. Not only is damage to the sidewalk from root expansion expensive to repair, but trees would be more stable if they were planted in the open space on the other side of the walk. This is a simple solution that can reduce incidences of trees blowing over. When fewer curbs surround the tree, the tree grows faster and has a more balanced root system. The tree becomes more stable because the root flare is able to fully develop without obstruction from the sidewalk and curb.

Step 2—If there is no open space, provide more rootable soil.

Sidewalks in high traffic, downtown areas must be designed to support emergency vehicle weight. Hence, the soil beneath the sidewalk is compacted to prevent settlement and cracking of the sidewalk. However, trees thrive best in loose, porous soil that encourages root growth. These two objectives—stable walks and loose soil for roots—typically conflict with each other unless we design the space appropriately. So how do you create a stable wearing surface and space for trees to grow?

Root paths

Root paths are narrow channels of loose soil that provide a small path for air that encourages root growth under pavement (Figure 10). A trenching machine is used to cut a trench through the compacted soil. Aeration mats are then placed in the trenches, which are backfilled with loose soil once the mat is in place. Roots tend to follow the paths because they provide a channel for airflow adjacent to the mat; roots follow the air. Encouraging roots to spread under the pavement can help to prevent roots from circling around in the small cutout in the sidewalk, which is a common cause for trees blowing over during hurricanes. This method is preferred over just providing a cutout or box of soil, though it does not significantly increase the amount of soil space.

photo courtesy of Chuck Lippi

Figure 9

Rather than planting in the thin strip of soil space between the sidewalk and the street (top), plant trees in the open space on the other side of the walk (bottom).

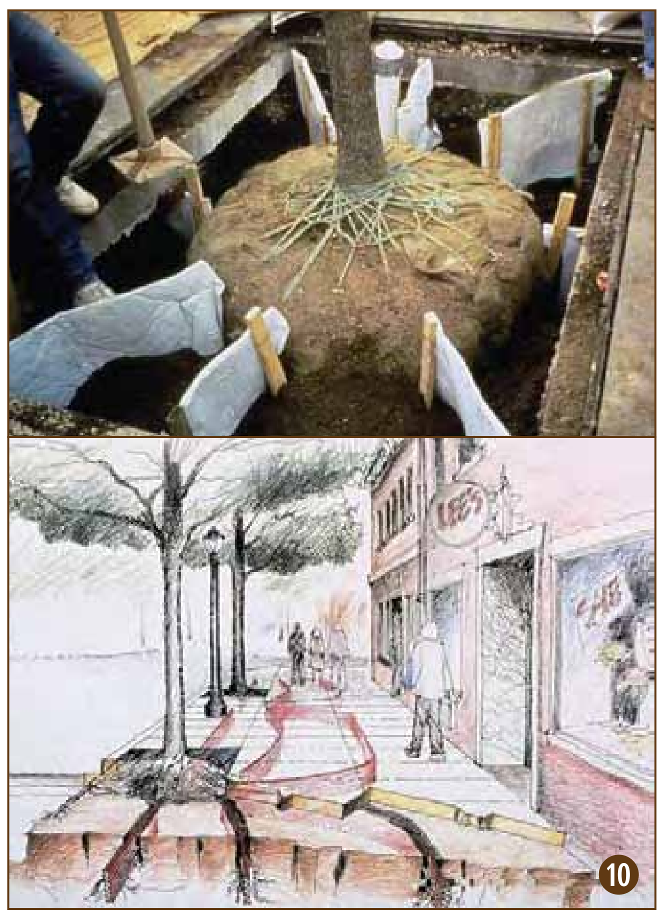

photo and illustration courtesy of Jim Urban, Urban and Associates

Figure 10

Root paths provide channels for air beneath the sidewalk to allow roots to spread beyond the planting pit.

Planting strips

Planting strips are long sections of soil without pavement on top that provide much more soil volume for trees than root paths. Notice the sidewalks bisecting the strips of turf in the right photograph (Figure 11). This is a necessary design consideration because it is important to keep pedestrian traffic off of the open soil around these trees to prevent soil compaction. Given this consideration, planting strips may be more practical in areas that are less busy. Planting turf and flowers at the base of the tree make it far more likely that the trees will receive adequate irrigation and could improve tree growth, though this may attract people to sit or walk on the turf. Never pile soil on top of the root ball or on the trunk.

Structural soil

Structural soil is designed to support the weight of walks, roads, pedestrians and vehicles, as well as provide a well-aerated soil substrate for tree root growth (Figure 12). In structural soil, weight is transferred from one aggregate (rock) to another, with enough soil to almost fill the space between the aggregates. The aggregates are angular rocks that are typically about 1 inch in diameter. Roots grow well in the soil between the aggregates, which is not compacted because load is transferred to the rocks.

This technique is being used in urban areas due to its effectiveness at supporting heavy traffic and allowing tree growth in tough urban situations. The process of mixing the soil can be labor intensive and needs to be done very carefully. Because 80% of the volume of structural soil is comprised of rocks, a large amount is needed to meet adequate root volume requirements.

Figure 11

Planting strips increases the soil area significantly, but the soil can become compacted in high traffic areas. Consider using paths to direct traffic (top). Planting in narrow strips (bottom) can cause walks to lift prematurely; gravel under the walk can help reduce sidewalk lifting

photo courtesy of Dr. Jason Grabosky, Rutgers University

Figure 12

Structural soil can be used beneath paved surfaces that bear heavy traffic. The weight on the surface is transferred to the rocks, while the soil between the rocks is not compacted and provides space for roots to grow. Soil typically represents about 20% of the volume of structural soil.

Suspended sidewalk

Sidewalk suspension or cantilever can allow a great deal of soil volume for trees and addresses the issue of compaction (Figure 13). There is no contact between the bottom of the sidewalk slab and the soil; the slabs rest on supports and pilings. This allows the planting pit to be filled with well-aerated, quality soil. Suspending the sidewalk avoids issues with soil compaction so that roots can spread without interrupting the hardscape. One product that has been recently introduced to the market, Silva Cells®, is an example of the suspended sidewalk technique.

Step 3—Plant trees in groups.

In addition to root space, a key design consideration for a wind-resistant landscape is to plant trees in groups (Figure 14). The definition for a grouping is five or more trees sharing the same soil space. The goal is to create a healthy urban forest with a mixture of young and mature trees that provides benefits such as canopy cover and protection from high winds. Damage to buildings and other structures is usually less severe on properties with high tree density than on properties with isolated trees spaced far apart.

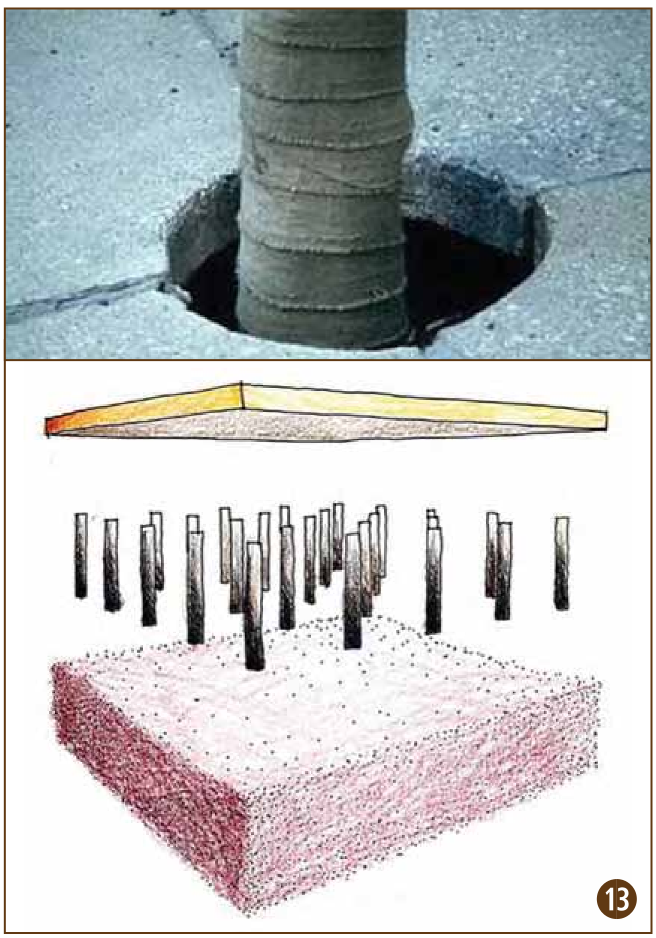

illustration courtesy of Jim Urban, Urban and Associates

Figure 13
Suspending the sidewalk on vertical supports stabilizes the walk and allows roots to grow well in uncompacted soil.

Figure 14
A historic neighborhood a few blocks from the downtown area of a small city has large trees due to large soil spaces (top). New trees positioned far apart in small soil spaces will take many years to form a canopy cover, if ever (middle). Merging soil into long wide strips allows roots to share space, resulting in successful urban designs (bottom).

A sustainable approach to designing parking lots

We have become accustomed to seeing large areas of land stripped to make a parking lot, and all the large trees clear cut to be replaced by a few small saplings. A more sustainable approach would be to evaluate the mature trees, remove the ones that are in decline or have poor structure or poor root systems, and design the parking lot around the existing, healthy trees. Replace the trees removed with groupings of young trees, rather than small islands that can only support one or two trees for a short period of time. Consider that large healthy trees, even if confined to one area, will shade a greater portion of a parking lot than lots of little islands with small, short-lived trees providing little to no shade. Trees in islands frequently have to be replaced and rarely fulfill the design intent.

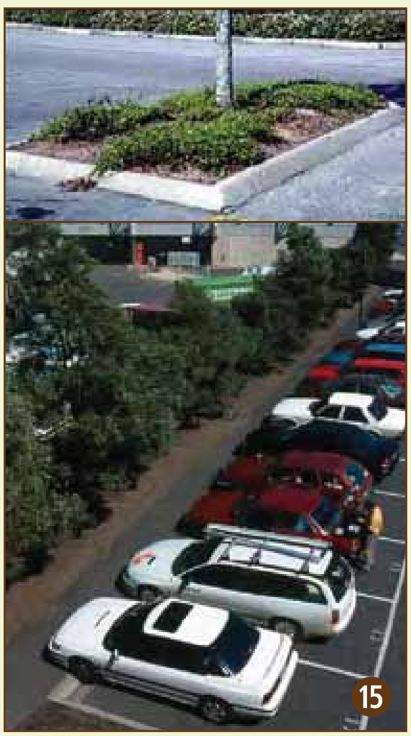

Figure 15

Contrast the typical planting island (top) where trees rarely become large with a buffer strip of trees (bottom). Grouping trees together in one large area is a sustainable design practice. These kinds of plantings will last many years.

New Design/Construction: Selecting the Right Tree

When soil space is limited, or the soil is shallow (less than 2 or 3 feet), rocky, or of poor quality, plant small maturing trees (those that mature at less than about 35 feet). There is an exciting variety of small trees that is currently underused for urban plantings but some of them are not available in large sizes. Although they are shorter than large maturing trees, small trees still provide some shade benefits (Figure 16). Rather than planting a large tree in a confined space, where much damage could occur from the tree blowing down during a hurricane, the preferred option is to go with the smaller tree which is more likely to survive a hurricane (see *Chapter 7—Choosing Suitable Trees for Urban and Suburban Sites: Site Evaluation and Species Selection*). Research has found that certain tree species, including many native species and palms, tolerate hurricanes (see *Chapters 8 and 9—Selecting Species for Wind Resistance*).

Figure 16

Small trees planted in a small space can help preserve the sidewalk but small trees provide very little canopy or shading unless planted close together as shown here.

Literature Cited

Gibbons, J. 1999. Pavements and Surface Materials. University of Connecticut Cooperative Extension System Technical Paper 8. Haddam, CT. 7 pp.

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