Structural Pruning: Part 1

Edward F. Gilman, Brian Kempf, Nelda Matheny, and Jim Clark

Introduction

A landscape filled with strong, long-lived trees is most easily achieved when appropriate species selection and placement are combined with high-quality, well-structured nursery stock, good planting techniques, and appropriate pruning. This article is based on a new publication (*Structural Pruning: A Guide to the Green Industry*) which describes an approach to pruning that manages risk and tree health by promoting a sound tree structure that resists failure, provides clearance, and improves aesthetics.

From training young trees to managing mature ones, structural pruning to guide and manage tree architecture should be the primary goal each time a tree is pruned. A well-structured tree is aesthetically pleasing, supports the crown as it grows larger, is long-lived, and provides the greatest benefits at the lowest cost. Poor tree architecture or inferior branch structure can be costly, leading to tree failure and early tree removal and eliminating the benefits that could have been provided by a mature tree.

This paper introduces and describes a standard approach that begins with structural pruning and may include other pruning objectives such as raising, reducing, and cleaning the crown. It focuses on enhancing tree structure as the most important task when pruning rather than on thinning tree crowns. Structural pruning trains young- and medium-aged trees by guiding future growth; it also is applied to mature trees by managing weight distribution to reduce the likelihood for tree failure. Structural pruning should be applied each time a tree is pruned, keeping in mind the tree’s response or reaction to pruning.

ANSI A300 (Part 1) (2008) identifies structural pruning as one of five pruning objectives. It states,

“Structural pruning shall consist of selective pruning to improve tree and branch architecture primarily on young- and medium-aged trees.”

The Structural Approach to Pruning

Why Prune for Structure?

Structural pruning has one primary objective: to develop and maintain structurally stable trees. Structural pruning performed on most tree species that become large at maturity

- promotes longevity by reducing tree failure;
- can decrease future maintenance costs;
- reduces conditions that could place people or property at risk; and
- sustains environmental benefits to the community.

Much of the pruning that is performed today focuses on creating clearance and improving aesthetics. The approach presented here adds risk reduction to those customer desires. It is common to see correctable structural problems, such as codominant stems, remaining in young and medium-aged trees after they have been professionally pruned. This is a missed opportunity to reduce future pruning needs and reduce tree failure.

When trees are structurally pruned regularly from a young age by suppressing growth on the largest branches, the need to remove or prune large branches as the tree matures is minimized. When done correctly, fewer (if any) large branches require removal in the mature tree crown. This has the added benefit of minimizing costs associated with debris removal and disposal.

Get More Bang for Your Buck with Structural Pruning

Properly pruning young and middle-aged trees to form a strong structure decreases the need for pruning when trees are mature. Because smaller trees are less expensive to prune than large trees, pruning budgets go farther. It pays to solve structural problems while the tree is young and branches are small than when the tree is mature and branches are much larger.

Consequences of Not Pruning for Structure

Poor tree structure can lead to failure and possibly personal injury or property damage. During storms, trees with poor structure are usually the first to fail, knocking out power lines, increasing the costs for cleanup, and sometimes interfering with emergency operations. The lost canopy reduces the benefits provided by urban forests.

Poor pruning by cutting the wrong branches can cause structural and health problems for trees. Examples include trees that have been excessively thinned, lions-tailed, raised, or topped.

How Structural Pruning Is Different from Other Pruning

Pruning for structure differs than other pruning objectives because it focuses on directing growth and developing the framework of the tree to enable it to withstand future loads. The primary focus is on pruning the parts of the crown that contribute to weakness. Rather than a one-time event, structural pruning should be thought of as a training process that improves tree structure over a period of time.

In most cases structural pruning uses two primary strategies: develop and maintain a single dominant trunk with smaller branches distributed horizontally and vertically around it; and reduce the likelihood of tree failure caused by defects in structure and poor weight distribution. Structural pruning slows the growth rate of large, aggressive, or long branches and thins uncharacteristically dense clumps of branches.

Removing growth primarily from the end of the largest diameter branches encourages other parts of the tree to grow larger. This treatment is called subordination, and it is the cornerstone of structural pruning. By using subordination treatments, branch size remains small, so cuts are small if the pruned branches are removed in the future. Once structural pruning is completed and while the arborist is still in the tree, additional pruning can be accomplished if needed for aesthetics and clearance provided the specified amount of foliage removal has not been exceeded.

Should All Trees Be Structurally Pruned?

The short answer is yes. There are, however, variations in how structural pruning is applied, depending on the mature size of the tree, tree age, its current architecture, species characteristics, and location in the landscape. The ideal condition of one dominant trunk with smaller branches distributed horizontally and vertically around it is particularly important for trees that become medium to large at maturity (e.g. oaks, *Quercus*). Trees must support heavy loads that include the branches, foliage, and in some cases vines, and also must hold up under external forces such as wind, rain, and in some locations, ice and snow.

Components of Strong Tree Structure

Introduction

Trees with strong structure are able to support the weight of the crown, even in most normal storm conditions. In contrast, trees with weak structure are more likely to fail, especially under storm conditions. Many planted trees develop defects or weaknesses if they are not structurally pruned correctly at planting and through the early to middle years. The larger the tree becomes at maturity, the more important strong structure becomes. Large trees support more weight and are exposed to larger forces from wind than are smaller trees because wind velocity increases with height above the ground. Larger trees also can cause more damage than small trees should they fail.

Natural Tree Form

Some tree species naturally tend to self-maintain a single central trunk from which smaller lateral branches arise. This growth pattern creates a cone-shaped tree that is called excurrent form. This type of structure tends to be strong and stable. Examples include conifers such as Canary Island pine coast redwood (*Sequoia sempervirens*) and Colorado blue sprune (*Picea pungens*), as well as hardwoods such as and London plane (*Platanus* × *hispanica*) and black gun (*Nyssa sylvatica*).

Other trees naturally tend to develop a round-headed, or decurrent, form. Many species that have decurrent form naturally develop clustered branches that grow upright or spreading and overtake or replace the leader; examples are oaks (*Quercus* spp.), pistache (*Pistachia chinensis*), jacaranda (*Jacaranda mimosifolia*) and maple (*Acer* spp.). Others tend to form branch attachments and codominant stems with inclusions that are prone to failure; these include red ironbark (*Eucalyptus sideroxylon*), trumpet-tree (*Tabebuia* spp.) and Bradford callery pear (*Pyrus calleryana*).

Left to grow in nature, the natural form of the tree will develop according to its genetic code and as well as in response to its environment. In a forest or woodland environment, trees competing for sunlight grow taller rather than wider. This commonly forces growth into one leader. Even species with decurrent form such as oaks (*Quercus* spp.), eucalyptus (*Eucalyptus* spp.) and elms (*Ulmus* spp.) tend to maintain a dominant central leader under such conditions.

Branches that are low in the crown are shaded out before they become long and heavy. Branches high in the crown compete with adjacent trees for space, which also limits how large these branches can become.

Open-grown trees tend to develop lower and larger branches than stand-grown trees, and the central leader may be lost as the largest-diameter branches (called scaffold branches) become dominant. Some of these branches rest on the ground, which helps stabilize the tree. In town, planted trees that are spaced well apart are similar to open-growth trees except that branches cannot rest on the ground, which results in unsupported wide crowns. Usually the planted trees are irrigated and fertilized, adding to their growth rate. This can become a problem because they may not have developed a strong enough framework to support large, wide crowns. If the loads from wide, exposed crowns are larger than the strength of the framework, the tree will fail. Structural pruning to develop a stronger framework and manage weight will reduce the incidence of failure.

The difference in form of a tree in a typical urban landscape from its form in its native habitat is a result of its growing and cultural conditions in the nursery combined with subsequent pruning in the landscape. Tree form is controlled during nursery production to create a symmetric, dense crown on a single trunk that is considered attractive and marketable. If nursery-grown trees with poor structure are planted, they often continue to have poor structure as they age because new wood builds on top of existing wood. These trees must be regularly pruned for several years after planting to correct structural problems before reaching middle age. It is best to plant trees that have been grown with good structure. Selecting tree stock grown in accordance with the *Guideline Specifications for Nursery Tree Quality* (see http://www.urbantree.org/specs.asp) specifications ensures that trees start with good structure.

Characteristics of Strong Structure

Several attributes contribute to structural strength. These are addressed by structural pruning when necessary.

Number of Trunks

Trees with a dominant leader extending well up into the crown are strong and have a durable form. The leader may or may not be straight. Trees with two or more main stems with similar diameters (codominant) are weaker and less durable than is a single trunk with smaller-diameter branches. Certain trees with more than one main stem can be fairly stable. Trees with a small stature such as redbud (*Cercis occidentalis*) can be grown with the structural issues commonly associated with large trees because there is little mass associated with these small trees.

Branch Aspect Ratio

The size of a branch relative to the trunk or parent branch, known as the branch aspect ratio, is extremely important because of its effect on how the branch and trunk are held together. Branch aspect ratio is determined by calculating the ratio of the diameter of the branch to the diameter of the trunk. For example, where a 3-inch branch is growing from a 6-inch trunk, the aspect ratio is 1:2 ($3 \div 6 = 0.5$, or 50 percent).

Branches with a small aspect ratio (e.g., 30 percent) are more strongly secured to the trunk than are those with a large ratio (e.g., 70 percent) because the trunk and branch wood overlap with each annual growth increment (ring). When trees are young and adolescent, branch aspect ratio is a prime indicator of where future growth will occur—that is, on branches with the largest ratio. When branches are much smaller in diameter than the trunk (e.g., 30 percent) a natural protective region called a branch protection zone develops within the branch base that extends inside the trunk. This unique zone of cells resists the passage of decay organisms into the trunk when the branch dies or is removed. The branch protection zone does not develop on branches with a large aspect ratio (e.g., 70 percent).

Branches: Why size and placement matters

Strong branch attachments develop when the annual growth rings (wood) of the trunk and branch overlap, creating laminated, dowel-in-post-type of structure. The result is development of an enlarged area at the base of the branch called the collar. A branch protection zone that limits the spread of decay from the branch into the trunk forms within the collar.

Strong branch attachments, collars, and branch protection zones are most likely to develop where

- the size of the branch is less than one-half the diameter of the parent stem (branch aspect ratio less than 50%);
- a single branch rather than several branches arises at one location; and
- bark is not included in the attachment.

Branch Spacing

Branches spaced along and around the trunk are better connected to the tree than are branches clustered together that originate from one position). Where several branches arise at one point on the trunk (multiple attachments), there is not enough space for trunk wood to wrap around the base of each branch in the normal fashion. The branch attachment is therefore weaker, and there is a greater likelihood that one or more of the branches will fail. A clustered branched arrangement can also lead to poor growth in the leader because resources from the roots are diverted into the large branches at the cluster. Wood cannot properly wrap around the branch bases to reach the leader.

For small-statured trees, vertical branch spacing can be 6 to 8 inches apart. For medium-height trees (less than 40 feet at maturity), 1 or 2 feet between branches may be adequate; for large trees, 4 or more feet is considered ideal.

On excurrent trees like white alder (*Alnus rhombifolia*), Baldcypress (*Taxodium distichum*) and most conifers, vertical spacing is less critical because the branches usually have a small aspect ratio. Little or no pruning is needed except when an occasional limb becomes overly vigorous and competes with the leader.

Bark Inclusions

Strong branch unions develop where trunk wood wraps around the base of a branch, sometimes forming the visible swelling, or collar when the aspect ratio is small. Collars rarely form on branches with a large aspect ratio. Bark sometimes becomes included (i.e. squeezed or embedded) within the union instead of growing on top of it. The naturally strong connection cannot form, resulting in a weak attachment. Inclusions in unions are among the most severe branch defects; the form of inclusion varies considerably from species to species or even from branch to branch within a tree. Inclusions on codominant, large, and long branches are of greatest concern because the mechanical stress from the heavy load being supported by the weak union is likely to result in failure.

Branch Orientation

Upright branches on some species grow more vigorously than do horizontally oriented branches. Branches on open-grown trees originating from low on the trunk often grow large in diameter, are long, and can make up a large portion of the crown. Vertical branches are also more prone to forming bark inclusions in the union when they grow at an acute angle with the trunk. Branches with an upright orientation may become long and heavy enough to bow outward, away from the central leader, because they are not strong enough to support the increasing weight of the branch. Such branches are more likely to fail during loading by wind, rain, snow, or ice.

Large branches low on the trunk may be oriented horizontally for a certain distance but eventually sweep upward, often at the edge of the crown. These branches may develop an aspect ratio greater than 50% and comprise a large portion of the total crown. They are subject to failure when pushed toward or away from the trunk, a pattern called a hazard beam. Branches that form dips can crack if they grow too long or are subject to excess loads from wind, snow or ice. The strongest condition is where branches have a consistent orientation, recognizing that some branches tend to become more horizontal over time. Some horizontal branches can become too long and break under their own weight.

Trees with several trunks or large stems and with most branches growing upright and then spreading are generally less resistant to breakage in storms than are those with one trunk and mostly horizontally oriented branches.

Branch and Trunk Taper

A well-tapered branch or trunk decreases in diameter with length or height. Taper allows distribution of mechanical stress over the length of the branch or trunk. Long branches with poor taper are more likely to break than are branches with good taper because branches with good taper are stronger under dynamic loads caused by wind. Good branch taper is fostered by maintaining foliage and smaller lateral branches along the length of the branch or trunk.

Structural Defects Caused by Pruning

Certain pruning practices create or encourage structural defects, such as when trees are pruned solely for clearance, crown cleaning, or thinning, without regard for structure.

Lions-Tailing

One of the worst ways to prune trees is by removing interior and small lateral branches from main scaffold branches, leaving foliage only toward the ends of the branches. This is called lions-tailing, also known as over-lifting, over-raising, over-thinning, cleaning out, stripping out, lacing out, gutting out, and skinning out the crown. It is an incorrect and substandard pruning practice that must be avoided.

One of the biggest problems caused by lions-tailing is that it usually results in branches that grow long and with poor taper. It shifts future growth to the ends of branches rather than along the length of the branch. Because of poor taper and foliage concentrated at the ends, lions-tailed branches are more prone to failure than are branches with foliage retained along their length. Lions-tailing also shifts the center of gravity higher, where wind speed is greater. It creates substantially weakened branches that may break easily in storms or under their own weight.

Trees pruned in this manner are also extremely difficult to restore after storm damage because there are few interior branches to assume the role of the damaged branch ends. For the same reason, it is difficult to reduce lions-tailed branches to manage risk because there are few lateral branches for making reduction cuts.

Excessive Crown Thinning

Excessive thinning typically removes one-third or more of the foliage throughout a tree. The effects are similar to lions-tailing. Problems created by this substandard pruning include creating many pruning wounds on branches that could lead to decay or disease, exposing previously shaded branches to strong light and sunburn, and temporarily increasing wind or snow loading on retained branches. These potential issues can be more problematic on certain species.

Excessive Crown Raising

Removing low branches shifts future growth into the existing branch structure in the middle and top of the tree. This perpetuates formation of weak structure that can result in breakage, or the tree will require a larger pruning dose later in the tree's life. Over-raising trees has the same effect of pushing growth higher into the tree. Wind speed increases with height above the ground; with no low branches, crown movement at the top of the tree cannot be counteracted, or dampened, by the missing lower branches. The result can be more damage to the tree in storms. Removing too many lower branches can also result in sunburn on the lower trunk of certain trees with thin bark, reduce the taper of the trunk, cause the crown to become unbalanced, and cause uncharacteristic sprouting on the trunk and remaining branches. When raising the crown of a tree past what is considered ideal because of its position in the landscape, it is best to do so over time. Structural pruning is recommended in conjunction with raising.

Topping

Unfortunately, the trunk and large-diameter branches are sometimes pruned using only heading cuts to reduce a tree to a desired size. This practice is referred to by various names including topping, tipping, hat-racking, stag-heading, de-horning, lopping, and rounding over. It is not recommended because it damages trees permanently by compromising structure, health, and aesthetic value.

Lack of Structural Pruning

When decurrent trees are left to grow without structural pruning they often develop large-diameter branches originating low in the crown. Other defects that may form include codominant stems; large branches low on the trunk that droop and become obstructions; and large, vigorous branches low on the trunk that compete with the leader or extend outside the crown. Branches that develop a large aspect ratio become a major part of the crown, and their attachment may be weaker than branches with a small ratio. These should be the focus of pruning efforts early in the tree's life.

Branches are like levers, with the hinge point near the point of attachment to the trunk. Large, long branches usually experience large mechanical stresses in their middle and basal sections. These branches are among those most likely to break, and depending on their position in the tree, they can lead to long-term clearance and management challenges.

What happens when trees are not structurally pruned?

- poor crown structure;
- cracks and decay in wood;
- split trunk or branch unions;
- broken branches;
- low, large branches that block access and must be removed;
- decay enters large pruning wounds on the lower trunk;
- shorter tree life;
- could increase cost of maintenance; and
- risk to people and property.

Another problem with retaining large-diameter branches low in the crown on trees in urban settings is that it is difficult to raise the crown to provide clearance. Raising the crowns of these trees by removing secondary branches from the large low branches provides only partial, temporary clearance and can result in overextended, weak branches. Sprouts will grow in the lower pruned section of the tree and will again obstruct passage and views. Removing one or more of these large branches can create a void in the crown that would be objectionable and also creates a large wound. Branches like this should have been removed or subordinated when the tree was young, before they developed a large aspect ratio and before they became a large part of the crown.

The preferred strategy is to structurally prune early and consistently suppress growth of lower branches that will eventually be removed (temporary branches) and those that compete with the leader. No single branch should support a large portion of the crown. By keeping low branches small in diameter (small aspect ratio), it is easier to raise for clearance and visibility when the tree grows larger and the low branches are no longer needed. Crews can quickly remove lower branches because of their small aspect ratio, creating a small amount of debris while minimizing the size of the pruning wound. These small wounds result in little, if any, decay in the trunk.

There is no substitute for the arborist’s objective observation and experience in the field. Talking with arborists about their experiences is invaluable. A good method of learning more about tree defects and structural weakness is to examine failed trees.

- Determine what may have caused the failure and discuss with colleagues how pruning earlier in the life of the tree could have prevented it.
- Pay particular attention to defects known to cause weakness.
- Consider what pruning treatments could have reduced stress on the weak area or, over time, created a stronger structure.
- Apply those treatments to trees pruning and watch how the trees respond over a period of years.