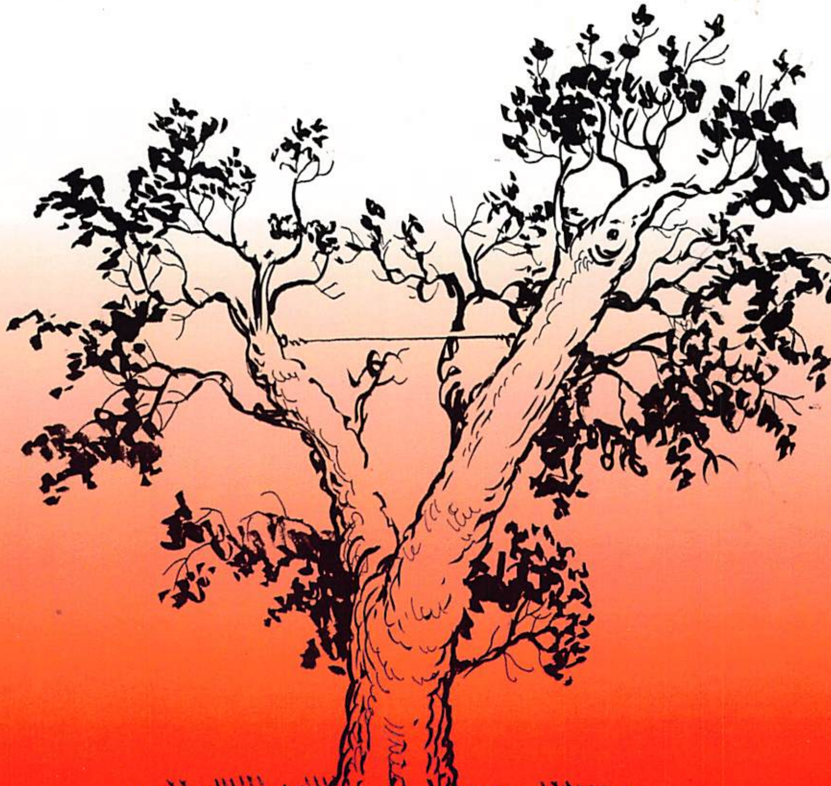
Best Management Practices

Tree Support Systems: Cabling, Bracing, Guying, and Propping

Third Edition



Special companion publication to the ANSI A300 Part 3: Tree, Shrub, and Other Woody Plant Management—Standard Practices (Supplemental Support Systems)

Best Management Practices

TREE SUPPORT SYSTEMS
Cabling, Bracing, Guying, and Propping
Third Edition 2014

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Special companion publication to ANSI A300 Part 3 (2013), Supplemental Support Systems

ISBN: 978-1-881956-85-3

ISA
International Society of Arboriculture

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Printed by Martin One Source, Champaign, Illinois, USA

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0821/CA/450

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Purpose

The International Society of Arboriculture (ISA) has developed a series of Best Management Practices (BMPs) for the purpose of interpreting tree care standards and providing guidelines of practice for arborists, tree workers, and the people who employ their services.

Because trees and other plants are unique living organisms, and they—as well as the ecosystems in which they live—are variable by nature, not all practices can be successfully applied in all cases. A qualified arborist should write or review contracts and specifications using national standards and this BMP. Departures from the standards should be made with careful consideration of the objectives and with supporting rationale.

This BMP is for the selection and application of support systems for trees and shrubs. It also serves as a companion publication for the supplemental support systems portion of the 2013 *American National Standard for Tree Care Operations—Tree, Shrub, and Other Woody Plant Management—Standard Practices (Supplemental Support Systems)* (A300 Part 3).

Introduction

Tree failures are often associated with defects or conditions that weaken tree structure. When tree failure is likely to impact a target and cause damage, it might be necessary to recommend tree removal, extensive pruning, or the installation of a tree support system to reduce risk. Of these three general risk mitigation options, installing a support system will often have the least impact on tree health, aesthetics, and function in the landscape. It is important to keep in mind, however, that not all risk can be mitigated by installation of a tree support system.

Tree support systems can be divided into four general categories: cables, braces, guys, and props. Cables are steel or fiber ropes installed between branches within a tree. Braces are metal rods installed through branches or stems. Guys are wires, ropes, or webbing installed from a tree to an external anchor. Props are rigid structures installed beneath a low branch or trunk.

Tree support systems are used to provide supplemental support to leaders, individual branches, and/or entire trees. Cables, braces, guys, and props provide supplemental support by limiting the movement of the branches, leader, or an entire tree. It is essential that each tree be examined carefully by a qualified arborist prior to the specification for, and installation of, any support system. It is critical to ensure that the system will achieve its objective of providing added support without increasing the risk of tree failure by changing the dynamics of the tree.

A common structural condition with a high risk of failure is a codominant stem, or weak junction often referred to as a "V-crotch" (Figure 1). Because of the lack of sufficient direct structural connections between codominant stems, they are structurally weaker than a single stem or normal branch union, especially if bark is included between two or more stems. These unions may fail when pulled directly apart or when moved to the side (shearing).

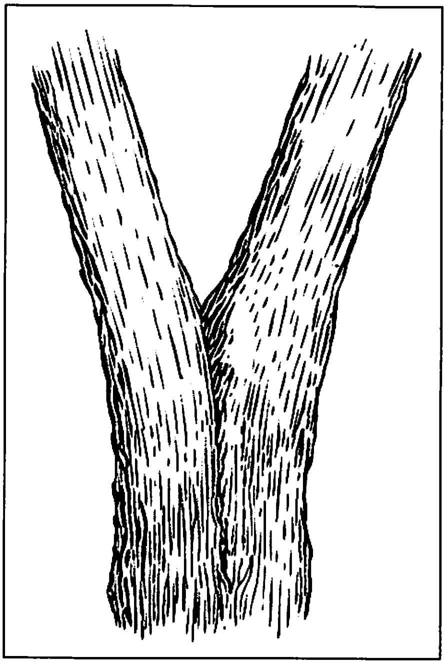


Figure 1. Codominant stems can have a high risk of failure, especially if there is included bark or a crack at the union.

Another common condition with a high risk of failure occurs with long, heavy, poorly tapered, or "overextended," branches. Overextended branches grow outside of the main crown, are unusually long for the tree species, and often have the majority of their foliage concentrated toward the end of the branch. Failure of these branches may occur at the union with the stem or by breakage across the branch (particularly at defects), or they may split as a result of excessive tension forces on the top and compression forces on the bottom of the branch. Splits usually occur when there is heavy loading, such as from snow or ice, or during a strong wind (Figure 2). Cables or props can be used to reduce the risk of breakage and/or to keep branches off the ground, above pedestrians' heads, or away from structures.

A third common defect is the weakly anchored tree. This condition exists when a tree is transplanted with a substandard root ball, has uprooted, has defective roots because of damage or decay, or has another condition, such as wet or shallow soil, that results in poor root anchorage. Guying or propping systems may reduce the risk of failure in these situations.

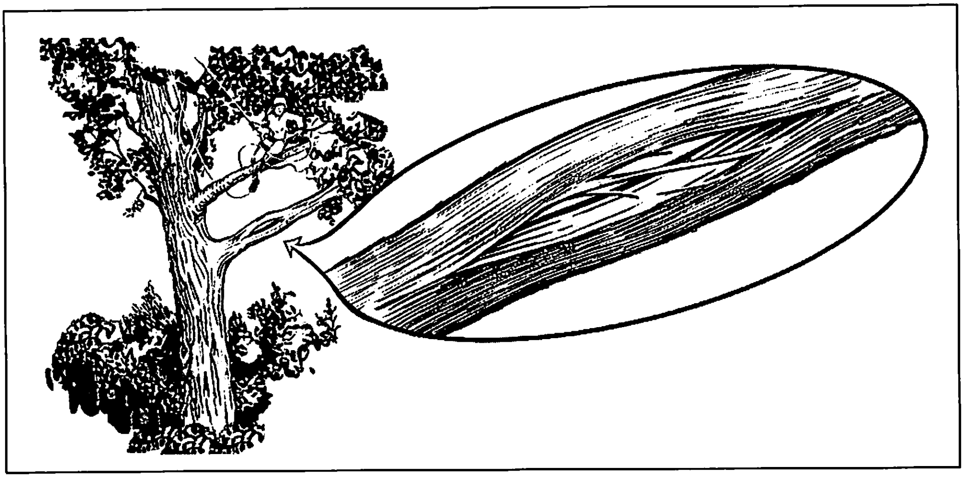


Figure 2. Crack at the neutral plane between the compression and tension sides caused by an excess load.

In each of these cases, pruning or removal should also be considered. For young trees, pruning is the preferred method to eliminate codominant stems. The codominant stem may be removed entirely or it may be subordinated. Pruning may remove structural defects or reduce the load on tree parts with high risks of failure. On larger, mature trees, the combination of pruning and a support system may reduce the risk of failure.

Removal may be the preferred risk mitigation option for trees with extensive decay, damaged root systems, or other conditions that result in high or extreme risk. Support systems may reduce the potential for failure, but they cannot eliminate it.

All support systems have a limited service life. Steel cables may be effective for 20 to 40 years in an arid climate or with a slow-growing tree, but in an area exposed to salt spray or with a rapidly growing tree, cable service life could be much shorter. The service life of synthetic-rope cabling systems is shorter because they deteriorate in sunlight.

Bracing materials are more likely to have an extended service life (because they are heavier and often protected inside the tree) but can become undersized in a rapidly growing tree.

Guy systems on newly transplanted small trees should normally be removed after one year unless a problem exists with the root system. On trees uprighted after storms or for large transplants, guys should remain in place for three years or more until it can be determined that the root system has re-established. On mature trees, a permanent guy or propping system may be required. Their service life is similar to cables, and they require replacement when worn or corroded. Maintenance or replacement of steel or wood support props is necessary if wood decay compromises the strength of the prop, if the prop leans excessively, or if the growth of the tree is affected by the prop.

A qualified arborist should write specifications that will guide the installation of tree support systems. Specifications for a supplemental support system should include the support method (cabling, bracing, guying, propping), its location, and the hardware to be used. The hardware specifications should include the type, number, and sizes of components.

The client should be informed of the limitations of support systems: that they reduce but cannot eliminate risk, and they require periodic (ground and/or aerial) inspection of the tree and support system by a qualified arborist. Unless otherwise specified in a contract or other document, the client is responsible for scheduling inspections, but the arborist should suggest appropriate inspection intervals based on tree species and condition, inclement weather, support system type, and materials used.

I. Safety

Tree management, especially practices that involve working aloft, such as the installation of support cables, should be performed only by arborists who have the training, equipment, and experience to complete the work safely and according to specification. All work must be performed following applicable safety standards and regulations.

The tree and work site must be inspected for visible hazards before beginning any work. The location and types of equipment used should be considered and discussed as part of the job briefing, and appropriate safe work practices must be planned to mitigate anticipated risks. Possible above- and belowground obstructions (e.g., utilities) should be considered before implementing any arboricultural operations.

While the system is being installed, the tree worker may find additional defects or conditions that could increase the likelihood of failure. These conditions must be reported to the responsible authority, usually a supervisor, the arborist, and/or the client. Such defects may require additional remediation efforts, such as pruning or cabling, or even removal of the entire tree.

Cables that are under tension should never be cut as a result of the potential for branch failure and/or recoil of the severed cable. When cables that are under tension must be removed, the tension should be removed first by bringing the branches closer together using a come-along or other device and providing temporary support using a rope or strap. The temporary system should be designed to allow for controlled, slow release of tension to enable continual monitoring of tree and hardware components.

2. Installation Tools

A wide selection of hardware and materials is used for tree support systems. The tools used depend on the type of system, hardware and materials used, size of the tree or tree parts to be supported, and preference of the installer. Commonly used tools include the following.

Cable Aid

A cable aid is a device designed to turn lag hooks. It can also be used to aid in attaching dead-end grips (Figure 3).

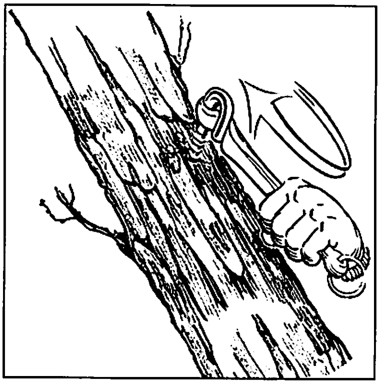


Figure 3. Cable aid used to turn lag hooks and attach dead-end grips.

Cable Puller (Grip)

Cable pullers are used to temporarily attach a rope or come-along to a cable. There are two types of cable pullers: one for common-grade, galvanized cable, called a Haven grip; and one for extra-high-strength (EHS) cable, called a Chicago grip (Figure 4). The Haven grip slightly bends the cable, which could lead to premature failure if incorrectly used on EHS cable. The Chicago grip pulls in a straight line, thus avoiding this problem.

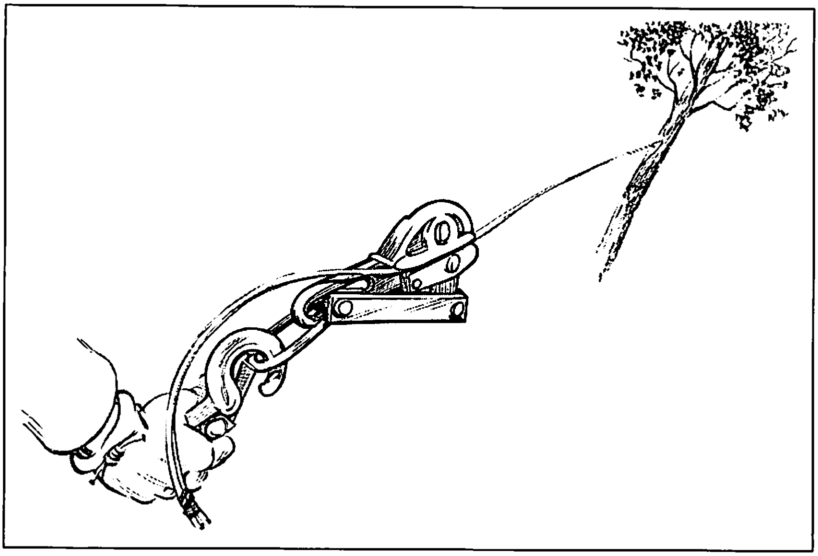


Figure 4. Chicago grip used to pull extra-high-strength (EHS) cable.

Come-Along/Block and Tackle

When it is necessary to bring branches closer together, a rope or wire come-along, block and tackle, or other mechanical advantage system can be used. A come-along is a manually operated, winch-type device. If a come-along or block and tackle is used, the tree should be protected by using slings as attachment points.

Cutting Tools

A hacksaw or a cordless electric reciprocating saw can be used for cutting rods and eye bolts. Bolt cutters or guy strand cutters are used to cut cables. Some guy strand cutters have a safety latch that fits over the cutting jaws to prevent user injury from the recoil of cut cable. Linesman's pliers are flat-tipped pliers used to bend individual cable strands when forming an eye splice in common-grade cable and to cut off the excess portion of the strand after wrapping.

Drills

Four types of drills are typically used for installing support-system hardware: hand-powered braces, cordless electric drills, corded electric drills, and gasoline-powered drills. Braces are lightweight, durable, inexpensive, and dependable. They are preferred by some arborists for installing hardware in small and medium-sized trees or branches.

Cordless electric drills, 18 volts or higher, do an excellent job of boring shallow or medium-depth holes for lags and eye bolts. They are moderately priced and medium weight. Little maintenance is required, but spare batteries should be carried as backup.

Corded electric drills are heavier and require more setup time and a power source, but they provide much more drilling power and unlimited run time. Lag-threaded rods, up to the capacity of the drill chuck, can be fastened into the chuck of most drills and driven into the tree. Custom adapters can also be fashioned to drive lag-threaded or machine-threaded bolts. High-torque electric drills usually have slower speeds to make this operation safer and easier. Higher-speed electric drills should not be used for large-diameter drilling or driving operations.

Cords on electric drills should be treated with great care to avoid accidental damage and potential electrical shock. In the United States, corded electric drills should be used in accordance with the ANSI Z133 safety standard for arboricultural operations. Power cords must be of sufficient capacity for the power draw (amperage) of the drill and the distance to the power source. Cords with insufficient capacity result in decreased drill torque, decreased drill motor life, and overloaded fuses or circuit breakers at the power source.

Gasoline-powered drills work well for many installations. As with electric drills, lag-threaded rods can be fastened into the chuck of most gas drills and driven into the tree. It is important to use a model that is reversible to avoid getting bits and hardware stuck in the tree.

It may be preferable to independently suspend gasoline and corded electric drills in the tree when drilling long holes for brace rods so that the drill bit does not bend. A drill heavier than 15 pounds (6.8 kg) should be tied into the tree on its own line, separately from the climber.

Drill Bits

Ship auger or wood auger drill bits are most commonly used for boring holes to install bolts or lags. Ship augers are designed to cut green wood; they have a single cutting edge and no cutting spur. They cut cleanly and quickly by rapidly removing chips through the hollow center (Figure 5).

Single- and double-spur, solid-center augers are acceptable for smaller-diameter holes and relatively short drilling lengths to install lags or short bolts. Drill bits should be sharp; they will not cut straight if dull or damaged. For bracing, extremely long bits are often needed. Long bits or extensions can be purchased through arborist supply stores, or a steel rod can be welded onto the bit.

When long brace rods are being installed, a progression of drill-bit lengths can assist in maintaining straight hole alignment and reduce the potential for bit breakage. A typical progression is in 2- to 3-foot intervals (60 to 90 cm). Use of a nonphytotoxic lubricant, such as vegetable oil, and frequent withdrawing of long bits can reduce the potential for a bit to become stuck in the tree trunk while also reducing the load on the drill. Flat-spade bits are not generally recommended for arboricultural work. If they are used, however, they should be completely straight. If a flat-spade bit is even slightly bent, it will cut oversized (often somewhat triangular) holes, which will affect the holding power of anchors.

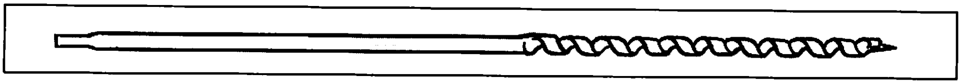


Figure 5. Ship auger drill bit used to drill live wood.

Selecting the correct size of drill bits for the hardware and application is a critical aspect to the strength of hardware systems installed in trees. Selection of the drill-bit diameter depends on the type of anchor or rod, as well as the characteristics of the wood. When machine-threaded rods (through-bolt installation) are installed, the drill-bit diameter should be equal to or slightly greater than the rod diameter (Table 1). With lag-threaded hardware (dead-end installation), the hole must be smaller than the hardware so the threads can "bite" into the wood. When a system that terminates in a cable stop is being installed, the drill-bit diameter should be slightly larger than the cable diameter.

Flat-bottom drill bits, such as Forstner bits, can be used for countersinking through-bolt hardware in thick bark.

Table 1. Recommended drill-bit sizes for dead-end (lag) and through-bolts installed in most tree species.

Hardware diameter in inches (mm)	Diameter of the hole drilled in the tree, in inches (mm) for	
	Dead-end installation	Through-bolt installation*
1/4 (6.4)	3/16 (4.8)	1/4 (6.4)
3/8 (9.5)	5/16 (7.9)	3/8 or 7/16 (9.5 or 11)
1/2 (13)	3/8 (9.5)	9/16 or 5/8 (14 or 16)
5/8 (16)	1/2 (13)	3/4 or 11/16 (17 or 19)
3/4 (19)	5/8 (16)	13/16 or 7/8 (21 or 22)
7/8 (22)	3/4 or 11/16 (17 or 19)	15/16 or 1 (24 or 25)
1(25)	13/16 or 7/8 (21 or 22)	1-1/8 (29)

*With species such as ash (*Fraxinus* sp.), which tend to close holes rapidly, use the larger drill-bit size.

Hammers

A ball peen or other hammer can be used to peen (deform) the last set of threads at the end of through-bolt hardware after installation to prevent the nut from backing off, to drive through-bolt hardware through a hole if necessary, or to strike a chisel or gouge when countersinking in thick bark.

Rod Driver

A rod driver is a threaded cap-like device used to aid in driving long sections of threaded rod. One end of a rod driver screws over the end of a threaded rod, and the other end is chucked into a power drill. The power drill is then used to screw the rod into the tree. This protects the thread from damage and allows power driving with a drill chuck too small to accept a large-diameter rod. A matching driver is required for each rod diameter and thread type.

Swaging Tool

A swaging tool is a long-handled plier-like tool used for securing swage sleeves onto wire rope.

Tool Bucket or Bag

To hold the necessary tools and materials aloft, a linesman's canvas tool bucket or other suitable lightweight bucket or bag is typically used.

Torch

A propane- or butane-powered torch melts the ends of synthetic rope used for tree cabling. Pocket-size, self-igniting torches are preferred.

Wrenches

Wrenches are used to turn nuts on all through-bolt installations. An adjustable wrench or box wrenches of the correct size for the nuts can be used. A ratchet wrench to allow rapid tightening of nuts in confined quarters (Figure 6) may be preferable for eye-bolt or rod installation. A ratchet wrench that allows the bolt or rod to pass through it is more useful than an ordinary socket wrench. A pipe wrench can be used for installing a lag-threaded, dead-end brace, but caution must be taken to avoid damaging threads.

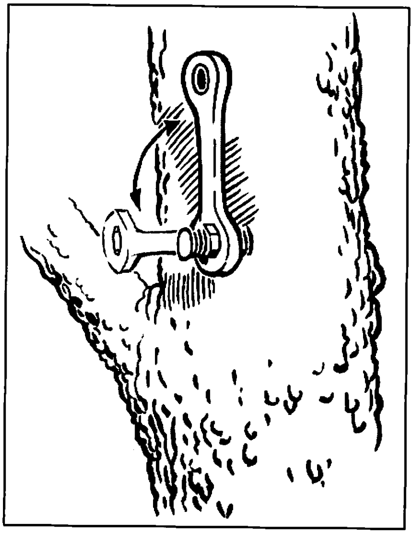


Figure 6. Ratchet wrench used to rapidly tighten nuts on long bolts or in confined spaces.

Hardware

Various pieces of hardware are used in support systems. The hardware installed should be resistant to weathering or treated with a weather-resistant coating.

Steel hardware should be stainless, galvanized, or painted to reduce the potential for rusting. Synthetic ropes used in cabling should be treated to resist ultraviolet (UV) degradation; resistance to squirrel and bird feeding would also be beneficial. Wooden supports used for propping should be treated to resist rotting.

3. Cabling

Cables are installed to restrict the distance that branches can move in relation to each other. Installed across a weak junction, they can greatly reduce the risk of failure. Installed on overextended branches, cables can carry some of the load when the branch moves excessively. Cables should be strong enough to support the weight of the branch if it were to fail so that the likelihood of impact and/or consequences of failure are reduced.

At a minimum, cable systems consist of an anchor, a cable, and the appropriate means of termination or of connecting the cable to the anchor. Because one cable will not necessarily protect a branch from twisting or shearing off at the union, it is sometimes necessary to install more than one cable or a system of cables and brace rods. The objective of the installation must be clearly defined before a cable is installed.

Cabling alters the way a tree moves and the accompanying stresses, so additional cables and/or pruning may also be required to offset these changes. For example, a single cable may require an opposing cable from the anchor point to avoid overloading the anchoring stem or branch.

Placement and Number of Cables

Cable anchors are installed about two-thirds the distance from the branch union to the ends of the branches or leaders (Figure 7). Exact placement depends on the location of lateral branches and defects. At the point of cable attachment, branches or leaders must be large and solid enough to provide adequate strength for the added load. Installing cables farther from the junction can theoretically increase system strength, but much farther than two-thirds the distance might result in cables attached to branches that are too small to hold anticipated loads. When anchor locations are being selected, it is important to avoid branch unions with decay, sharp bends, or other defects.

Installing the cable directly across the union being supported will maximize support. The correct angle of the cable is perpendicular to an imaginary line that bisects the angle between the branches being cabled (Figure 8). Cables are installed taut—that is, with the minimum tension required to eliminate visible cable slack.

When selecting the number of cables, it is most important to look at the tree's needs rather than selecting a predesigned system type. A tree with codominant stems is the most common case where a cable is required, generally a single, direct cable. If the union has a split, decay, or other defect, installing a brace in addition to the cable should be considered.

If more than two stems or branches require cables, more complex systems may be required. The closer to "directly across" the union the cables are installed, the less movement will be allowed in the union, minimizing the chance of breakage.

In addition to direct cables, other systems include triangular, box, and hub-and-spoke (Figure 9).

Triangular systems connect branches in groups of three. This method is applied when maximum direct support is required.

Box systems can be used to connect four or more branches. This system provides minimal direct support, thus allowing more branch movement than with direct or triangular systems.

Hub-and-spoke systems consist of a centrally attached steel-ring hub with cables radiating from it to three or more branches. These systems are installed when there is no usable central leader or when there is a need for many cables. The central anchor point may allow for a reduced number of cables. Hub-and-spoke systems tend to be more difficult to install because the tension of each cable must be adjusted independently.

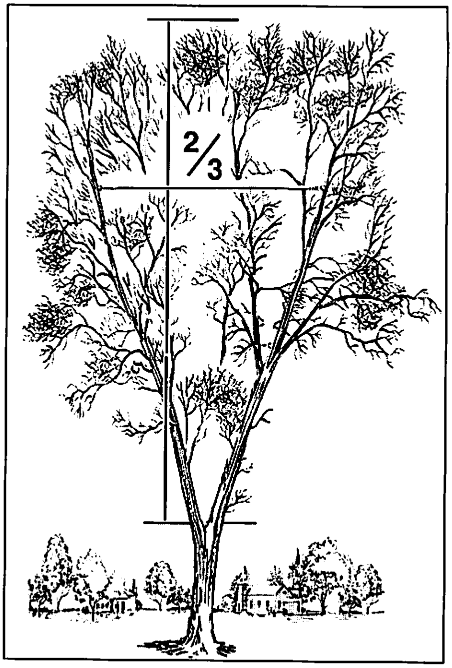


Figure 7. Cable anchors are installed two-thirds the distance from the union to the ends of the branches. The placement depends on the branch size and configuration.

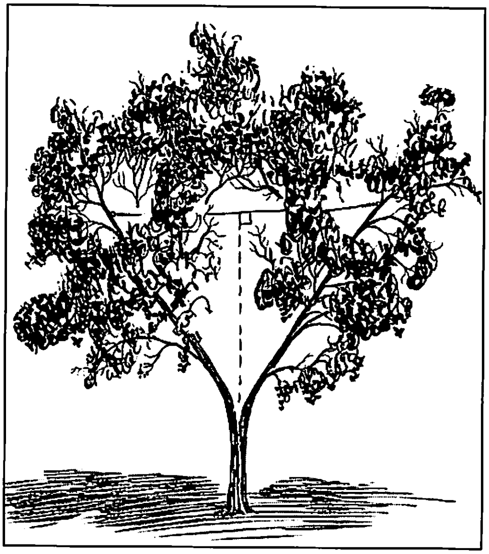


Figure 8. The cable should be installed perpendicular to an imaginary line that bisects the union.

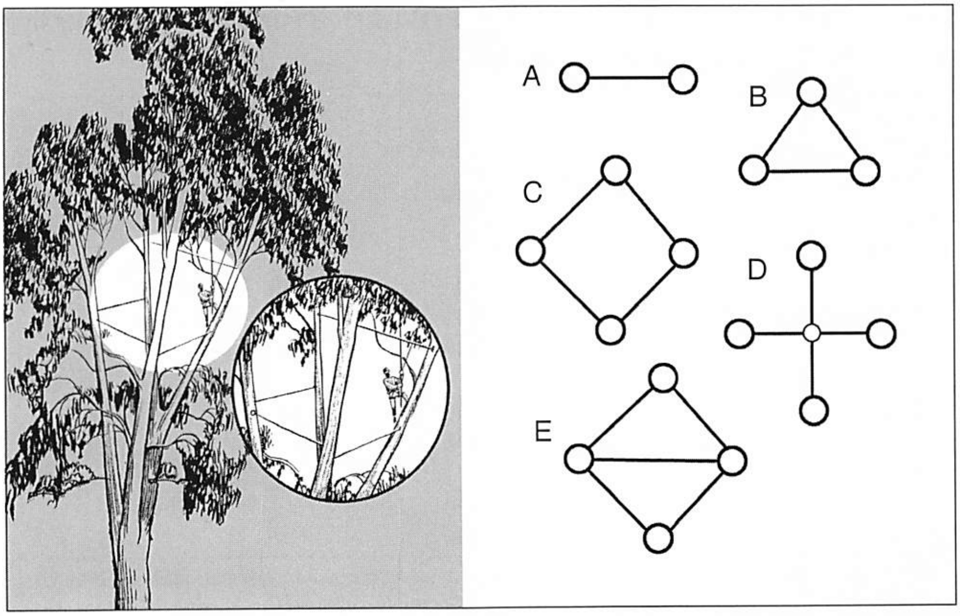


Figure 9. Configurations of commonly used cable systems. A) direct cable, B) triangular, C) box, D) hub and spoke, E) triangular.

Static (Steel) Cabling

Anchoring Steel Cables

Steel cables are anchored to branches with eye bolts, amon-eye nuts on threaded rods, lag hooks (J-lags), lag eyes, or cable-stop termination devices. Lags (Figure 12) have the least strength and holding power (Table 2), and they are restricted from use in decayed wood and branches greater than 10 inches (25 cm) in diameter. Because of these limitations, eye bolts or threaded rods with amon-eye nuts or cable-stop termination devices are the preferred type of anchor for most steel cables (Figure 10).

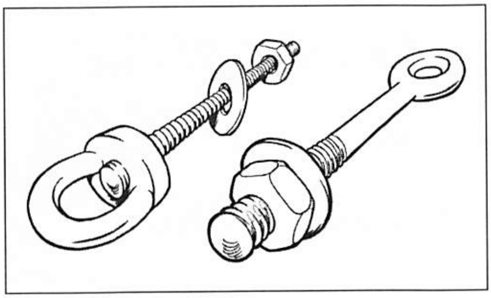


Figure 10. Threaded rod with amon-eye nut (left); eye bolt (right)

Eye bolts can be installed in decayed branches if the decay does not exceed 70 percent of the diameter of the branch. The remaining 30 percent of solid wood should be nearly equally distributed around the branch. If the side of the branch where the nut will be attached has less than 15 percent solid wood thickness, another location in the tree should be found for anchoring

Table 2. Approximate working-load limit (WLL)* of various components in tree support systems (in pounds).

Hardware diameter in inches (mm)	Eye bolts	Lag hooks	Amon-eye nuts	Common galvanized cable	EHS cable
1/8 (3.2)				108	
3/16 (4.8)				230	798
1/4 (6.4)	550	100	520	380	1330
5/16 (7.9)	850	200	840	640	2240
3/8 (9.5)	1250	300	1240	850	3080
7/16 (11)			1700	1140	4160
1/2 (13)	2250	600	2400	1480	5380
9/16 (14)					
5/8 (16)	3600	900	3600		
7/8 (22)	7200		7200		

*Working-load limit is defined as the breaking strength, as determined by the manufacturer, divided by a design factor. For this table, the design factor was assumed to be 5:1, or 20 percent, of the breaking strength.

†Cobra is constructed of polypropylene rope.

‡TreeSave is constructed of polyester or high-molecular-weight polyester (HMWPe) with or without a core. Shown in parentheses are TreeSave diameters (given in millimeters) and tensile strength (in 1,000 pounds).

the system. If a branch does not have sufficient solid wood for the installation of support hardware, consideration should be given to installing a synthetic cable system, pruning, or removal (Figure 11).

Eye bolts should be drop-forged rather than circular bent because of the higher strength of forged eyes. They are installed in holes equal to or slightly larger than the bolt (Table 1). Using an

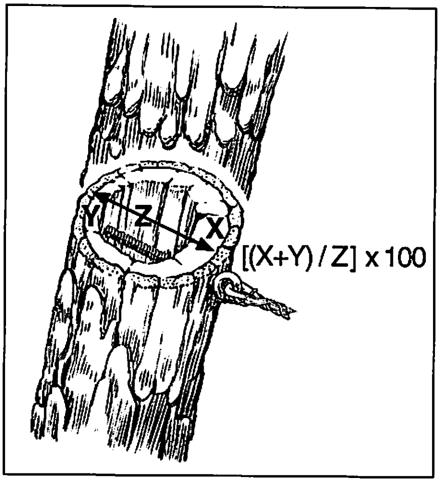


Figure 11. Branches or trunks with less than 30 percent solid wood {[(X+Y)/Z] x 100} should be removed rather than cabled or braced.

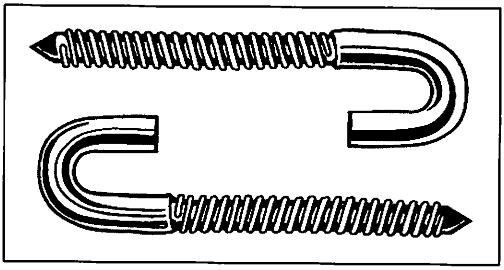


Figure 12. Left- and right-hand threaded lag hooks.

Wire rope (aircraft cable)	Polypropylene rope†	Polyester HMWPe‡	Turn-buckles	Compression springs
400				
840				
1400				
1960				890
2880	220	(10/5) 1000 (10/20) 4000	1040	1247
3900				1620
5000	880	(13/11) 2200	1960	2020
8000				
	1760		3160	

eye bolt several inches longer than the diameter of the branch allows room for adjusting the tension of the cable. If a large-diameter anchor is installed in a small branch, there will be an increased chance of branch breakage. If too small of an anchor is installed, tension from the cable might break or pull out the anchor. Minimum and maximum sizes of branches for anchor installation are specified in Table 3.

Anchor hardware must be installed in direct line with the cable (Figure 13). An off-center pull (side loading) on anchors greatly increases the likelihood of anchor failure from metal fatigue or hole elongation.

Table 3. Minimum and maximum diameters of branches for eye-bolt installation.

Eye-bolt diameter in inches (mm)	Minimum branch diameter in inches (cm)	Maximum branch diameter in inches (cm)	Maximum commonly available length in inches (cm)
1/4 (6.4)	1.5 (3.8)	5 (12.7)	4 (10.2)
5/16 (7.9)	2.0 (5.1)	8 (20.3)	4 (10.2)
3/8 (9.5)	2.25 (5.7)	18 (45.7)	6 (15.2)
1/2 (13)	3 (7.6)	24 (61)	18 (45.7)
5/8 (16)	3.75 (9.5)	28 (71.1)	24 (61)

To aid in aligning the second hole drilled at the other end of the cable for eye-bolt installation, a laser pointer can be inserted into the first hole and then the installer can sight through the drilled hole to identify the spot to drill the second hole. To avoid bending the anchor, only one cable shall be attached to an anchor.

To avoid the risk of wood splitting, when more than one anchor is installed in a branch, the anchors should be no closer together than the diameter of the branch (Figure 14), or with a separation of 12 inches (30 cm), whichever is less. Anchors should not be installed in the same direction of pull.

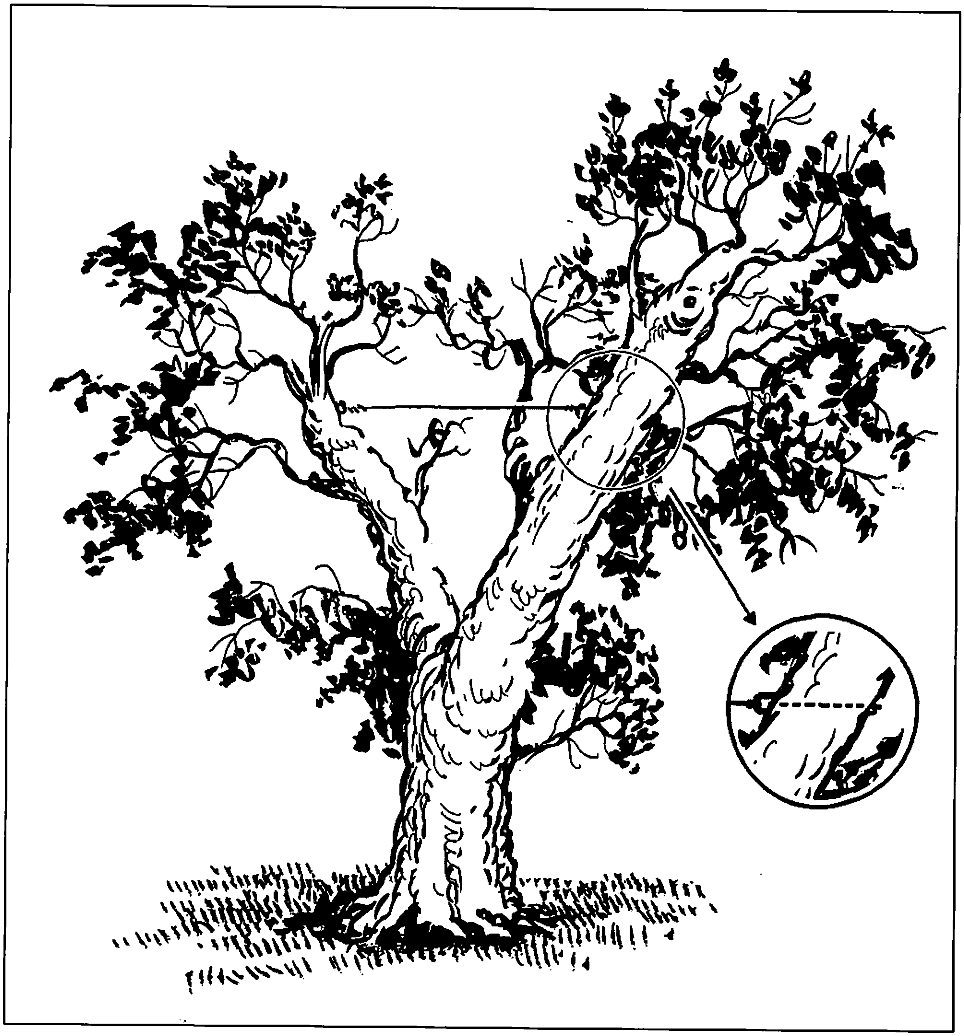


Figure 13. Anchor hardware must be installed in direct line with the cable to ensure maximum strength of the system.

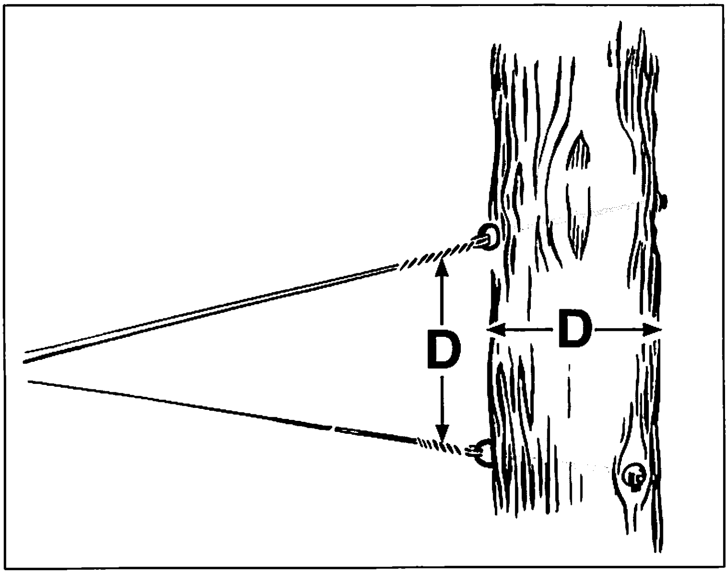


Figure 14. Hardware should be installed no closer together than the diameter of the branch or with a separation of 12 inches (30 cm), whichever is less.

Steel Cables and Terminations

Steel cables are typically named according to their diameter, number of strands, and the metal used in their construction. Several types of steel cable are commonly used for tree support systems. One type is wire rope composed of many strands, often subdivided into multi-strand groups. Smaller-diameter, corrosion-resistant wire rope is often referred to as aircraft cable. Two of the other types are composed of seven-strand steel cable. One is common-grade (soft galvanized cable), and the other is extra-high-strength (EHS) cable. While these two types of cable appear to be identical and weigh the same, there are major strength (Table 4) and bending differences, which will be described later. Before any type of cable is cut, it should be wrapped with electrical or other tape at the cut site to prevent unraveling of the cable.

Steel cables have traditionally been terminated (attached to the anchor hardware) with an eye that includes a heavy-duty thimble (see the following section on thimbles) through the anchor (eye bolt, amon nut, or J-lag). The type of eye that is formed depends on the cable type.

Manufactured cable-stop or swage-stop termination devices (fasteners that hold the cable, which is passed through the branch from the back of the branch) are acceptable under the ANSI standards but are not well researched. One trial found that some cables installed with cable-stop terminations caused

Table 4. Minimum hardware size requirements for cabling trees (adapted from ANSI A300 Part 3, Table A-1).

Maximum branch diameter at point of attachment in inches (cm)	Estimated load in pounds	Lag-hook diameter in inches (mm)	Eye-bolt diameter in inches (mm)
2 (5.1)	100	1/4 (6.4)	1/4 (6.4)
3.5 (8.9)	200	5/16 (7.9)	1/4 (6.4)
5 (12.7)	300	3/8 (9.5)	1/4 (6.4)
8 (20.3)	600	1/2 (13)	5/16 (7.9)
10 (25.4)	900	5/8 (16)	3/8 (9.5)
15 (38.1)	1000	NA*	3/8 (9.5)
18 (45.7)	1200	NA	3/8 (9.5)
20 (50.8)	1400	NA	1/2 (13)
24 (61)	2200	NA	1/2 (13)
28 (71.1)	3300	NA	5/8 (16)
30 (76.2)	3700	NA	NA

*Indicates that the application is not acceptable.

an increase in the size of the hole through the branch or trunk resulting from lateral movement of the branch.

Common-grade cable is relatively easy to bend and is commonly terminated with a handmade eye splice. To make the eye, the cable is wrapped around the thimble and bent parallel to the working side of the cable. One of the seven strands of the cable is separated from the free end of the cable, close to the thimble. That strand is then wrapped tightly across the throat of the thimble and at least twice around both sections of the cable (the section that enters the thimble and where it exits the thimble). There is no strength gain by wrapping the strand more than twice around the cable. Any excess wire is cut off. The process is repeated with each strand, wrapped in the same direction, until all strands are wrapped (Figure 15). The resulting eye splice will be tapered from the thickest part at the thimble to cable size at the end of the wraps.

Because EHS cable is much stiffer than common-grade cable, it cannot be hand spliced. Instead, it is terminated with a manufactured dead-end grip. It is essential that the grip size matches the cable size. The manufactured grip, including a heavy-duty thimble, is inserted through the anchor and, beginning at the mark located near the bend in the grip, the short leg of the grip is wrapped around the cable (Figure 16). The long leg is then wrapped around both the cable and the other leg of the grip (Figure 17). The last portion of the grip must be locked into place around the cable. Dead-end grips cannot

Amon-eye threaded rod diameter in inches (mm)	Common-grade cable diameter in inches (mm)	EHS cable diameter in inches (mm)	Wire rope (aircraft- cable) diameter in inches (mm)
1/4 (6.4)	1/8 (3.2)	3/16 (4.8)	1/8 (3.2)
1/4 (6.4)	3/16 (4.8)	3/16 (4.8)	1/8 (3.2)
1/4 (6.4)	1/4 (6.4)	3/16 (4.8)	1/8 (3.2)
5/16 (7.9)	5/16 (7.9)	3/16 (4.8)	3/16 (4.8)
3/8 (9.5)	3/8 (9.5)	1/4 (6.4)	1/4 (6.4)
3/8 (9.5)	7/16 (11)	1/4 (6.4)	1/4 (6.4)
3/8 (9.5)	1/2 (13)	1/4 (6.4)	1/4 (6.4)
1/2 (13)	1/2 (13)	5/16 (7.9)	1/4 (6.4)
1/2 (13)	NA	5/16 (7.9)	3/8 (9.5)
5/8 (16)	NA	7/16 (11)	1/2 (13)
7/8 (22)	NA	7/16 (11)	1/2 (13)

be shortened, left unfinished, or altered in any way because doing so reduces the strength of the system.

Wire rope (e.g., aircraft cable) can also be used in tree applications. This type of cable is strong and flexible (Table 4). Terminations are made using oval swage sleeves or wire rope clamps. When swage sleeves are used with wire rope terminations, an appropriately sized swage sleeve is inserted over the working side of the

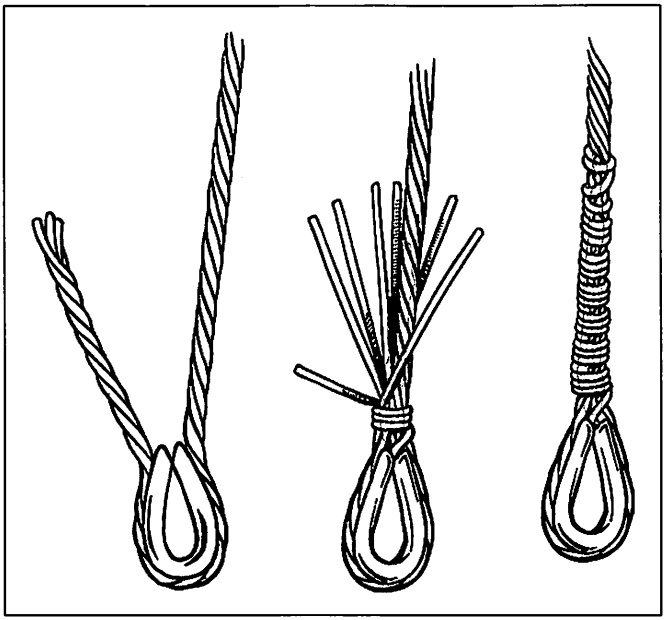


Figure 15. Common-grade galvanized cable is terminated with an eye splice that includes a thimble. The splice is made by wrapping each strand at least two times around all of the other strands. After wrapping, the excess wire is cut off. The process is continued until all of the strands have been wrapped.

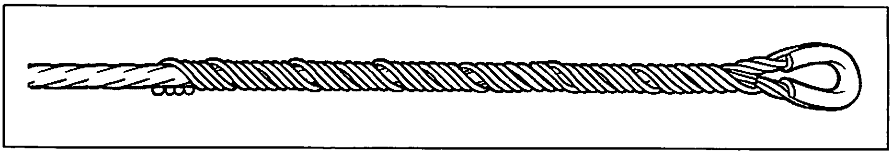


Figure 16. A thimble must be installed when using a dead-end grip.

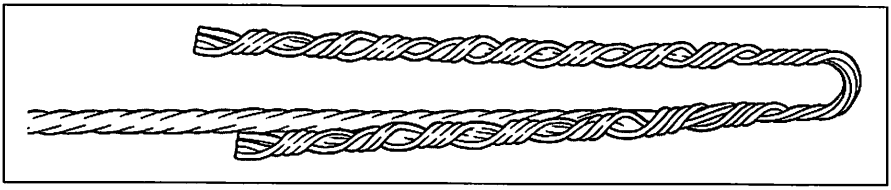


Figure 17. Dead-end grips are installed on the cable by wrapping the short leg of the grip around the cable, then wrapping the long leg. Both legs must be wrapped completely.

cable. The end of the cable and thimble are inserted through the anchor, forming an eye. The free end of the cable is then inserted through the swage sleeve, and the swage sleeve is positioned close to the thimble and compressed using a specialized swaging tool (Figure 18). Excess cable is cut off, usually before the swage sleeve is fastened.

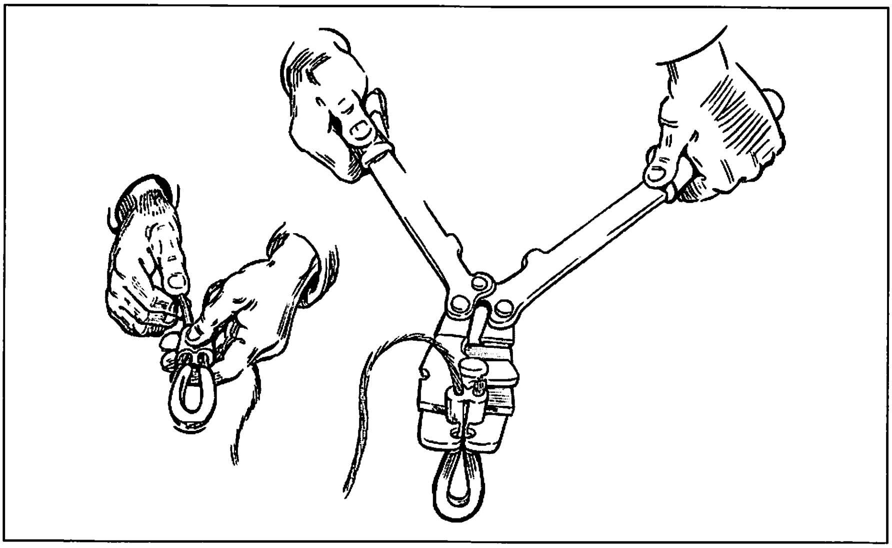


Figure 18. Wire rope is terminated with a thimble and an oval swage sleeve. This is done by inserting the cable through the swage sleeve and forming the eye (including the thimble), then moving the swage sleeve close to the thimble with the end of the cable extending past the swage sleeve. The termination is finished by crimping the swage sleeve with the swaging tool.

Cable clamps (wire rope clamps, Bulldog clamps™) can also be used for terminations. This use is common in the United Kingdom and some Commonwealth countries. In the United States, however, the ANSI A300 standard does not allow use of cable clamps on cables larger than 1/8 inch (0.3 cm) diameter. Cable clamps bend the cable, reducing the strength of the system, which might not hold the cable securely under repeated shock loading. Wire rope clamps are installed with the saddle side of the clamp against the longer section of cable. All three clamps are installed in the same orientation.

Thimbles

No matter what type of cable is connected to an eye bolt or lag eye, a galvanized or stainless-steel thimble must be incorporated in eye terminations. The thimble reduces abrasive wear and increases the cable-bend radius. Heavy-duty thimbles must be used with EHS cable. These thimbles have deeper gullets as well as thicker steel. The thimble should be left open with EHS cable so that the thimble cannot fall out of the dead-end grip. With common-grade galvanized cable and wire rope, thimbles should be closed after inserting through an eye.

Washers

Washers are used in all through-bolt applications to reduce the risk of the nut pulling through the tree. Washers should be heavy duty or heavy duty *and* heat treated. Heavy-duty washers are made of thicker metal than standard-duty washers and have a larger outside diameter. Heat-treated washers have even greater metal strength than heavy-duty washers. There is no benefit to using standard-duty fender washers because the steel is the same thickness as standard-duty washers.

Safety

To avoid potential electrical shock and be in compliance with ANSI Z133 safety standards in the United States, cables should not be installed over or within 10 feet (3 m) of energized electric wires.

When replacing cables, it is not always necessary to remove the old cable. However, if the client prefers removal of the old cable, the new cable must be installed first. Whether removing an old cable for replacement or for branch/tree removal, the tension should be removed from the cable before cutting the cable. Tension is removed using a come-along or other load-control system. If a cable under tension must be cut, steps should be taken to control the cable once cut. The tree worker must be in a position to avoid cable recoil or branch failure should either occur.

All leftover bits of cut-off wire, cable, and brace rod should be immediately collected and disposed of so as not to cause flat tires, personal injury, or lawn-mower or chipper damage.

Cables and Lightning

If a tree with a steel cable is struck by lightning, there is a greater likelihood for tree damage because the lightning can be conducted into the cambium and xylem. If there is a lightning protection system in a tree with a cable, the two systems should be connected (bonded) to reduce the risk of a lightning strike traveling between the two systems and causing tree damage. The connection should be made by fastening a section of conductor between the cable and the tree lightning protection conductor. A specially designed bronze or stainless-steel connector clamp (multipurpose clamp) should be used for this purpose. Copper conductors should never be wrapped around the cable because galvanic corrosion will lead to premature cable rusting. Any bends in the conductor should have a radius of 8 inches (20 cm) or greater.

Dynamic (Soft) Cabling

An alternative to steel cabling is a "dynamic" or "soft" cable system. These systems use ropes and belts, sheaths or straps instead of cables and anchors. Several proprietary brands are available and are widely used in Europe. These systems share many properties, but their materials and installations differ. For advantages and limitations of traditional cabling systems, see Table 5.

Dynamic cables use some form of rope that is wrapped around a stem. Therefore, these cables do not require the arborist to drill into the tree. Several systems use a hollow-braid, polypropylene rope, which enables the use of simple splices for attachment.

Dynamic cables may reduce the potential for shock loading the system, which can occur if two stems move in opposite directions with great force. Some systems include an additional shock-absorbing rubber component; others incorporate an overload indicator, which can signal that the system was overstressed and prompt the arborist to perform a closer inspection or possibly replace the system.

Since most dynamic systems are installed by wrapping the support cable around the stem, the potential for girdling or damaging the rope is always present. Tree damage can be reduced with the use of a strap or band that distributes the load over a wider area than the unsheathed cable.

Some systems call for the formation of tension/compensation loops of cable, which are intended to accommodate tree growth and further minimize the potential for girdling. These loops should be monitored since they do not always indicate a problem.

One hybrid system uses the traditional through-hardware installation with rope between the anchors. The goal of this system is to provide the shock-absorbing properties of dynamic cable without the potential for girdling.

The shock-absorbing and nondrilling advantages of dynamic cabling systems must be weighed against their potential limitations. The major concern is the potential for UV degradation. Because of this risk, control intervals or life expectancies are sometimes defined in regional tree care standards or even by municipalities. Some systems incorporate color-coded indicators so that the year of installation can be determined easily. One European standard requires that manufacturers ensure adequate strength for a minimum of eight years. A close inspection on a one to five-year interval is appropriate in most locations.

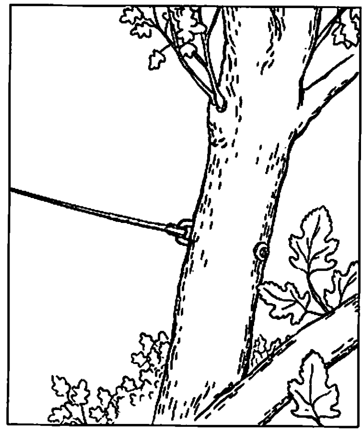
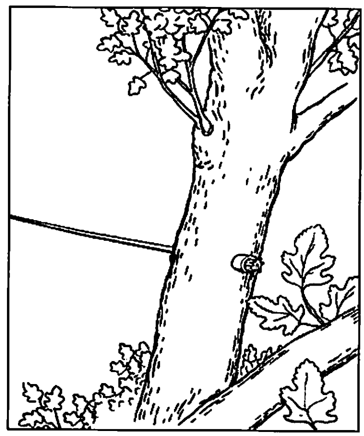
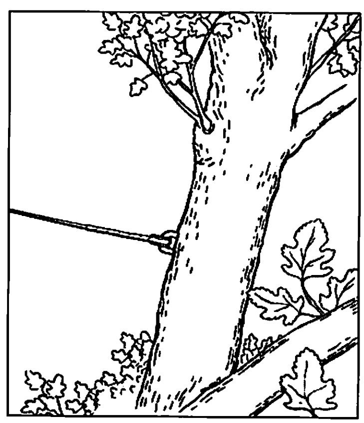
Another potential limitation of dynamic cable that has been noted by researchers and practitioners is that small animals, such as squirrels and tropical birds, may chew on the dynamic cable, which can quickly and dramatically reduce its strength.

Some manufacturers also limit applications of dynamic cable. Dynamic cables may not be recommended for branch unions that are already split because the dynamic movement can allow the split to enlarge. In addition, cables spanning long distances require greater stiffness, so steel cables are sometimes preferred in those cases.

Compression Springs

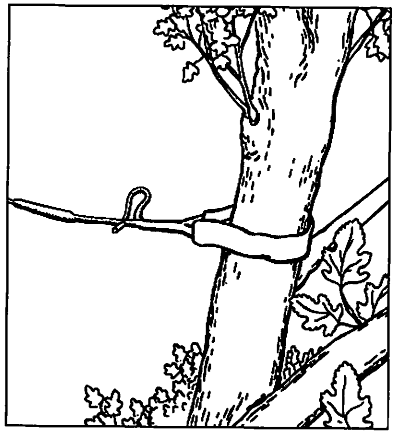
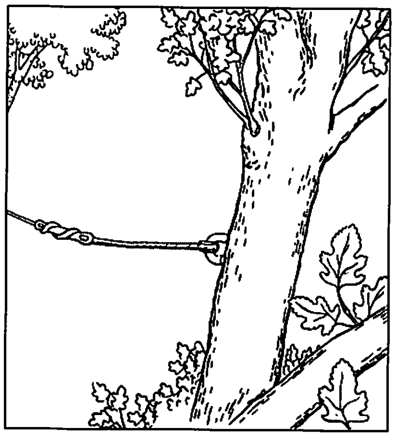
Compression springs are occasionally used in a cable system to decrease dynamic loading and to allow for branch movement. The efficacy of compression springs is not well studied, so they are not widely recommended. If they are used, they must meet the same minimum strength requirements as the rest of the system hardware (Table 4).

Table 5. Comparison of traditional cabling systems.

Cabling system	
Eye-bolt-anchored steel cable	
Cable-stop-terminated steel cable	
J-lag-anchored steel cable	

Advantages	Limitations
• Greatest strength/diameter ratio • Not visually intrusive • High longevity	• No stretch • Requires drilling through branch • EHS cable can be difficult to work with
• Faster to install than an eye bolt • Especially effective for small branches • Just as effective on large branches • Not visually intrusive	• Branch movement may enlarge drilled hole if there is slack or great range of motion • Requires drilling through branch
• Faster to install than an eye bolt • Works well for small branches • Not visually intrusive	• Cannot be installed into decayed wood • Lag can open or pull out when overloaded • Installation limited to branches no larger than 10 inches (25 cm) in diameter • Requires drilling into branch

Table 5 (continued). Comparison of traditional cabling systems.

Cabling system	
Sling-terminated synthetic rope	
J-lag-anchored synthetic rope	

Advantages	Limitations
• Fast installation • Minimal tools required • No drilling • Good for temporary support • Absorbs some shock through stretching • Polypropylene is easy to splice during installation	• May require a branch union for installation • May girdle the branch or leader • May be damaged by animals or UV degradation • Large-diameter rope has high visibility from the ground
• Absorbs some shock through stretching without risk of girdling	• Requires drilling through branch • May be damaged by animals or UV degradation • Large-diameter rope has high visibility from the ground • Difficult to splice during installation

4. Bracing (Rigid Bracing)

Brace rods are used to reduce the risk of two or more leaders spreading apart or moving sideways in relation to each other. They are also used to fasten together a union or branch that is split or cracked. Usually, when weak unions are braced, at least one cable is installed for added support before installing the brace rod(s). In cases where it is impractical to install cables, rods can be used alone, but the strength gain will be less, and there will be more stress on the rod. Before brace rods are installed, the objective of the installation must be clearly defined.

There are two types of rod installations: through-braces and dead-end braces. Through-braces go entirely through the tree and are fastened at both ends with washers and nuts. Rods used for through-bracing are machine-threaded or lag-threaded steel. Heavy-duty washers and nuts are used to fasten each end of the rod. If a lag-threaded rod is used, special nuts with lag threads are required. If internal decay is present in a tree, only through-braces can be used, and there must be a minimum thickness of sound wood of no less than 30 percent of the diameter of the tree at the point of installation (Figure 11).

Dead-end braces go entirely through the smaller of the two leaders and at least halfway into the larger leader. The rod used for dead-end braces is lag-threaded to hold the wood without nuts. Solid, decay-resistant, strong wood is required for this system. Dead-end braces cannot be used if decay is present in the path of the rod, if the tree is a poor compartmentalizer, or if it has weak wood characteristics. Because of these limitations, through-bracing is preferred for most bracing situations.

Table 6 specifies the minimum number and diameter of steel brace rods for various sizes of trees. The tree diameter should be measured below the union being supported (Figure 19).

Brace rods installed in small trees can create hidden hazards when new growth grows over and hides the rods. Rods can inadvertently be sent into a chipper during tree removal. Steel rods can quickly destroy chipper blades and throw pieces of metal out of the chipper. Therefore, some arborists use bronze rods in small trees to reduce the risk of injury to tree workers. Quarter-inch-diameter (6.4 mm) bronze rods can be used in unions up to 4 inches (10 cm) in diameter.

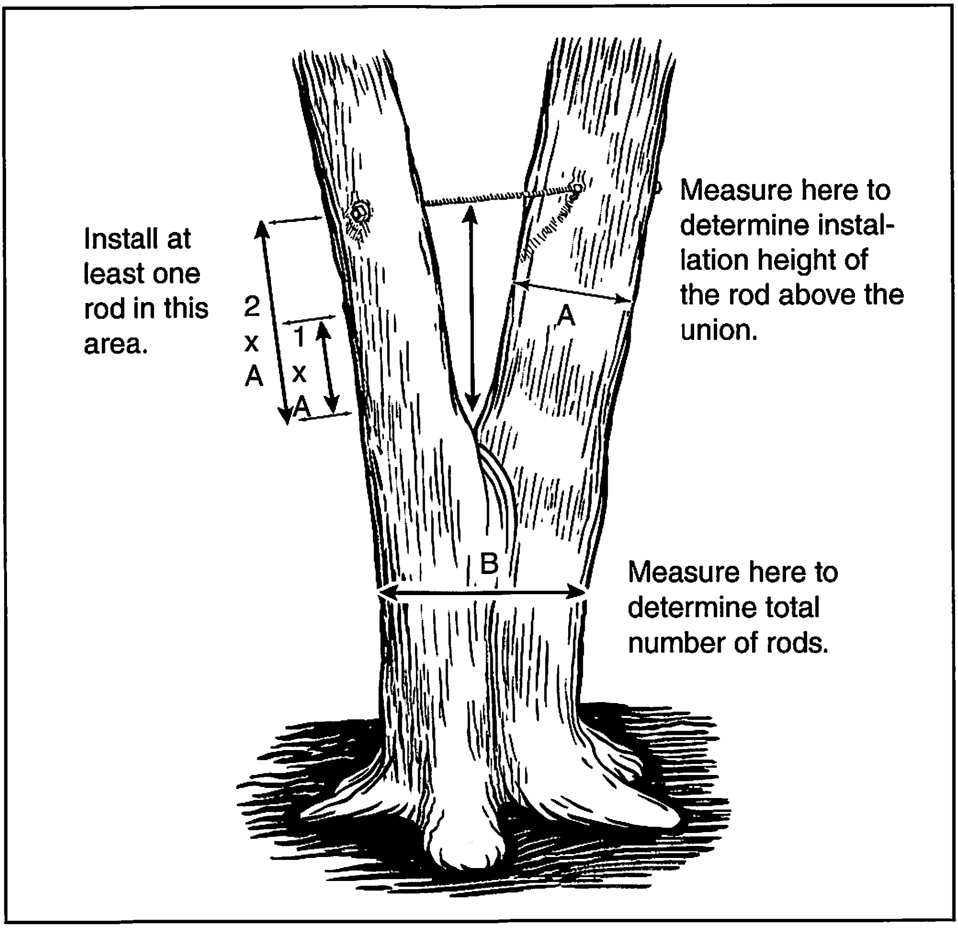


Figure 19. The number of rods is determined by measuring the diameter below the union. At least one rod should be installed above the union.

Table 6. Minimum diameter and number of steel rods to install for bracing trees.

Diameter below the junction in inches (cm)	Brace rod diameter in inches (mm)	Minimum numbers of rods in trees with: Split limbs or included bark/split union	Minimum numbers of rods in trees with: No split in the union
<5 (<13)	1/4 (6.4)	1	1
5–8 (13–20)	3/8 (9.5)	1	1
8–14 (20–36)	1/2 (13)	2	1
14–20 (36–51)	5/8 (16)	2	1
20–40 (51–102)	3/4 (19)	3 + 1 for each 8" (20 cm) above 30" (75 cm)	2 + 1 for 8" (20 cm) above 30" (75 cm)
>40 (>102)	7/8 (22)	4 + 1 for each 8" (20 cm) above 40" (100 cm)	3 + 1 for each 12" (30 cm) above 40" (100 cm)

Rod Location

The preferred location for a single brace rod to support a union that has not split is above the union at a distance one to two times the diameter of the larger branch, measured above the union. For example, if the larger leader is 18 inches (45 cm) in diameter above the union, the brace rod should be installed 18 to 36 inches (45 to 90 cm) above the union. Because trees vary in structure, variables such as wood quality, species, and branch structure should also be taken into consideration when determining the distance above the branch union to install the brace rod.

Bracing System Types

Commonly used bracing configurations include single rod, vertically parallel, horizontally parallel, alternating, and crossing. Tree size, structure, and defects should be considered when deciding which system is used.

On small trees [8 inches (20 cm) or less diameter] without a split below the union, a single rod should be installed above the union (Figure 20). With medium-sized trees [8 to 20 inches (20 to 50 cm) diameter] that have a split or large amounts of included bark below the union, a vertically parallel system should be used (Figure 21). This system includes one rod above the union and at least one rod below the union to pull the split together. The lowest rod should be no lower than the bottom of the split. Distance between rods should be equal to or greater than the diameter of the tree at the lowest rod.

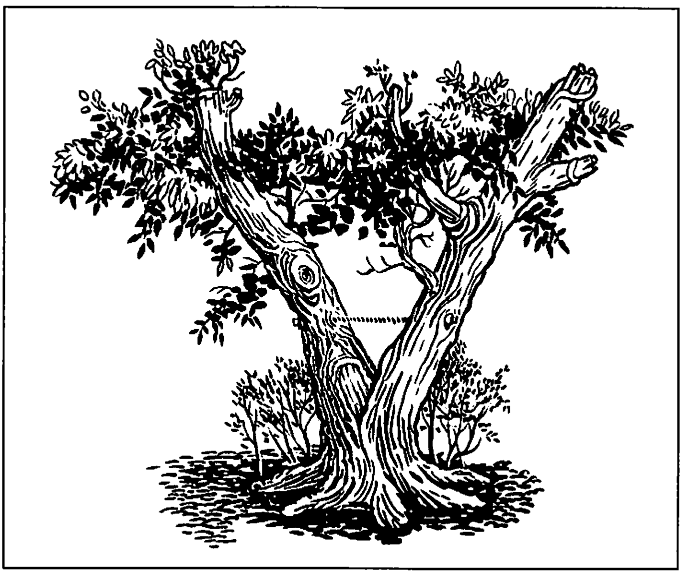


Figure 20. A single rod above the union is the most commonly used bracing system.

In larger trees [20 to 40 inches (50 to 100 cm) diameter] that have a single union and a split below the union, an alternating rod system should be used (Figure 22). This system includes one rod above the union and two or more rods below the union that are horizontally offset from each other. When practical, the vertical distance between rods should be equal to or greater than the diameter of the tree at the rod, or 12 inches (30 cm) apart, whichever is less.

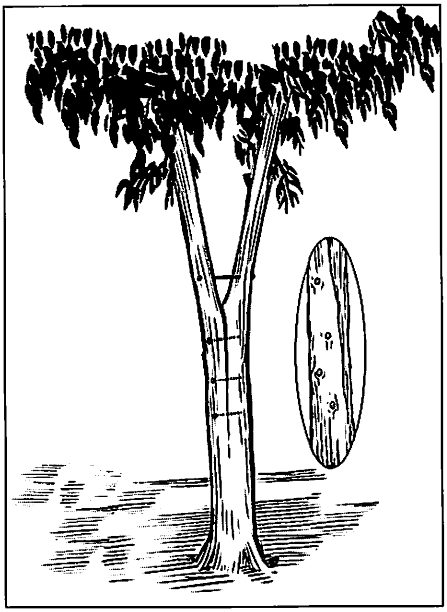


Figure 21. Vertically parallel rods are used in medium-sized trees with a long split or large amounts of included bark.

In very large trees [diameter greater than 40 inches (100 cm)] that have a single union and a split, a horizontally parallel system should be used (Figure 23). This system includes one or more rods above the union and sets of horizontally parallel rods below the union. Sets may consist of two or more rods spaced at least 12 inches (30 cm) apart horizontally. If multiple rows of rods are used, vertical spacing should be at least 12 inches (30 cm).

For trees with three or more codominant stems, a crossing system should be used (Figure 24). This system includes one or more rods above the union and two or more rods below the union. Each stem should have at least one rod installed across the weak union. Minimum horizontal rod spacing should be equal to or greater than the tree diameter at the rod, or 12 inches (30 cm), whichever is less.

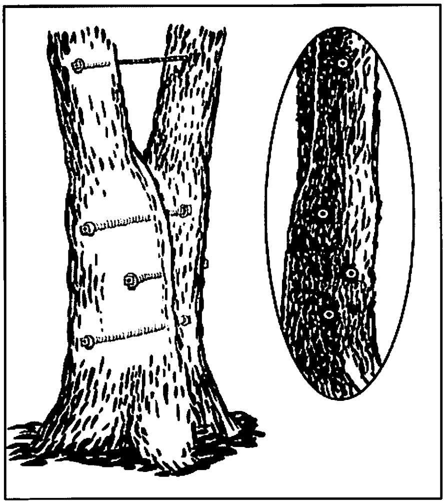


Figure 22. Alternating rods are used on large trees with a single union and a large split below the union. Rods are spaced at least 12 inches (30 cm) apart.

Through-brace rods can also be used in split branches to help prevent the split from enlarging. Cabling and pruning should be considered in conjunction with this type of bracing.

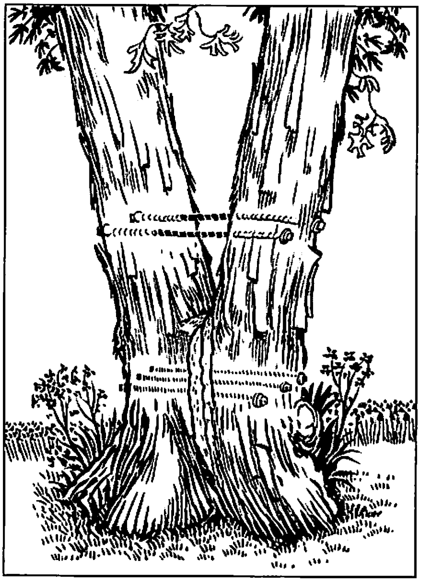


Figure 23. Horizontally parallel rods are installed on very large trees that have a split union or large amounts of included bark. Two rows of rods, and at least one rod above the union, may be used.

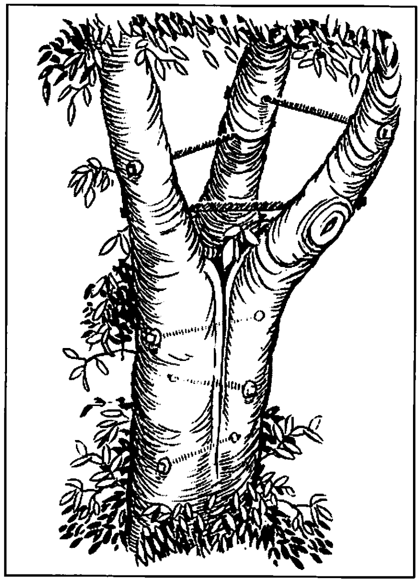


Figure 24. Crossing rods are used in large trees with more than one union. At least one rod should support each major union.

Installation Techniques

The hole for through-rod brace installation must be drilled completely through all sections of the tree to be braced from one direction (Figure 25). Completing a hole from the opposite side of the tree should not be attempted because the two holes will never directly meet.

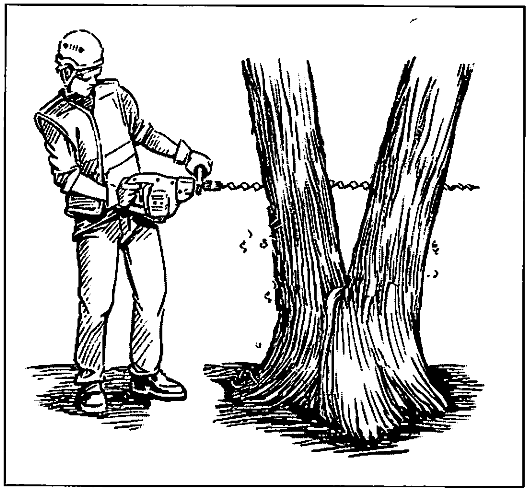


Figure 25. The hole for a through-brace should be drilled entirely through all sections of the tree to be braced.

To assist in closing a split union, it may be necessary to install a come-along or other rigging system above the union (where it will move the leaders at the union but not bend them at the come-along) and draw the split together as much as possible before drilling the holes for the brace rod. In some cases, it may be necessary to pull the leader side to side in an attempt to realign the split. If installing multiple rods, it is usually preferable to install the uppermost rod below the union first.

Through-Bracing

When through-rod braces are being installed, the holes should be drilled equal to or larger than the diameter of the rod (Table 1). Rods are terminated with heavy-duty washers and nuts. This allows for exerting considerable force on a split union, possibly enough force to close the gap. Once tight, the excess rod can be cut off with a hacksaw or power reciprocating saw and the nut secured. Nuts are secured so that they will not come unscrewed.

There are at least three options for securing the nut. A hammer can be used to peen at least one exposed thread toward the nut. Another method is to drill a hole through the nut and rod and insert a wire wrapped around itself to lock the nut in place. Other alternatives include installing a locking nut or using locking fluid (Figure 26). Peening is the most common method of securing a nut because it is inexpensive and has the benefit of not leaving sharp, exposed threads.

On trees with thick bark, the bark should be removed beneath each washer. This procedure is known as countersinking. Without countersinking, the bark will compress, allowing movement of the washer and nut, possibly reopening the crack. Because of the increased potential for decay, countersinks should not go into the wood. On trees with thin bark, countersinking is not required or recommended.

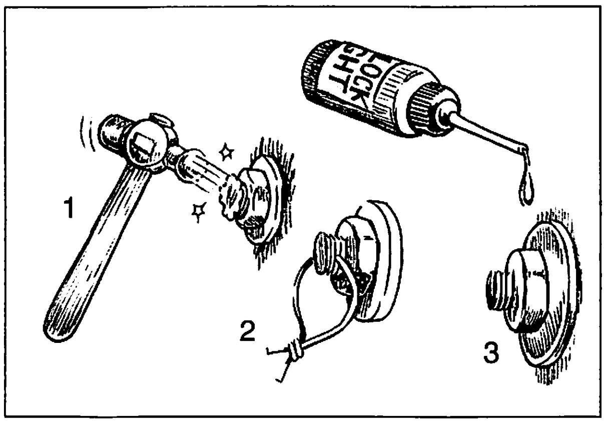


Figure 26. To secure nuts so they will not back off the rod, they can be 1) peened with a hammer, 2) secured with a locking wire, 3) or fastened with locking fluid.

There are two accepted methods of countersinking. The preferred method is using a flat-bottom drill bit, such as a Forstner drill bit, of the same diameter as the washer (Figure 27). This bit produces a flat surface for the washer to rest on, but care must be taken not to cut into the wood. These bits cut very smooth sides that will result in faster closure than chisel-cut countersinks. If the bit is center guided, it is easier to drill the countersink before starting the hole for the rod. On the opposite side, the

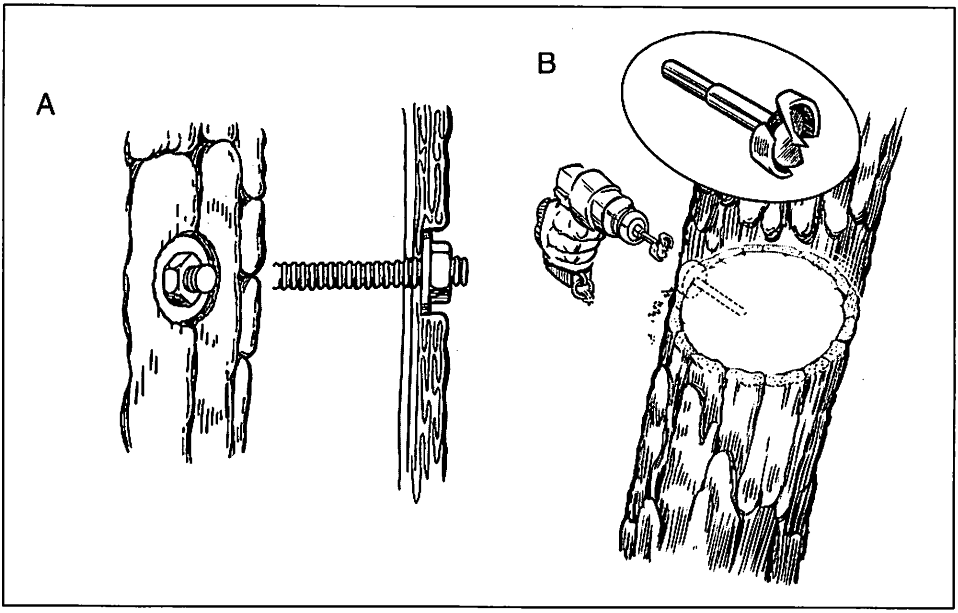


Figure 27. (A) On thick-barked trees, countersinking the washer and nut can reduce movement. Only the bark should be countersunk; the wood should not be cut into. (B) Countersinking can be done using a flat-bottomed, Forstner drill bit or a chisel.

countersink is drilled after the drill bit emerges from the tree. Forstner bits are edge guided and can be more easily used after the hole for the rod is drilled.

Chisels or gouges can also be used to cut countersinks. A gouge curved with the same radius as the washer is preferred. After the hole is drilled, the outline of the washer should be scribed to show where to chisel out the bark. It is important to avoid damaging the bark outside of the scribed area.

With rods that will be partially exposed between stems, the exposed portion of the rod may be painted or run through a length of PVC conduit, if desired. The conduit may provide some protection against the weather, and it can protect people and climbing lines from being cut by sharp threads. Corrosion-resistant nuts, washers, and rod ends do not need to be treated with paint or asphalt sealant except for aesthetic reasons or in areas exposed to high levels of corrosion.

Dead-End Bracing

To install dead-end braces, a come-along should first be used to bring the two stems together. A drill bit that is 1/16 to 1/8 inch (1.6 to 3.2 mm) smaller than the rod to be installed is drilled starting on the side of the tree with the smaller-diameter stem (Table 1). The smaller stem should be drilled completely through and the larger stem at least halfway through (Figure 28). It may be useful to mark the drill bit and rod with tape before drilling so that it will be obvious when the specified depth is reached. This is done by holding the bit next to the tree and estimating the length required.

Lag-threaded rods are screwed into the tree using a pipe wrench, drill, or rod driver. When using a pipe wrench, care should be taken to avoid damaging the rod if a nut will be attached. If a drill is being used, the end of the rod should be fastened in the chuck and driven in at a slow speed. With any of the driving techniques, the job can be made easier if the rod is lubricated with a nonphytotoxic lubricant such as beeswax, a water-based lubricant, soap, or vegetable oil. Petroleum-based lubricants should be avoided to reduce the risk of tree damage.

If a nut is not used to secure the exposed end of a dead-end installation, the rod should be broken off below the bark of the tree. This is done by driving the rod most of the way into the tree, sawing through the rod approximately two-thirds to three-quarters of the diameter of the rod, then carefully driving the rod in so that the precut portion is below the bark. The rod is then bent until it breaks at the cut.

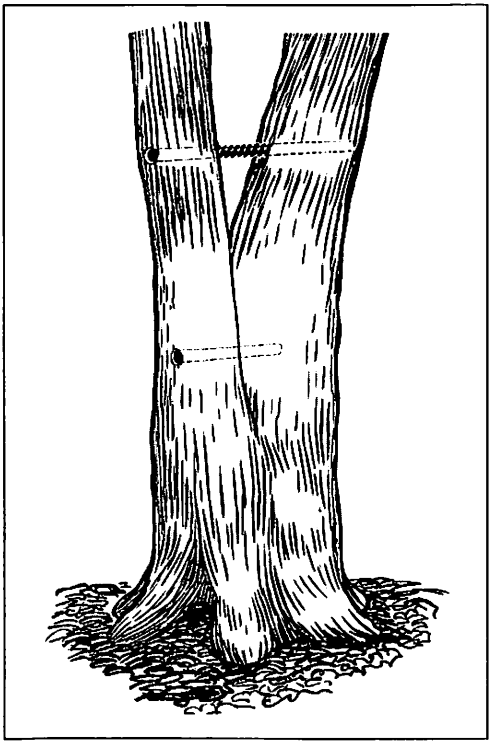


Figure 28. When dead-end bracing is being installed, the smaller stem should be drilled completely through and the larger stem at least halfway through.

5. Stabilizing Newly Planted Trees

Most newly planted nursery stock trees are stable without the addition of a support system. However, there are some cases where support systems will be beneficial in keeping the trunk in an upright position; for example,

- trees with undersized root balls
- bare-root, fabric-bag, and container-grown trees with lightweight root balls
- large evergreens with a high foliar wind resistance and the potential for additional weight of snow and ice accumulation during the winter
- trees planted in locations with persistent strong prevailing or sporadic winds

If supports are installed on newly transplanted trees, in most cases, they should be removed after one year to avoid trunk damage.

Guying, staking, and bracing (propping) are common methods for supporting newly planted trees. Guying is the installation of a cable between a tree and an external anchor to provide supplemental support and reduce tree movement. Guying is intended as a temporary support system and cannot permanently compensate for seriously deficient or defective root systems. When newly planted trees are guyed, some movement should be allowed to stimulate good trunk taper and root anchorage.

Guy systems with three points of attachment have been shown to provide the greatest support for new transplants. Guys used on most transplants are fiber straps, ropes, or steel wires that are attached to the trunk and an external ground anchor. Because guying of new trees is temporary, anchor hardware is not typically used. The traditional method for attaching guys to trees is a wire slipped through a piece of garden hose, but this method sometimes causes damage. Guying material should be wide, smooth, nonabrasive, flexible, and, if possible, photodegradable. Wide guying material can help dissipate pressure exerted on the tree by the guying system. Table 7 contains examples of minimum material requirements for tree guys.

Guys are typically attached on the lower half of the trunk. Attaching the guys above two-thirds the height of the tree can cause the trunk to break at the attachment point in strong winds. To prevent injury to the bark, the guy should be examined at least once during the growing season and adjusted if necessary. Turnbuckles can be installed to make adjustments in length as needed to avoid bark injury and allow some

Table 7. Examples of minimum material requirements for tree guys.

Maximum tree caliper		Minimum working strength		Poly-propylene rope		Poly-propylene webbing*		Steel wire Class I, galvanized		Soft galvanized cable, 1×7		Aircraft cable, galvanized, 7×19	
in.	mm	lb	kg	in.	mm	in.	mm	gauge	mm	in.	mm	in.	mm
1.5	38	75	34.0	3/16	4.8	3/4	19	16	1.3			1/16	1.6
2.5	63	100	45.4	1/4	5.4	3/4	19	16	1.3	1/8	3.2	1/16	1.6
4	101	180	81.6	5/16	7.9	3/4	19	14	1.6	3/16	4.7	3/32	2.4
6	152	320	145.1	3/8	9.5	1.0	25	12	2.0	1/4	6.4	1/8	3.2
8	203	640	290.3	NA	NA	1.25	32	NA	NA	5/16	7.9	3/16	4.8

Source: Dr. E. Thomas Smiley, Bartlett Tree Research Laboratory.

*Polypropylene webbing strength varies by thickness. These sizes assume webbing is heavy duty; weaker and stronger webbings are available. In this table, ¾-inch webbing has a rated breaking strength of 900 pounds (408 kg).

trunk movement. Compression springs can similarly be used to increase allowable movement of the trunk.

Short wood or metal stakes are often used as ground anchors. Various other anchors that are driven or screwed into the ground are also available. Guys should run at a 45-degree angle to the ground anchors. Ground anchors can be installed before backfilling for ease of installation.

Staking is the use of 2- to 6-foot (0.6 to 1.8 m) tall steel or wood posts that are driven vertically into the soil near the trunk. They are then connected to the trunk using horizontal fiber or elastic straps, ropes, or wire. Stakes are installed on one, two, or three sides of the tree to limit movement of the trunk. Two stakes, with separate flexible ties, usually are recommended. It is often easier to install stakes before the planting hole is backfilled. As with guying, staking so tightly that there is no trunk movement can result in poor trunk taper and root anchorage.

Propping is the use of posts as angled props to limit movement of the trunk. Props are typically installed in sets of three or four per tree. They are usually preferred for newly planted palms. Because props are temporary, they should be installed in a manner that does not damage the trunk or penetrate into the wood. On palms, short boards are often attached to the trunk using metal strapping, and then wood posts are attached to those boards rather than the trunk itself.

Underground root ball anchoring or stabilization systems are sometimes preferred for aesthetic or safety reasons. Several commercially constructed anchor systems are available, but systems can be constructed using an untreated wood frame held in place with wooden stakes. The untreated wood will rot away in a few years. Systems that require additional soil to be placed over the root ball should not be used. In the case of eventual tree removal, the possibility of future damage to stump-grinding machines and injury to operators should be considered when using steel ground anchors.

6. Guying Established Trees

Established trees are rarely guyed. However, there are a few cases in which installation of guys is appropriate—for example, trees that have been uprighted after being uprooted or blown over and trees with serious anchorage issues (either root defects or soil conditions that compromise anchorage). Trees that must be retained rather than removed because of their historic importance are also sometimes guyed. Trees with root, soil, or stem defects may be guyed to reduce the risk of failure or to limit the potential directions of fall. Before a guying system is installed, the objective of the installation must be clearly defined, and the system should be designed to achieve this objective. When components necessary to guy a large tree are outside the scope or range of standards or best practices, it might be worth having the plan reviewed or developed by a qualified engineer.

Public safety can be a concern when guying trees. It is important to notify the client of the risks involved with guyed trees; for example,

- Guyed trees can fail under extreme conditions.
- Pedestrians and vehicles can be injured by striking guy cables.
- Anchors can create a tripping hazard.

The client must be informed of the need for periodic inspections of the guying system. Inspection intervals depend on the tree, site, and guying system conditions. If defects are found in the tree or guying system, they must be corrected in a timely way to ensure that the guying system continues to achieve its objective.

Established tree-guying systems consist of an attachment point in the tree, the guy cable, and an anchor. Two types of anchors are common: ground or soil anchors (a tree-to-ground system) and anchor trees (a tree-to-tree system).

The attachment point in the tree consists of lag hooks or through-bolts. The size and installation considerations for these anchors are the same as for cables and are detailed in the Cabling section. Table 4 details the minimum hardware requirements. Hardware should be installed in the direction of pull from the tree to the anchor. Permanent guy cables should not be wrapped around the tree; however, temporary guys to stabilize the tree until the tree is removed or permanently supported can be wrapped around the stem. In these cases, the stem should be protected from excessive damage.

Tree anchors should be attached at a point not less than half the height of the tree. To avoid splitting the wood, multiple anchors must be separated by a distance not less than the diameter of the tree at the point of attachment, or 12 inches (30.5 cm), whichever is less.

With tree-to-ground guy systems, the stability of the ground anchor is of utmost importance. It must have sufficient strength, even under wet conditions, to support the tree. When an anchor is being selected, products specifically designed for the task should be used or an engineer consulted to aid in anchor design.

The ground anchor should be placed no closer to the tree trunk than two-thirds the distance from the ground to point of attachment on the tree. For example, if the lowest guy attachment on the tree is 24 feet (7 m) from the ground, the ground anchor should not be closer to the trunk than 16 feet (5 m) (Figure 29). Preferably, the distance from the tree should be nearly equal to the height of the attachment in the tree.

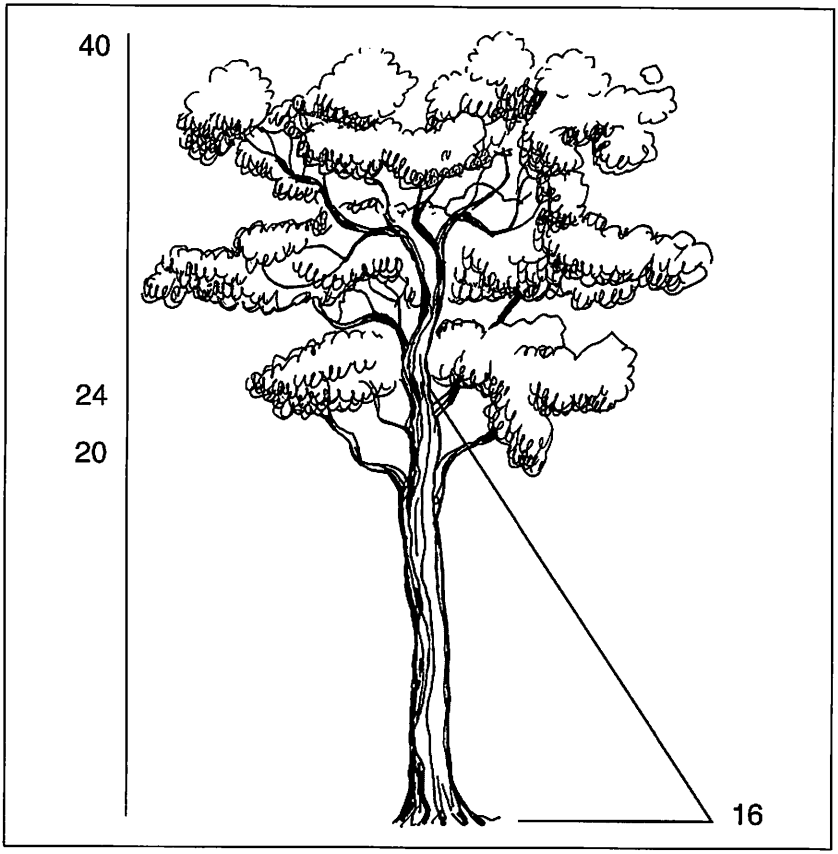


Figure 29. The ground anchor should be placed no closer to the tree trunk than two-thirds the distance from the ground to point of attachment on the tree. For example, if the lowest guy attachment on the tree is 24 feet (7 m) from the ground, the ground anchor should not be closer to the trunk than 16 feet (5 m) (Figure 34). Preferably, the distance from the tree should be nearly equal to the height of the attachment in the tree.

Turnbuckles or compression springs used to adjust cable tension in a guying system must meet the same strength requirements as the rest of the system (Table 4).

Installing the ground anchor and guy cable within a mulched area around the tree will protect it from lawn-mower damage better than if the anchoring system is in a turf area. If guy cables are in an area that has pedestrian or vehicular traffic, they must be clearly marked or protected with flagging, PVC pipe, or other means. The client must be informed of the potential risk to pedestrians from the guy.

In tree-to-tree guy systems, another tree is used as an anchor. The tree selected as an anchor tree must be carefully inspected to be sure it has the structural strength to support the other tree. Trees with root damage or extensive decay should not be used as anchors. If possible, the anchor tree should be larger than the guyed tree.

Lags or eye bolts attached to the anchor tree must be of sufficient size to meet the objective. They are attached on the lower half of the trunk, preferably at a height greater than 7 feet (2 m) above the ground if there is pedestrian traffic, or greater than 14 feet (4 m) off the ground if there is vehicular traffic under the guy cable (Figure 30).

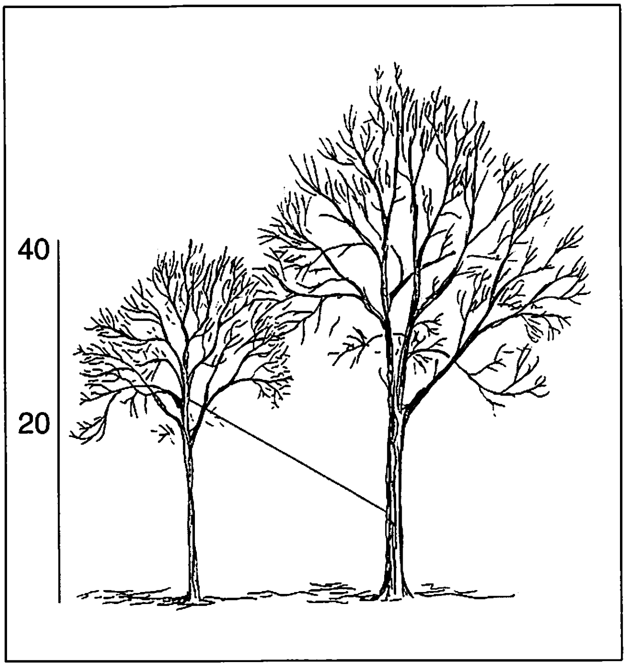


Figure 30. With tree-to-tree guys, the anchor should be installed at half of the tree height or higher on the guyed tree. The guy should be installed at least 7 feet (2 m) above the ground in areas with pedestrian traffic or 14 feet (4 m) above the ground in areas with vehicular traffic. It is preferable that the anchor tree be larger than the guyed tree.

7. Propping

Props are rigid structures installed between the ground and a branch or trunk to provide support from below. Props are used under branches or leaning trunks to keep the branch off the ground or a structure, to maintain clearance, or to reduce the potential for whole-tree failure.

Research about the use or design of props in arboriculture is limited, and there are wide variations in design. Props can be made from wood, steel, concrete, or other materials. They must have sufficient strength to support the expected load. Green wood typically weighs 50 to 80 pounds per cubic foot (800 to 1,280 kg/m^3), depending on tree species. The load should be expected to be greater when the tree is in leaf; if loaded with rainwater, ice, snow, or fruit; or if the trunk leans toward the branch. Props constructed from wood and steel should be protected from deterioration caused by decay or rust.

The design of the prop system should prevent the branch from detaching from the prop. Options for securing the branch to the prop include a pin, a bolt, a saddle, or a system of tying or strapping the branch to the prop (Figures 31, 32, 33, and 34). The prop and connecting rope or straps should not restrict growth of the branch and, in most cases, should allow some branch movement without causing damage to the tree. Saddles and straps can eventually damage the branch by girdling; therefore, they should be installed with minimal branch or stem contact. Ropes or straps that wrap

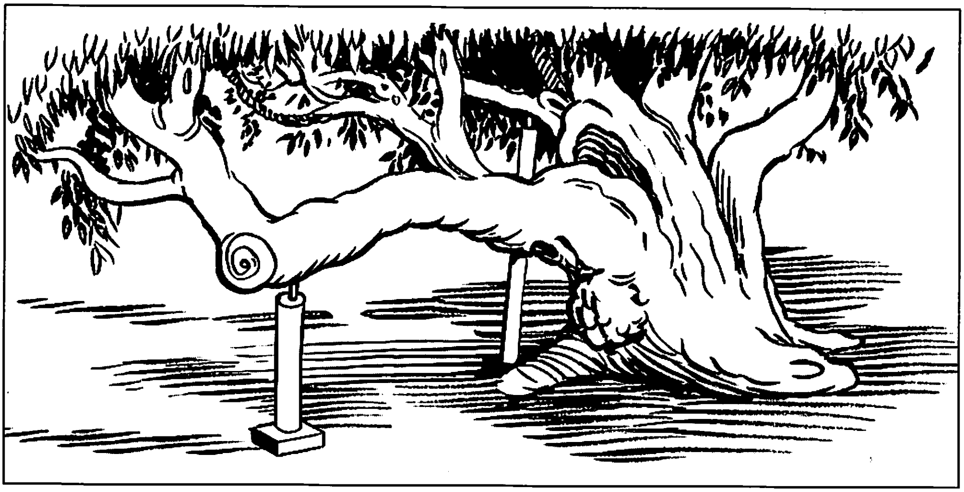


Figure 31. Basic prop designed for the branch to rest on a pin or bolt. This design is useful when side forces and trunk twisting will be minimal. Load and frost-free depth should be considered when determining the depth of the foundation.

around the branch should be adjusted annually or more often to allow for unrestricted branch diameter growth. Attachments that circle branches and cannot (or most likely will not) be adjusted should not be used.

The prop should be anchored in the ground so as to keep it in place and to support the load. A concrete footing is often the preferred anchor. It should be large enough to hold the expected load and deep enough to avoid frost heaving. If a hole is dug for this footing, root damage beyond the scope of the work must be avoided. Where loads or risks are extensive, it may be appropriate to solicit the services of a qualified engineer to aid in component design.

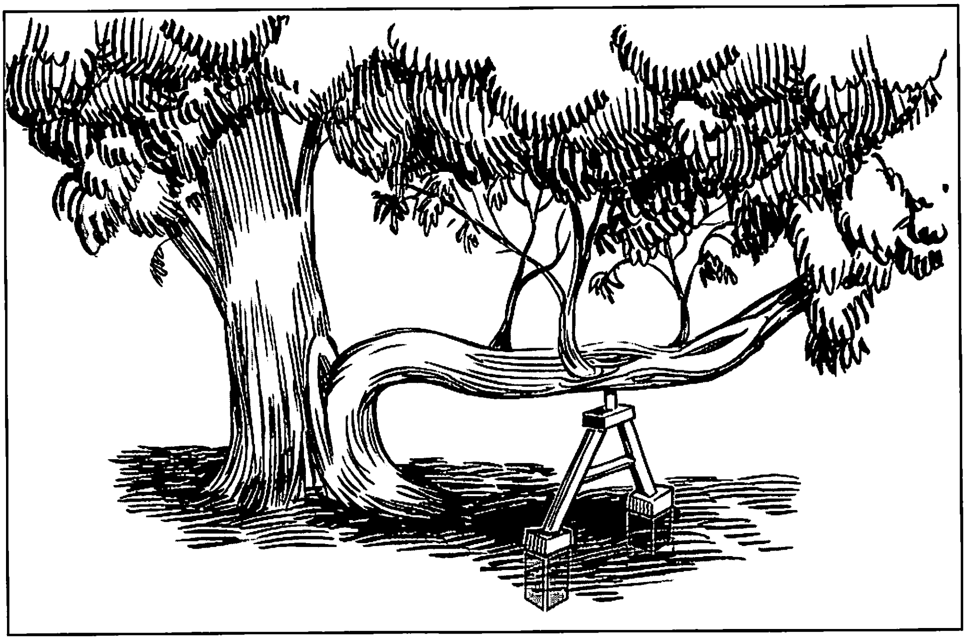


Figure 32. Prop design used to minimize the effects of side forces. The branch rests on a pin or bolt.

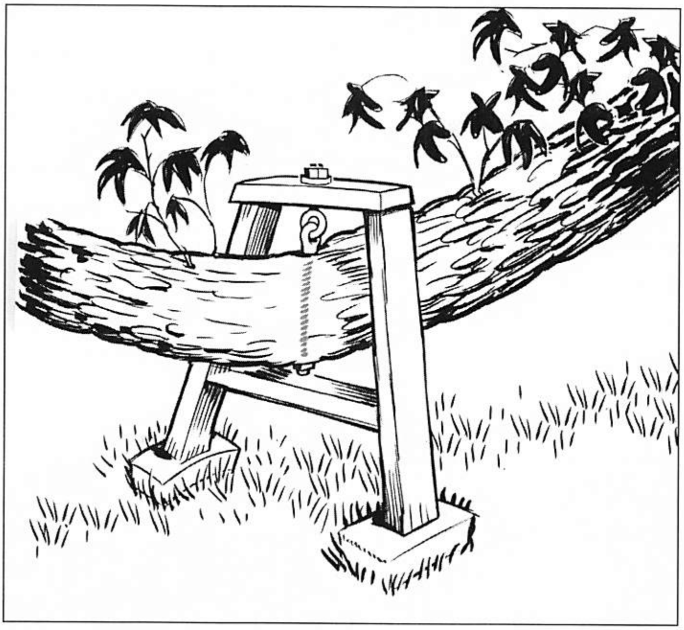


Figure 33. Prop design used to minimize the effects of side loading and to allow some movement of the branch. This design is more difficult to construct and assemble on the tree. It can be installed only with an eye bolt or amon eye.

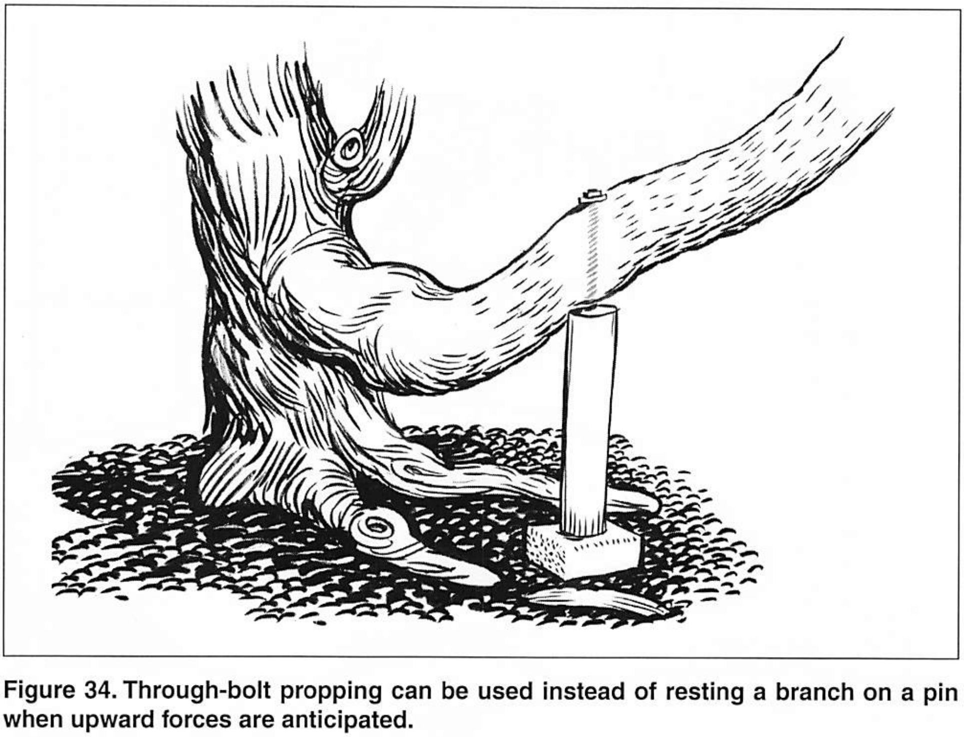


Figure 34. Through-bolt propping can be used instead of resting a branch on a pin when upward forces are anticipated.

8. Support System Inspection

Periodic inspections of all types of support systems are necessary to determine the need for maintenance, upgrading, and/or replacement of the system. Tree condition, growth and changes in architecture, and the integrity of system materials should be inspected. For trees with cables, the following should be inspected: tension; location above the union; condition of the cable, associated hardware, and bonding with lightning protection (if applicable); and the structural integrity of the tree.

Visual inspections are often conducted annually or biannually. Less frequently, the tree should be climbed and examined from an aerial lift, or by use of an airborne camera.

Inspections can be aided by the use of an inspection checklist, binoculars, and mallet or sounding hammer to detect the presence of severe decay.

The inspection should be documented and the client given a report of the results, which includes the date of the inspection, methods used to perform the inspection, and any findings.

Support systems should be adjusted, replaced, or repaired when any of the following conditions are discovered:

- excessive wear, corrosion, or degradation of any components of the support system
- the cable or other components are unintentionally rubbing against the tree
- partial girdling of the tree by encircling slings, saddles, props, straps, or ropes
- static components that have signs of excessive movement
- the cable too low to be effective, typically when the cable is less than half the distance from the union to the branch tops
- excessive slack or excessive tension in a cable
- increase in tree size or changes to wind exposure renders installed components inadequate (too small to hold the load)
- substandard or ineffective anchors or terminations
- damage to the tree at the anchor point (hole elongation, decay, fluxing, etc.).

Glossary of Terms

amon-eye nut—a drop-forged eye nut used to fashion a through-hardware anchor.

anchor—hardware installed to affix and/or terminate a cable or guy to the tree, ground, or other device.

anchor tree—a tree used to provide supplemental support in a guying installation.

arborist—a professional who possesses the technical competence, through experience and related training, to provide for or supervise the management of trees and other woody plants in the residential, commercial, and public landscapes.

bond—an electrical connection between an electrically conductive object and a component of a lightning protection system that is intended to significantly reduce potential differences created by lightning currents.

braces—metal rods installed through branches or stems to limit movement and provide supplemental support.

bracing—installing of lag-threaded screws or threaded-steel rods in limbs, leaders, or trunks to provide supplemental support to weak branch unions.

cable—*v.* to install steel cable or synthetic rope between branches within a tree to limit movement and provide supplemental support; *n.* steel wires twisted together in a uniform helical arrangement; cable intended for arboricultural applications typically contain seven wires that are zinc-coated; *n.* steel or fiber ropes installed between branches within a tree to limit movement and provide supplemental support.

cabling—installing of a cable within a tree between limbs or leaders to limit movement and provide supplemental support.

codominant stems—forked branches nearly the same size in diameter, arising from a common junction and lacking a normal branch union; may have included bark.

compartmentalization—a natural defense process in trees by which chemical and physical boundaries are created that act to limit the spread of disease and decay organisms.

connector clamp—a multipurpose bolt clamp used to bond conductors or to bond a conductor to a ground terminal or tree supplemental support system, and meets the specifications of ANSI/UL-96.

dead-end brace—a brace formed by threading a lag-threaded screw rod directly into a limb, leader, or trunk but not through the side opposite the installation.

dead-end grip—a manufactured wire wrap designed to form a termination in the end of a 1 × 7 left-hand lay cable.

dead-end hardware—anchors or braces that are threaded directly into the tree but not through the side opposite the installation; dead-end hardware includes but is not limited to lag hooks, lag eyes, and lag-threaded screw rods.

eye bolt—a drop-forged, closed eye bolt used to anchor cables to the tree in a through-fastened system.

eye splice—a closed-eye termination formed from common-grade cable by bending it back on itself and winding each wire around the cable a minimum of two complete turns.

grip—a mechanical device that grasps and holds a cable during installation.

guy—wire, rope, or webbing installed from a tree to an external anchor to limit movement and provide supplemental support.

guying—installing of a steel cable or synthetic-rope cabling system between a tree and an external anchor to provide supplemental support.

included bark—bark that becomes embedded in a union between branch and trunk or between codominant stems, causing a weak structure.

lag eye—a lag-threaded, drop-forged, closed-eye anchor used for dead-end systems.

lag hook (J-hook)—a lag-threaded, J-shaped anchor.

lag thread—a coarse screw thread designed for securing into wood.

lag-threaded hardware—anchor or brace with lag threads; lag-threaded hardware includes but is not limited to lag eyes, lag hooks, and lag-threaded screw rods.

lag-threaded screw rod—a lag-threaded steel rod used for dead-end and through-brace installations.

peen—the act of bending, rounding, or flattening the fastening end of through-hardware for the purpose of preventing a nut from "backing off."

props—ridged structures installed beneath a low branch or trunk to limit movement and provide supplemental support.

qualified arborist—an individual who, by possession of a recognized degree, certification, or professional standing, or through related training and on-the-job experience, is familiar with the equipment and hazards involved in arboricultural operations and who has demonstrated ability in the performance of the special techniques involved.

shall—as used in ANSI standards, denotes a mandatory requirement.

should—as used in ANSI standards, denotes an advisory recommendation.

swage sleeve—a hollow metal fitting used to terminate a wire rope (aircraft cable).

taut—tightened to the point of eliminating visible slack.

termination—a device or configuration that secures the end of a cable to the anchor in a cabling or guying installation.

termination hardware—hardware used to form a termination; termination hardware includes but is not limited to dead-end grips, thimbles used in eye splices, swage sleeves, and cable-stop termination devices.

thimble—an oblong, galvanized, or stainless-steel fitting with flared margins and an open-ended base.

threaded-steel rod—a machine-threaded steel rod used for through-brace installations.

through-brace—a brace formed by installing through-brace hardware into a limb, leader, or trunk, secured with nuts and heavy-duty washers; through-hardware includes but is not limited to eye bolts, lag-threaded screw rods, and threaded-steel rods.

turnbuckle—a drop-forged, closed-eye device for adjusting cable tension.

wire rope (e.g., aircraft cable)—a cable fabricated from individual wires twisted together in a uniform helical arrangement; wire rope used in arboricultural applications typically contains seven groups of 19 wires each.

wire rope clamp—a clamp consisting of a U-bolt, bracing plate, and fastening nuts.

Selected References

Blair, D.F. 1995. *Arborist Equipment: A Guide to the Tools and Equipment of Tree Maintenance and Removal* (2nd edition). International Society of Arboriculture, Champaign, IL.

Smiley, E.T., and K.D. Coder (Eds.). 2002. *Tree Structure and Mechanics Conference Proceedings: How Trees Stand Up and Fall Down.* International Society of Arboriculture, Champaign, IL.

Harris, W.H., J.R. Clark, and N.P. Matheny. 1999. *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines* (3rd edition). Prentice Hall, Upper Saddle River, NJ.

Shigo, A.L., and R. Felix. 1980. Cabling and bracing. *Journal of Arboriculture* 6(1):5–9.

Smiley, E.T. 1998. Countersinking for tree bolts. *Journal of Arboriculture* 24(5):245–247.

Smiley, E.T., C.M. Greco, and J.G. Williams. 2000. Brace rods for codominant stems: Installation location and breaking strength. *Journal of Arboriculture* 26(3):170–176.

Stobbe, H., D. Dujesiefken, and K. Schroder. 2000. Tree crown stabilization with the double-belt system Osnabrück. *Journal of Arboriculture* 26(5):270–273.

Thompson, A.R. 1959. Tree Bracing. *Tree Preservation Bulletin No. 3.* National Park Service. U.S. Government Printing Office, Washington, DC.

Tree Care Industry Association. 2013. *American National Standard for Tree Care Operations—Tree, Shrub, and Other Woody Plant Management—Standard Practices (Supplemental Support Systems) (A300, Part 3).* Tree Care Industry Association, Manchester, NH.

Watson, G., 2014. *Best Management Practices: Tree Planting.* International Society of Arboriculture, Champaign, IL.

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ISBN 978-1-881956-85-3

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