JOURNAL OF
ARBORICULTURE
June 1975
Vol. 1, No. 6

CABLING AND BRACING[1]

by Leslie S. Mayne

Most foresters in the past have been conditioned by education and practice to consider trees en masse for their economic or utility purposes rather than for their aesthetic and more intangible values. With the advent of the multiple use concept in our national forests, they now are aware that trees may have other values which in the past they may not have considered. With this recognition came the understanding that the tree, perhaps decayed or leaning, which previously would have been culled out, might be the very tree which added a quality to the natural landscape. With this thought in mind, they sought alternative methods to preserve such trees and yet relieve the public of many of the hazards associated with them.

Much that I am about to present is elementary to you and many of you may have given much more thought and have had much more experience than I in this field. However, I hope that you will bear with me if I review much that may be second nature to all of you who are practicing arborists. Hopefully there may be one thought or one technique suggested in this paper which stimulates you to give further thought to this matter of cabling and bracing.

I do believe that the time is ripe for a review of our methods for we are becoming each year more exposed to liability suits either as contractors whose cabling or bracing systems have failed or as consultants who have specified cabling or bracing inadequately. I stress this liability aspect because all of us are aware of the increasing number of malpractice lawsuits that physicians are having to face today, even to the extent that they are being sued not only for faulty performance but also for poor judgement. The suing for poor judgement is manifestly unfair because only God is infallible and we poor mortals are destined to make poor judgements time and time again. However, since this liability exposure does exist, the medical profession is becoming so cautious as to practice defensive medicine. Such defensive medicine is not only probably hard on the patient but also on the pocketbook of the patient.

The analogy of the practice of medicine and the practice of arboriculture is not far fetched. Both professions deal with living things. In both cases decisions must be made although there may be many unknowns. The practice, therefore, of both professions is an art rather than a science.

Although we cannot always be right in our judgement, yet where facts are known we must use all available knowledge of the strength of materials and their utilization. This is essential since we may be held responsible as either contractors actually installing the cabling or bracing or as consultants prescribing the methods and materials to be used.

Cabling is a means of holding trees upright, or together, or aiding the support of a limb by attaching cables either within one tree for mutual support, or the support of one member, by attaching to other sturdier trees, or to anchors in the ground.

Bracing consists of supporting split crotches and cavities by means of long bolts or lag

[1]Presented at the 50th International Shade Tree Conference in Atlanta, Georgia, August, 1974.

thread-rod or by the installation of pipe supports in order to brace a limb or a whole tree.

With the exception of split crotches and strengthening cavities, cabling and bracing generally are only undertaken after the alternatives of pruning and heading-back to laterals have been considered, and either rejected or considered to be inadequate for serving the purpose of caring for the tree or sufficiently diminishing the hazards connected with that tree. The rejection of pruning or the heading-back to laterals in order to reduce excessive terminal weight, or reduce the sail effect of the wind against the tree may be for the reason that certain aesthetic aspects would be lost by such pruning or the tree might not otherwise lend itself to such work. Then, and only then, should cabling and/or bracing be considered.

What is cabling? Cabling is the supporting of a limb or tree by means of a 7-wire strand attached to the tree by means of a lag (wood thread) eye of "J" lag screws or by boring through the tree and inserting an eyebolt with a washer and nut on the other end. Occasionally a turn-buckle and/or a compression spring is attached to the cable for certain reasons described later. The sizes of cable and lags have been reasonably spelled out in the past. Common sense must acknowledge that the size of cable must be related to the strength and/or holding power of the "J" lag or eyebolt.

Seven-wire strand can vary considerably in its tensile strength. However, we will only consider the 7-wire single galvanized strand because in order to quickly make a neat lineman's eyesplice, it is necessary to employ strand that is not too stiff. Generally speaking, the higher the tensile strength the greater difficulty there is in wrapping around each wire in a 7-wire strand.

Some of you may be aware of the National Park Tree Preservation Bulletins of December, 1935, particularly Bulletin No. 3 by A. Robert Thompson. Perhaps many of you remember Bob Thompson, as I do, and others may recall that he gave a paper at the National Shade Tree Conference (Proceedings of 1936) on cabling. Bob Thompson was a forester and the shade tree expert for the National Parks. He tested out all of the materials available for cabling and found the correct combinations to give the maximum tensile strength. He tested by machine, to the breaking point, finding not only the relationship for a given diameter cable to a given diameter lag but also found that the best size of hole for each size of lag varied with the species of wood.

Figure 1, taken from Thompson's bulletin shows the steps in making an eyesplice. You will note that each wire is wrapped around the remaining wires and the cable; the end result is a neat tapered splice. This is accomplished by using the jaws of heavy pliers as leverage when rolling the wires around.

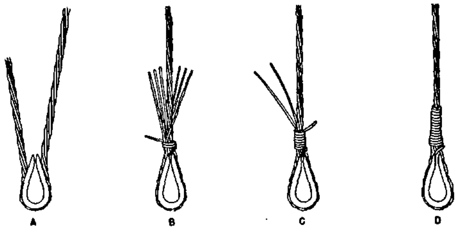

FIG. 19

STEPS IN MAKING AN EYESPLICE IN 7-WIRE STRAND

An eye splice in seven-wire strand is made as follows: First a loop is made by bending the cable about 10-12 inches from the end, then a thimble or eye is inserted in the loop. The wires of the 10-inch section are then unwrapped and laid along parallel to the main piece of cable. One strand is selected and wrapped with pliers tightly around both the cable and the remaining six strands. Two wraps are made with this strand which is then cut off. The rest of the strands are then wrapped, one at a time, as with the first strand. This results in a tapered eye splice which is not only efficient but is inconspicuous. Our tests have shown that one wrap of each strand will give maximum efficiency, but since it is practically as easy to make two wraps this number will be used in Park Service splicing for the sake of a possible margin of safety and for the improved appearance.

An eye splice in copper-covered steel wire or strand is formed essentially as described above except that a wire server is used in twisting the individual wires instead of pliers which would scrape the copper coating.

Figure 1

Thompson found that only two wraps were required to make a splice as strong as the cable. Clamps are not effective. Thompson recommends use of thimbles, yet it has been our experience that a cable without the thimble holds as much as one that does. The only drawback is that the cable without a thimble has a greater leeway for stretching. Off-setting this is the greatly reduced cost. It takes much less time to install and splice without thimbles. However, the California State Park Department calls for thimbles on their splices and this is undoubtedly the best procedure.

Figure 2 not only illustrates the type of hardware used in cabling but also gives various designs for cabling systems. Note that the "box" method of cable placement permits more mutual movement of the limbs. A greater stress will be placed on one cable in a straight cable method should the two connecting trunks or limbs not sway in unison. Only one cable should be attached to one "J" lag or eyebolt.

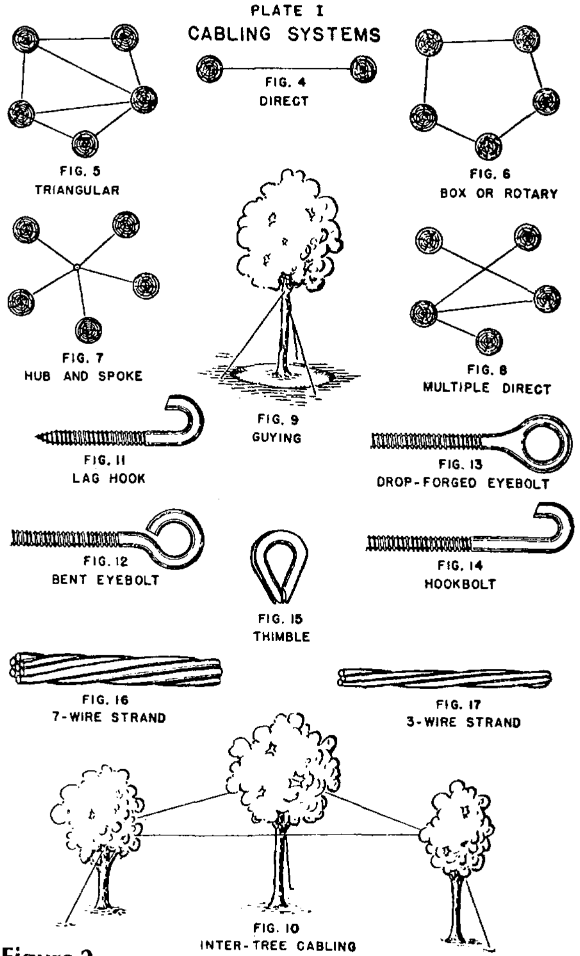

Figure 2

Since 90 percent of all cabling is done with a "J" lag hook, let me draw attention to its design. The threads should be deep and sharp for holding power. As a rule of thumb, the holes drilled are 1/16-inch smaller than the diameter of the lag. However, under some circumstances a hole 3/32-inch smaller is better.

These "J"lags come in pairs, one with a left and the other with a right thread. After the cable installers have inserted about 4 turns of the thread and have made their splices, each one of the pair of installers screws his lag into the tree. The result is a taut cable since the pair of lags act as a turnbuckle. This method does away with the necessity of "come alongs" and tackle.

Although not illustrated, a word should be given on the anchors for holding guy cables. The use of different types of anchors will vary with the type of soil and the degree of anticipated strain. The simplest anchors are screw anchors consisting of a round-slotted plate, 2 to 8 inches in diameter, welded to a 30- to 72-inch eyerod varying in thickness from 3/8- to 3/4-inch in diameter. These anchors are easy to install in a damp, loam or clay soil.

Utility companies have developed a cone anchor, consisting of a cast-iron cone on the end of a long eyebolt. The cones vary in size from 6 to 12 inches in diameter. The hole, 3 to 4 feet deep, is bored into the ground, anchor and eyebolt are placed into the hole, followed by 2 feet or so of sharp 1 1/4-inch drain rock. Soil is then tamped in up to ground level. The 12-inch diameter cone anchors are supposed to hold six tons.

A clumsy but efficient anchor driven into the ground by means of a sledge hammer is an impact anchor made from reinforcing steel with an angle plate to take the lateral pull of the anchor cable. However, they do not hold effectively if the guy cable anchor is greater than 45° to the plane of the ground.

The tables of tensile strengths of materials refer to the "static load" omitting the dynamic load or stress. It can be assumed that the dynamic load is twice the static load and since the American Society of Civil Engineers suggest that the safety factor of four is acceptable, then it can readily be seen that the static load should not be over one-eighth of the tensile strength of the material. In other words, the safety working stresses should consider 1) ratio of static load to sudden dynamic load; 2) effect of repeated stress; and 3) necessary factor of safety.

While we are on the subject, I might mention that because we were dissatisfied with a 3-way guy anchor system, because of its rigidity, we had made up heavy compression springs, one of which is added to one of the guy cables thus permitting some sway. These compression springs can be used in an intertree cabling system where it is estimated that the irregular sway of each tree may cause undue stress on the cable and attachments.

The following tables are taken from Bob Thompson's bulletin or from the ISTC Proceedings of 1936.

Figure 3 gives the results of the lag hook test. In this table you will find the best, but not the ideal combination of sizes of cable to sizes of lag screws, namely 1/4-inch cable - 1/2-inch lag; 3/8-inch cable - 5/8-inch lag; 1/2-inch cable - 3/4-inch lag.

The most common size used is 3/8-inch diameter cable which, allowing for the holding power of a 5/8-inch lag in wood has a holding power of about 4200 pounds; the cable itself has a breaking strain of about 5200 pounds.

HOOK LAG TEST

A total of 270 hook lag screws of all commercial sizes from ¼ inch, to ¾ inch diameters were screwed into logs, approximately one foot in diameter and six feet long, which had been freshly cut and coated with paraffin wax in June. The following species were represented: silver maple, red oak, yellow poplar, white ash, and American elm.

The lead holes were drilled 1/32 inch, 1/16 inch, and 3/32 inch diameters smaller than the lag threads for each size lag for each of the above species.

The tests were made to determine the force required to pull the screws from the logs or to induce failure in the hook lag screws. Table No. 2 summarizes the tests of hook lag screws:

TABLE NO. 2

HOOK LAG TEST—STATIC LOAD

ULTIMATE STRESSES REQUIRED FOR FAILURE

Nominal Diameter of Lag	Lead Hole Diameter	Species of Green Timber: Silver Maple	Red Oak	Yellow Poplar	White Ash	American Elm
inches	inches	pounds	pounds	pounds	pounds	pounds
1.	2.	3.	4.	5.	6.	7.
1/4	5/32	650 S	730 S	640 S	740 S	710 S
	3/16	570 S	560 S	530 S	600 S	610 S
	7/32	610 S	740 S	620 S	540 S	690 S
5/16	7/32	1110 S	1040 S	950 S	1300 S	1050 S
	1/4	990 S	1010 S	870 S	1280 S	960 S
	9/32	1050 S	1090 S	800 *	700 *	810 *
3/8	9/32	1390 S	1430 S	1420 S	1640 S	1610 S
	5/16	1550 S	1500 S	1300 *	1540 S	1490 S
	11/32	1390 S	1430 S	640 *	1320 *	1440 *
1/2	13/32	1370 *	2590 S	2590 S	2610 S	2600 S
	7/16	2570 S	2630 *	2610 S	2620 S	2580 S
	15/32	2590 S	2450 *	1390 *	1520 *	1740 *
5/8	17/32	3940 *	1970 *	4280*	3720 *	4860 S
	9/16	4150 *	4710 *	3640 *	4740 S	4650 S
	19/32	1510 *	2690 *	1050 *	2660 *	1540 *
3/4	21/32	5530 S	5000 S	5470 S	3540 *	4840 S
	11/16	4610 *	4830 S	4400 *	5670 S	2580*
	23/32	2410 *	4010 *	2530 *	4540 S	2960 *

Type of failure: *—pulled out of log. S—straightened.

Figure 3

THOMPSON: TREE CABLING MATERIALS 33

TABLE NO. 1

GALVANIZED WIRE STRAND TEST—STATIC LOAD

Nominal Diameter of Cable	Ultimate Strength: Minimum	~~Minimum~~ Maximum
inches	pounds	pounds
3/16	1,200	1,450
1/4	2,100	2,560
5/16	3,970	4,150
3/8	4,920	5,680
1/2	9,500	10,450

These tests led to the following observations and conclusions:

1. Ultimate stress tests were consistent in all sizes of cable, whether 1, 2, 3, 4, 5, 6, or 7 wraps of each wire was used in splicing. Therefore, using more than two wraps of each wire in making a splice is needless.

2. In no case did a splice break. The breaks invariably occurred at the base of the splice or in the free length. There was no consistent difference in ultimate stresses at either point. Therefore, we must conclude that a wrapped eye splice or serving approximates 100 percent in efficiency.

3. A definite yield point was noted in the strand stretch tests. This point was fairly consistent for all diameters and occurred at about 80 to 85 percent of the ultimate stress. It was noted that galvanized strand stretched approximately 1.1 inches per foot before reaching the ultimate stress.

4. The relative efficiency of an eye splice or serving over wire rope clamps and clips is clearly demonstrated when it is realized that the efficiency of each clip is only 13 to 15 percent that of the wire rope itself.[1] Clips are also undesirable because the bolts become loose as the wire stretches, and because clips frequently crush and bruise the wires, thus allowing slippage.

[1]Federal Standard Stock Catalogue. RR-R-571. 1933. Sect. IV. Part 5, Table XLIV.

Figure 4

Figure 4 shows the tensile strength of galvanized 7-wire strand as determined by Thompson.

Bracing when using lag rod (wood-threaded rod) or bolts with nuts is an extension of cabling and is often used with it.

The materials used in lag rod or bolt bracing are two types—the simplest is a long bolt with thread and nuts with washers on each end. It has the advantage that considerable "squeeze" can be applied by taking up on the nuts. The drawback is that since the holes for the bolts must be at least 1/32-inch larger than the diameter of the bolt and the impossibility of thoroughly painting the sides of the hole, decay can result due to fungus invasion. However, such bolts are cheaper and can be readily cut and threaded to length at the site.

Lag rod which comes in 10-foot lengths and from 3/8 to 3/4 inch in diameter is more expensive. It has the advantage that it holds in the wood and, consequently, requires no washers or nuts except where the walls are too thin for holding or where some "squeeze" is required. Should "squeeze" be required then one of the two aligned holes must be the same diameter as the lag rod, then a washer and lag-threaded nut is used. The nut and washer should be below the cambium layer.

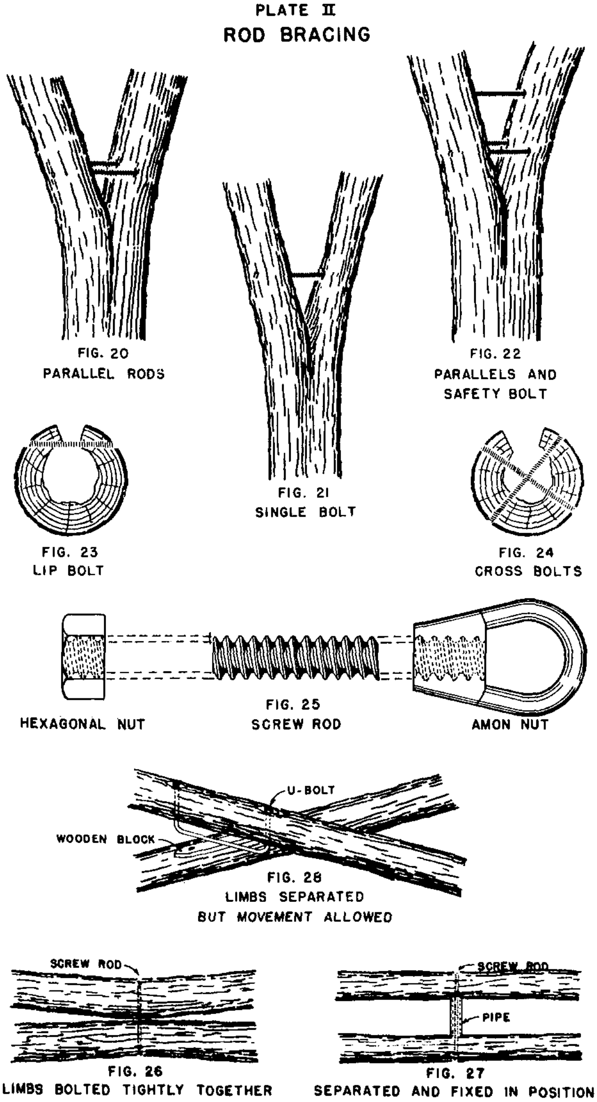

Figure 5

Figure 5 illustrates some of the uses of lag rod including methods of alleviating the problem of rubbing limbs.

We have not considered the amon nut very satisfactory except in a straight pull as there is a tendency for threaded rod to crystalize if there is any sway motion. "J" lags and eyelags should be inserted so that the round unthreaded shank is inserted at least 1/2 inch below the cambium.

Although unaesthetic because of their conspicuousness, pipe supports (Figure 6) are often the only answer when a long heavy limb is to be preserved or where a tree has become unstable due to a weak root system or excessive lean.

Figure 6

The pipe supports are installed in a manner to permit a very slight swaying of the tree. The method used is to seat the pipe on a steel plate on top of a concrete foundation rather than in the foundation for the reason that if the pipe is imbedded in the foundation it is so rigid so that consequently any slight sway will either crack the foundation or in time crystalize the pipe support. Likewise the top of the pipe permits some movement by the counter-sinking of the pipe cap in the wood with a lag bolt inserted through the cap into the tree.

Generally, pipe supports are less noticeable and less unsightly if they are vertical. However, there are times, particularly with a tree which leans excessively, where pipe supports, sloping with the line of thrusts is most appropriate.

You will note that in spite of my emphasis of matching the strength of each unit in the support system whether a cable, bolt, or steel pipe seldom are the matchings entirely correct even when the strength and/or holding power of the materials are known. For instance, we are limited in sizes of lags, and even if the sizes were available, different manufacturers cut the thread to a varying degree of depth thus varying the tensile strength or degree of sharpness which influences their holding power. Another fault in the system is when lag threads extend level with the end of the hook of a "J" lag. Such a lag tends to crystalize and break at the threads where they enter the wood if there is sway. A further problem has arisen—namely that 3/4-inch "J" lags appear to be no longer available. They were not an ideal match with 1/2-inch cable but were the only alternative to specially-made 3/4-inch eyelags. I know that 1/2-inch cable is seldom used, particularly in the East, but we have found a use for it in California when guying or supporting particularly heavy trunks and it does give a margin of safety above that of 3/8-inch cables.

Finally, for those of you who act as consultants, may I strongly advise that your cabling specifications be detailed and thorough for it is only by precise specifications coupled with a careful inspection on the completion of the contract that uniform good work is obtained. Not only are specifications no better than the ultimate inspection but for those of you whose duty it is to invite contractors to bid on tree work, those firms which have high standards will be so discouraged when they see the winner get away with poor quality of workmanship that they may tend in the end to ignore invitations to bid.

Mayne Tree Expert Co., Inc.
Burlingame, California

ABSTRACT

Davies, W. J. and T. T. Kozlowski. 1974. **Stomatal responses of five woody angiosperms to light intensity and humidity.** Can. J. Bot. 52: 1525-1534.

Stomatal responses to changes in light intensity and humidity were studied in green and chlorotic *Fraxinus americana, Acer saccharum, Quercus macrocarpa, Citrus mitis,* and *Cercis canadensis* seedlings. Stomata opened and closed faster in green than in chlorotic plants. Stomatal opening in chlorotic plants was faster in *Acer* than in other species, where stomata opened to equilibrium in about the same time. With changes in humidity from 20% to 80%, and the reverse, stomata of *Fraxinus* and *Acer* opened faster than they closed. Stomatal resistance was affected more by humidity changes at low light intensity than at high intensity. Postillumination CO_2 bursts from leaves occurred in all species and were greater in green than in chlorotic plants. Physiological responses of stomata are discussed in relation to leaf anatomy and metabolism.

Les auteurs ont étudié les réactions des stomates à des changements d'intensité lumineuse et d'humidité relative chez des plantules vertes et chlorosées de *Fraxinus americana, Acer saccharum, Quercus macrocarpa, Citrus mitis,* et *Cercis canadensis.* Lest stomates s'ouvraient et se fermaient plus rapidement chez les plantes vertes que chez les plantes chlorosées. L'ouverture des stomates chez les plantes chlorotiques était plus rapide chez *Acer* que chez les autres espèces, ou l'ouverture des stomates prenait le même temps pour atteindre l'équilibre. A la suite de changements dans l'humidité relative de 20 à 80% et vice versa, les stomates de *Fraxinue* et d'*Acer* s'ouvraient plus rapidement qu'ils ne se fermaient. La résistance des stomates fut plus fortement affectée par des changements d'humidité à faible intensité lumineuse qu'à haute intensité. L'émission subite de CO_2 par les feuilles après illumination a eu lieu chez toutes les espèces et était plus importante chez les plantes vertes que chez les plantes chlorosées. Les auteurs discutent les réactions physiologiques des stomates en relation avec l'anatomie et le métabolisme des feuilles.