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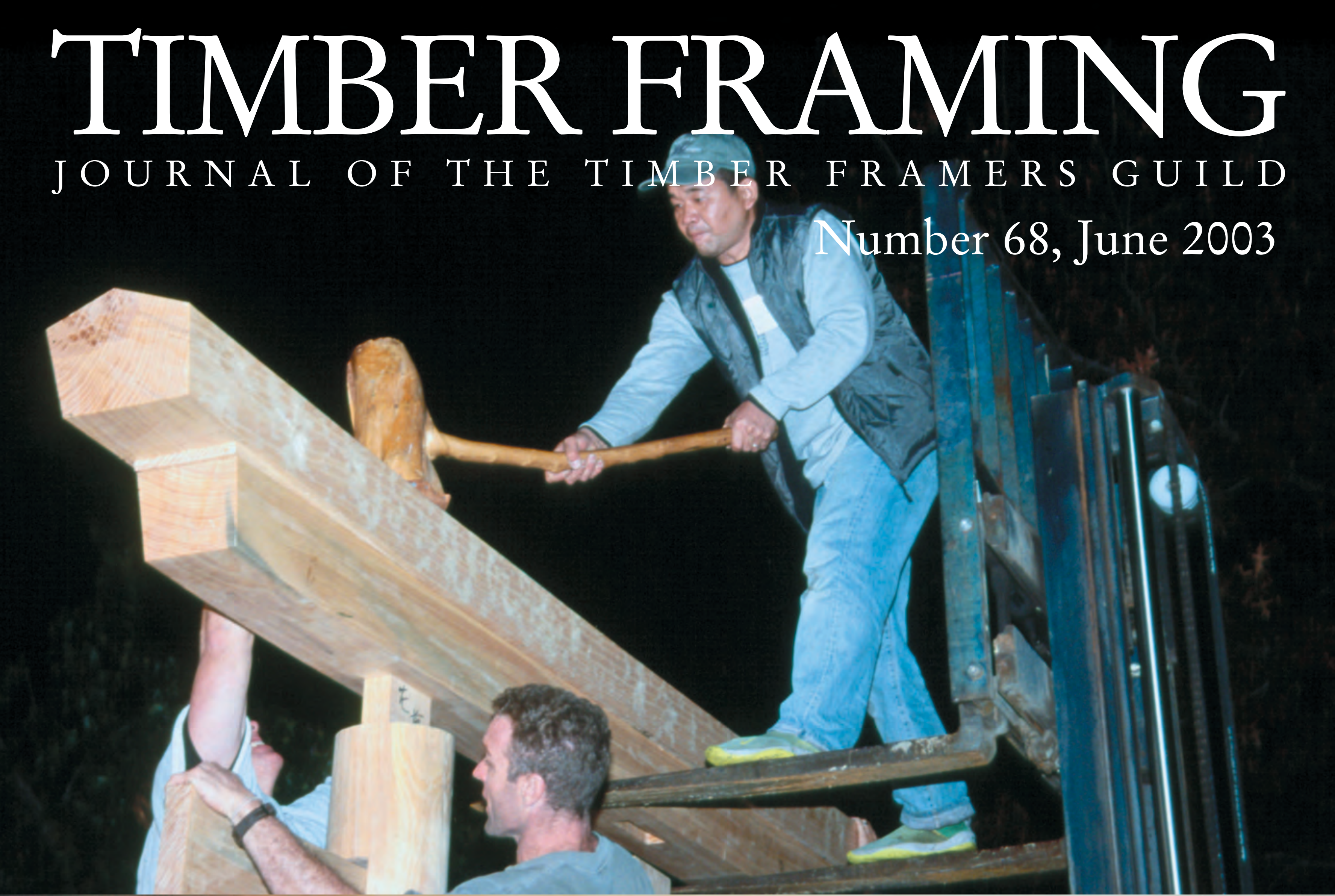


Kezurou-Kai in America

Ropes and Knots

ROPE and knot work is often regarded as some sort of black art. Climbing and arborist catalogs list all sorts of exotic (and expensive) ropes. Knot books with their endless variety of knots leave one in despair as to which knot to use. How can you select or remember the right knots or rope for a timber framing application? Like much of life, once you get past the clutter, a small group of simple things learned and done well will cover almost any situation. Most human-scale frame rigging can be done with readily available Manila or polyester rope. And six different knots will handle any timber frame rigging job.

Rope in all its forms is a collection of small fibers bound or wound together to allow the fibers to grip each other and withstand tension. All that transmits a pull from one end of a 120-ft. rope to the other is the friction between the individual short fibers. Rope works only by pulling (tension) in a straight line. You cannot push on a rope. Anything that causes a rope to deviate from a straight line (such as a knot) decreases the strength of the rope. For negotiating turns, manufacturers specify minimum acceptable ratios of pulley diameter to rope diameter according to the type of rope.

Natural rope. Plant fibers have been twisted into rope since before recorded history. Individual fibers can be up to 10 or 12 ft. long. Natural rope is probably the most easily obtainable, but it suffers the limitations of an organic material.

Sisal rope is normally a three-strand rope twisted from the henequen fibers of the agave plant, with a whitish color and a rather coarse feel. Sisal is low in price but not durable. It is susceptible to decay from weather and should be examined often for signs of deterioration. Because it degrades rapidly, sisal is not recommended for loading. This is the stuff found in small coils at the local hardware store, fine for tying bundles but not for lifting bents.

Manila rope is made from the fiber of the abaca plant, which grows in the Philippines. Much of this golden brown rope is shipped from the port of Manila, explaining the name. Manila rope is flexible and strong and stands up well to wear and weather. Number 1 Manila rope is suitable for most rigging applications and readily available in the US.

Hemp rope is made from the fibers of the hemp plant. Hemp is generally light gray in color and has a soft feel, with strength similar to Manila's, but it's much more flexible. Hemp generally is used in small sizes, for detail work (rope ladders, bell pulls, floor mats) and for rat and service lines (parts of the rigging on a traditional sailing ship), but not for main lifting tackle. Hemp rope is not readily available in the US. There is political resistance to the cultivation of the plant as well as confusion about its uses.

All of the natural fiber ropes are most readily available as standard, three-strand twisted rope. Manila can also be found in an eight-strand braided configuration.

Synthetic rope is made up of individual fibers that can run the entire length of a piece of line. The longer fibers give the rope greater strength for a given size than rope of vegetable fiber. As synthetic materials, these ropes are also impervious to rot and mildew. They also tend to be more resistant to wear and abrasion. However, it's worth noting that they do soften at high temperature.

Nylon rope has a chalky white color, with a soft feel and over twice the strength of Manila. It is available in both three-strand and braided construction. Nylon is highly elastic and can absorb shock. As it wears, its outer surface becomes fuzzy, protecting the rope from further abrasion. It is resistant to alkalis but weakened by acid. Also, nylon does absorb water and loses about 10 percent of its strength when wet. Because of its elasticity, nylon rope can snap back dangerously if it breaks under load.

Polyester (Dacron) rope is slightly heavier than nylon, and with slightly lower strength. Its abrasion and chemical resistance are similar to nylon's, and it too is available in both three-strand and braided construction. Polyester rope does not absorb water and therefore loses no strength when wet. Its shock-absorbing capacity is about two-thirds that of nylon. Polyester rope is often tinted brown to look like Manila for historic rigging purposes.

Polypropylene rope is weaker than both nylon and polyester. It stretches about the same amount as nylon, and has similar chemical and abrasion resistance. Polypropylene rope is lighter than nylon and floats in water. It is unaffected by wetting. Perhaps the most recognizable use of polypropylene rope is as water-ski tow rope.

Exotics. Development of special fiber such as Kevlar has led to the production of high-strength, lightweight (and expensive) ropes such as Spectra, Technora and Vectran. These ropes are commonly composed of a core of parallel high-strength fibers protected by a braided cover of an abrasion-resistant material such as polyester. (Vectran is also available without a cover.) The core does the work while the cover serves to protect the core. Such ropes have more use in sailboat and specialty rigging than in timber frame raisings.

The table below gives the relative strengths and costs of the ropes discussed. Cost data are from McMaster-Carr (www.mcmaster.com), a principal supplier.

Most normal timber framing raising loads can be safely handled with one or more sets of block and tackle threaded with ½-in. to 1-in. Manila or polyester. (Nylon's stretch is a problem for lifting applications.) If larger forces or more complex problems are involved, don't be bashful about asking rope suppliers or manufacturers for help. They can and will provide extensive technical help in choosing and using their products correctly. An Internet search will quickly turn up a number of rope suppliers.

Rope Type	½-inch Diameter Breaking Strength (lb)	½-inch Diameter Weight 100ft (lb)	½-inch Diameter Cost 100ft (*$*)	1-in. Diameter Breaking Strength (lb)	1-in. Diameter Weight 100ft (lb)	1-in. Diameter Cost 100ft (*$*)
Sisal, 3-strand	2120	7.5	*13*	7200	27.0	*48*
Manila, 3-strand	2380	7.5	*17*	8100	27.0	*60*
Nylon, 3-strand	5670	6.3	*38*	22,230	25.3	*125*
Nylon, double-braid	8500	6.3	*56*	34,000	25.4	*198*
Polyester, 3-strand	5750	8.0	*61*	19,800	30.4	*160*
Polyester, double-braid	8200	8.0	*92*	38,000	33.0	*243*
Polypropylene, 3-strand	3780	4.7	*14*	12,600	18.0	*54*
Spectra, double-braid	16,984	7.2	*403*	70,000	31.0	*1530*
100% Vectran, braided	18,400	8.1	*483*	71,000	32.0	*1835*

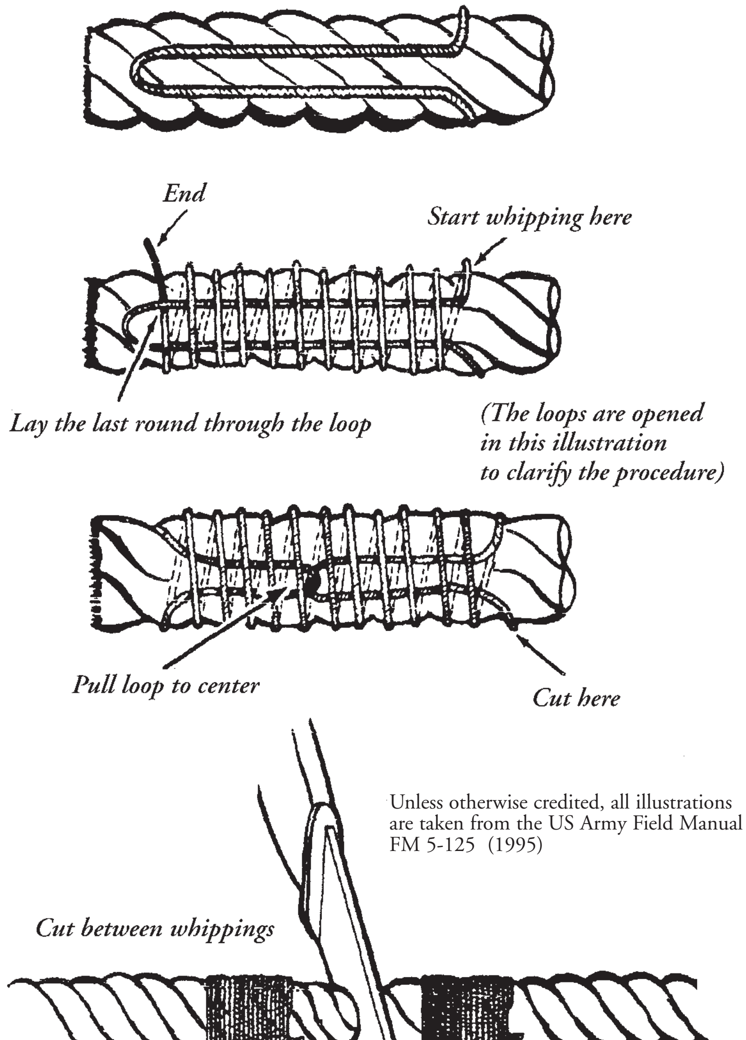
TABLE 1. COMPARISON OF ROPE STRENGTH, WEIGHT AND COST.

Care and handling of rope. The strength of rope relies on the individual fibers remaining intact and retaining their full strength. Each fiber of the rope has to carry its appropriate portion of the total load for the rope to reach maximum strength. Any action that damages the individual fibers of the rope or creates an uneven distribution of load within the rope decreases its strength. Dirt in the rope can cut individual fibers, weakening the rope. Kinks in a rope concentrate the load in the fibers at the outside of the kink, overloading and breaking them.

The first step in putting a rope into service is to uncoil it in a smooth line without developing any kinks. Assuming coiled, three-strand rope, the bundle is placed on the floor with the inside rope end at the bottom. Reach into the coil, grab the end and begin to pull the rope out through the middle. It should uncoil smoothly in a counterclockwise direction. Carefully straighten out any kinks that may develop.

When a rope is not in use, it should be coiled up and stored properly. Recoil in a clockwise direction. As each loop is added to the coil, give the rope a clockwise half-twist to make it coil smoothly without kinking. An alternate method is to coil the rope purposely in a figure-eight configuration. The half-twist that makes each figure untwists as the rope is paid out, preventing kinking.

Whenever a rope is cut, the ends must somehow be tied off to prevent the rope from unraveling. With three-strand rope, the fibers untwist, rendering the rope progressively shorter and less useful. With double-braided rope, failure to secure the ends can cause the braids to slip in relation to each other, causing part of the rope to carry more than its share of the load.



Unless otherwise credited, all illustrations are taken from the US Army Field Manual FM 5-125 (1995)

FIG. 1. WHIPPING THE ENDS BEFORE CUTTING THE ROPE.

The cut end of a rope can be quickly secured using twine and a constrictor knot. A more durable solution is to wind a *whipping* on the end of the rope (Fig. 1). For three-strand rope it's also possible to make a *backsplice* (Fig. 2) to prevent the end of the rope from fraying. An inelegant but effective solution for synthetic ropes is to melt the end of the rope together with a cigarette lighter (the rigging author Brion Toss calls this procedure the Butane Backsplice).

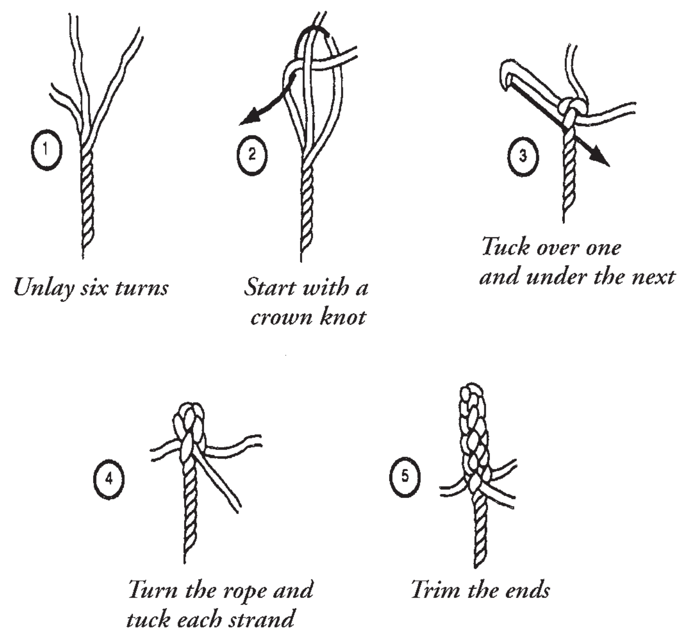


FIG. 2. BACKSPLICE FOR THREE-STRAND ROPE.

The following information on the proper use and care of rope is taken from www.manilacordage.com, the web site for The Manila Cordage Company. This information can be found elsewhere, but it's stated succinctly and particularly well here:

> *Select the best rope for the job. Economy as well as service depend on the right size and quality for the work. Allow a safety factor of at least five to one to determine the safe working load for new rope. As rope ages, the safety factor should be increased.*
>
> *Store the rope properly. Rope should always be dry before storing. Storing wet rope causes mildew and rot. A cool, dry room with free air circulation makes ideal storage. If necessary to store on metal or concrete floors, protect the rope with planking to prevent contact with the floor.*
>
> *Reverse the ends of the rope. Changing ends of the rope regularly when used in tackle permits even wearing and assures longer useful life. If a short section shows undue wear or damage, cut out the worn section and splice the rope for best service. Then make sure the cause of the excess wear is corrected.*
>
> *Keep rope clean. Dragging rope on the ground or over rough, gritty surfaces allows abrasive particles to work into the rope and weaken fibers. If rope becomes muddy or dirty, it should be washed and dried thoroughly before storing.*
>
> *Kinks cause rope failure. Prevent kinks which cause permanent damage and weakening of the rope. If kinks should form, or if the rope is continually twisted in one direction, as over a winch, remove kinks or restore balance in the rope by throwing in twist in the opposite direction.*
>
> *Protect rope from chemicals. Acids and their fumes, alkalis, oils, paints, and barnyard mud are injurious to vegetable fibers and will quickly damage rope.*
>
> *Avoid sudden strains. Jerking or sudden strain may cause failure of a rope normally strong enough to handle the load safely. A steady, even pull will assure full strength from rope.*

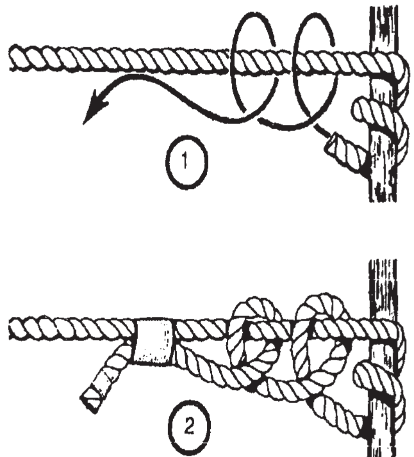


FIG. 3. A ROUND TURN AND TWO HALF-HITCHES.

KNOTS, bends and hitches are just fancy names for some method of attaching a rope either to an object, to itself or to another rope. Books the size of unabridged dictionaries have been written on the subject of knotting. But most timber frame rigging applications can be safely handled with the six (well, seven) knots described below.

A *round turn and two half-hitches* (Fig. 3) are used to secure a rope to a fixed object. This knot is particularly useful for tying off the end of a guy line that will not need to be adjusted for length. It works well around an object such as a tree trunk, telephone pole or trailer hitch ball. The rope wraps smoothly around the anchor, gradually distributing the tension in the rope to the anchor. Without major kinks, the knot reduces the strength of the rope only slightly.

The *clove hitch* (Fig. 4) is another knot used to tie a rope to a fixed object. But it has additional uses as the starting knot for various seizings and lashings. It can also be modified slightly to form a constrictor knot to prevent the unraveling of the cut end of a rope. Like the round turn and two half-hitches, the clove hitch provides a smooth transition of load to the anchor, thereby preserving much of the strength of the rope.

The *tautline* or *rolling hitch* (Fig. 5) is excellent for making an adjustable loop. The primary use in timber framing is for securing guy lines that may need to be adjusted for length. The knot can be tied fairly easily in a rope under load. Also, the length of a guy tied with a tautline hitch can be adjusted under load.

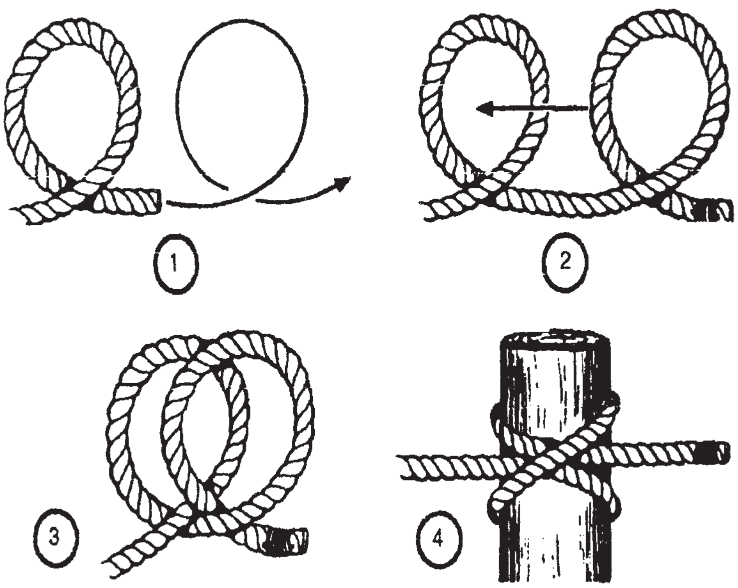
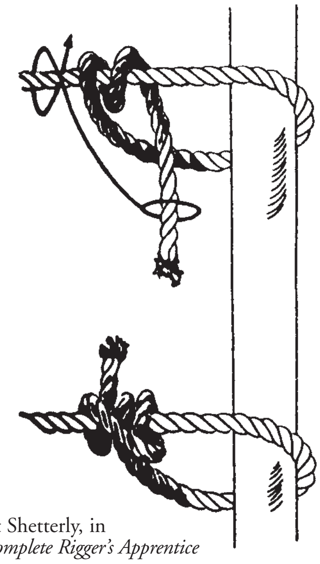


FIG. 4. THE CLOVE HITCH, WHICH MAY BE TIED AT THE END OR IN THE MIDDLE OF THE LINE.



Robert Shetterly, in *The Complete Rigger's Apprentice*

FIG. 5. THE TAUTLINE OR ROLLING HITCH.

The *bowline* (Fig. 6) creates a loop that will not slip. It's particularly useful for attaching guys at the top of gin poles or shear legs and safety ropes for hand raisings. Another use is to attach a rope to the *becket* (the tieoff point on the outside of a block) in a set of block and tackle.

The *sheet bend* (Fig. 7) and *double sheet bend* (Fig. 8) are secure knots for joining two ropes together. The arrangement of ropes in the sheet bend is identical to the bowline, except that the two ropes are joined end to end instead of forming a loop in one rope. The knot works equally well with ropes of equal or different sizes. It can be used also to join a rope to a sling. The double sheet bend is just a more secure version of the single.

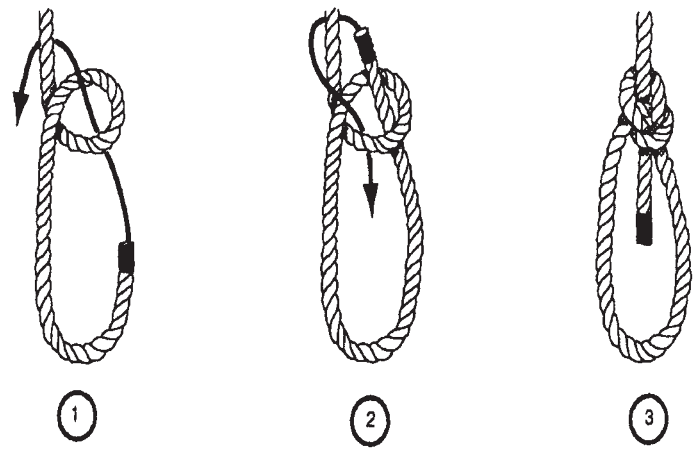


FIG. 6. THE BOWLINE.

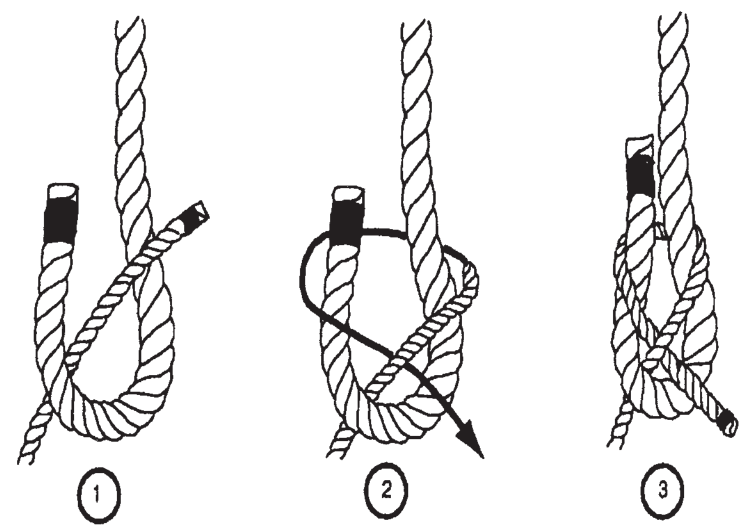


FIG. 7. THE SHEET BEND.

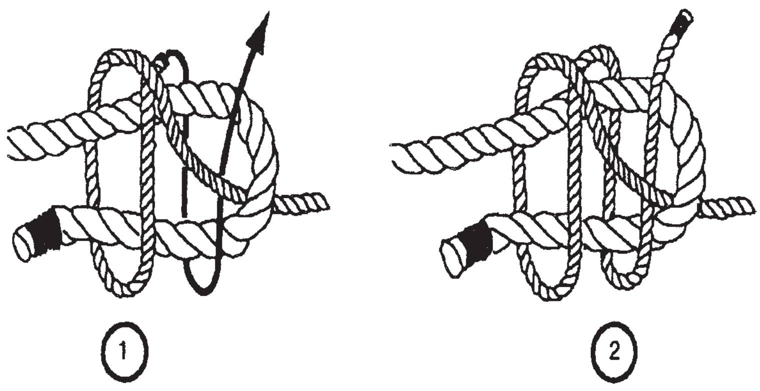


Fig. 8. The Double Sheet Bend.

The Boy Scouts were wrong. The *square knot* is not a good bend for joining two ropes. The ends can snag on an object and cause the knot to untie. The square knot will also come loose quickly with repeated cycles of load or vibration. The sheet bend and double sheet bend are much more secure methods of joining two ropes. Avoid the square knot.

The *trucker's knot* or *Baker bowline* (Fig. 9) is used to form a non-slip loop in the middle of a rope. By passing the running end of the rope around an attachment and back through the loop, it's possible to gain a 2-to-1 mechanical advantage. Truckers use the knot to securely tie down loads. It can shake loose in a slack rope but can be secured by inserting a peg through the knot.

Seizing. Most knots, particularly those used to form a loop or to join two ropes, can be made more secure by a process called *seizing*. Seizing prevents the knot from untying, making a safer and more nearly permanent fastening. The bitter (free) end of the rope is secured to the standing (continuous) part of the rope by wrapping both together with small twine. An example is seen in Fig. 3-2.

Start a seizing by tying a clove hitch around one of the parts of the rope. Then tightly wrap the twine around both parts of the rope for a distance of about two rope diameters (*seizing turns*). Next, reverse direction and cover the seizing turns with another layer of twine (*riding turns)*. Finally, pass the twine between the two ropes and wrap perpendicularly around the middle of the seizing and riding turns. Tie off the ends of the twine and you're done.

I have found seizing particularly useful as a safety measure when attaching a line to a set of blocks. Once the blocks and tackle are in place for a large lift, it's very difficult to get to the top block to ensure all is well. A seizing on the bowline around the becket at the bottom of the block is cheap peace of mind. —Grigg Mullen

Grigg Mullen teaches engineering at the Virginia Military Institute. This article is second in a series on timber frame rigging, which began in TF 67 with "Raising Calculations and Prep" and will conclude with an article on the use of gin pole, shear legs and derrick.

References:

The Complete Rigger's Apprentice, by Brion Toss, illustrated by Robert Shetterly (International Marine/Ragged Mountain Press, Camden, 1998). I highly recommend that any student of rope work obtain this work. Its wit, wisdom, information, advice and humor will last a lifetime. Also useful from a more technical standpoint:

Handbook of Rigging for Construction and Industrial Operations, 4th Edition, by W. E. Rosnagel, Lindley R. Higgins and Joseph A. McDonald (McGraw-Hill, New York, 1988).

Rigging Techniques, Procedures, and Applications, US Army Field Manual FM 5-125 (Headquarters, Department of the Army, Washington, DC, 1995), approved for public release. Also at www.adtdl.army.mil/cgi-bin/atdl.dll/fm/5-125/fm5-125.htm.

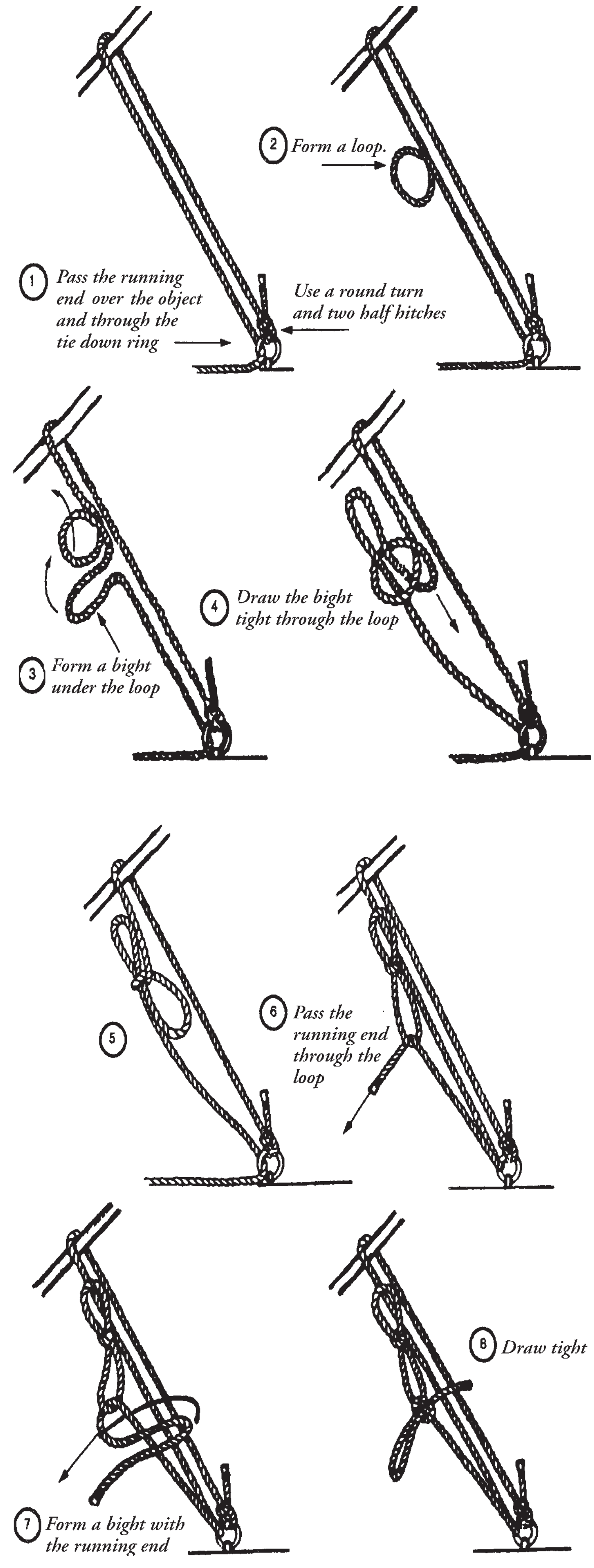


Fig. 9. The Baker bowline or Trucker's Knot.