Chapter 8.
Anchorage Of Floating Bridges

All military bridges must be held in position by some system of anchorage. Anchorage systems can be classified as short-term or long-term. Short-term anchorage generally refers to a method of holding a bridge in position for a limited period of time. Assault bridges, such as the ribbon bridge, are normally anchored using only short-term means. Chapter 4 describes the method of anchoring such bridges, using BEBs. Lines of communications bridges, such as M4T6 and Class 60 bridges, remain in position for longer periods of time. For these bridges, use long-term anchorage systems. This chapter describes the design and construction of these long-term anchorage systems.

DESIGN OF LONG-TERM ANCHORAGE SYSTEMS

Basic Considerations

The design of any system of anchorage is influenced by several factors, including –

- Width of the river
- Velocity of the river's current
- River depth
- River bottom conditions
- Height and slope of riverbanks
- Soil conditions
- Depth of the groundwater table
- Available equipment

Each of these factors must be considered when deciding upon the type of anchorage system to be installed. Generally, the velocity of the river and the river bottom conditions will have the greatest impact upon the type of long-term anchorage system that will be selected for a given site.

Basic Design

The three basic components of all long-term anchorage systems include approach guys, an upstream anchorage system and a downstream anchorage system.

Approach guys

Approach guys are cables which prevent the bridge from being pushed away from the shore as a result of the impact of vehicles driving onto the ramps of the bridge. One approach guy is attached to each side (upstream and downstream) of the first bay of bridge on both ends of the bridge. The other end of each approach guy is secured on the shore, normally using chain picket holdfasts. Place approach guys at approximately a 45-degree angle with the bridge centerline. A minimum of 1/2-inch Improved Plough Steel (IPS) cable should be used for each.

Three components of a long-term anchorage system

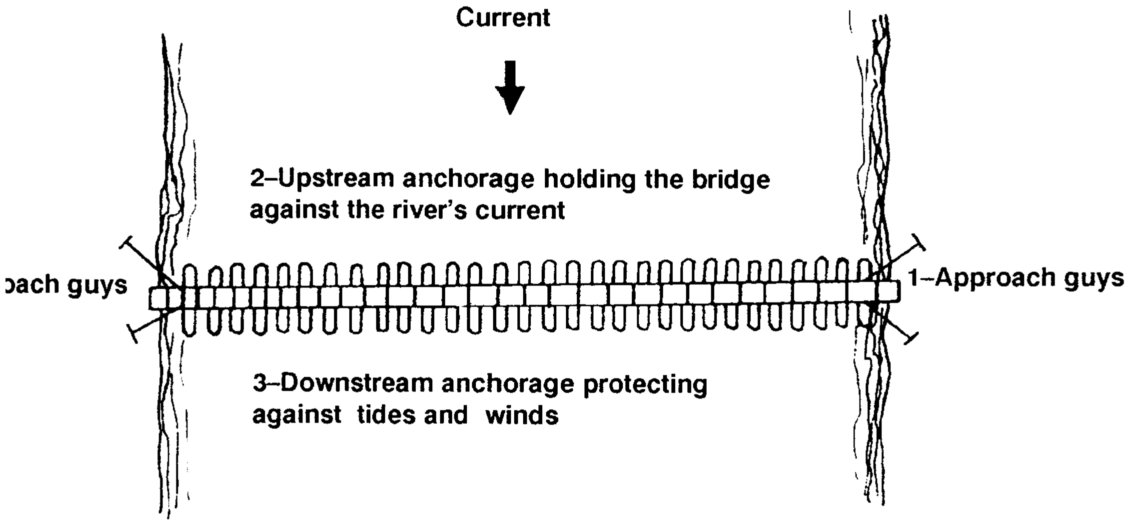


Table 35. Design of upstream anchorage systems

Current velocity (FPS)	Bottom conditions	
	Soft	Solid/rocky
0–3	Kedge anchors every float upstream or shore guys every 6th float upstream	Shore guys every 6th float upstream
3.1–5	Combination system (kedge anchors every float upstream and shore guys every 6th float upstream)	Overhead cable system
5.1–11	Overhead cable system	Overhead cable system

Table 36. Design of downstream anchorage systems

Reverse current (FPS)	Bottom conditions	
	Soft	Solid/rocky
None expected	Kedge anchors every 3d float downstream or shore guys every 10th float downstream	Shore guys every 10th float downstream
0–3	Kedge anchors every float downstream or shore guys every 6th float downstream	Shore guys every 6th float downstream
3.1–5	Combination system (kedge anchors every float downstream and shore guys every 6th float downstream)	Overhead cable system
5.1–11	Overhead cable system	Overhead cable system

Upstream anchorage system

The upstream anchorage system is the system which holds the bridge in position against the force of the river's normal current. This system is the bridge's primary anchorage system and its design is, normally, the most critical. There are four types of anchorages which can be used for the purpose of upstream anchorage:

- Kedge anchors
- Shore guys
- Combination of kedge anchors and shore guys
- Overhead cable system

Although several factors may come into play when determining which of these systems to install, the primary considerations are normally the current velocity and river conditions. Table 35 provides guidelines for the selection of an upstream anchorage system.

Downstream anchorage system

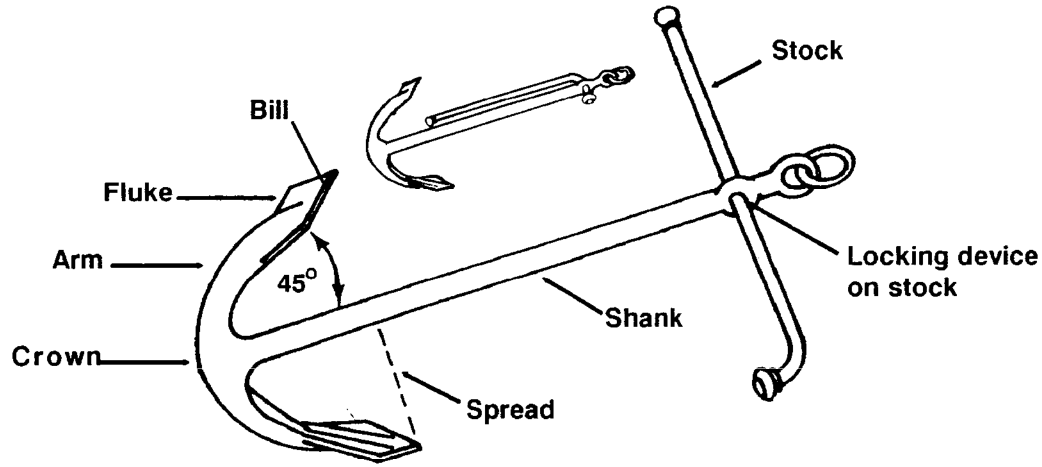
The downstream anchorage system protects the floating bridge against reverse currents, tidal conditions, eddies, and high winds or storms which might temporarily alter or reverse the natural flow of the river. Kedge anchors, shore guys, a combination of kedge anchors and shore guys, and overhead cable systems can be used as methods of anchoring the bridge downstream. Once again, the design of downstream anchorage systems can be based upon several factors. Normally, river bottom conditions and the velocity of the expected reverse current will be of primary importance. Table 36 provides guidelines for the design of downstream anchorage systems.

TYPES OF ANCHORAGE SYSTEMS
Kedge Anchors

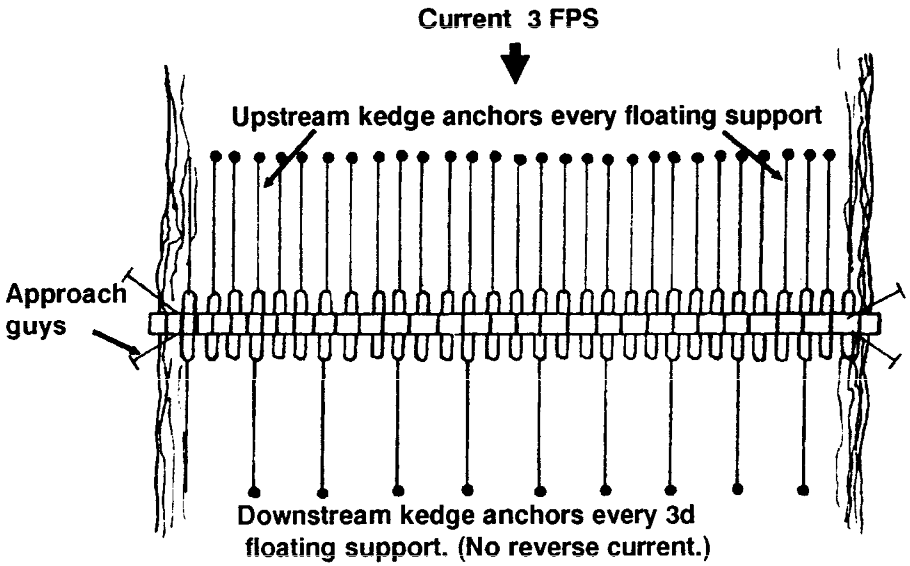
Planning considerations

Kedge anchors lie in the streambed and are secured to bridge bays with anchor lines. They are designed to sink with the stock lying flat and the fluke positioned to dig into the bottom. The kedge anchor depends on the streambed for holding power, and is useful only when the bed is composed of sand, silt, loose rock, or other material into which the fluke can take hold. On hard bottoms, the kedge anchor is useless. Where the streambed is suitable, anchors of the kedge type can be used as a primary anchorage in low debris currents up to 3 FPS for all heavy floating bridges.

Kedge anchor



Typical kedge anchor system



Note: For a reverse current of 0–3 FPS, kedge anchors would be attached to every floating support.

EXAMPLE: Given the following reconnaissance data, design a complete long-term anchorage system for an M4T6 normal bridge:

River width: 500 feet

Current velocity: 3 FPS

River bottom is composed of clay

No reverse current is expected

SOLUTION: Anchorage system will include –

1. Approach guys: Use 1/2-inch manila rope

2. Upstream system: Use kedge anchors attached to every float (Table 35)

3. Downstream system: Use kedge anchors attached to every 3d float (Table 36)

Note. Shore guys could also be used for upstream and downstream anchorage in this situation.

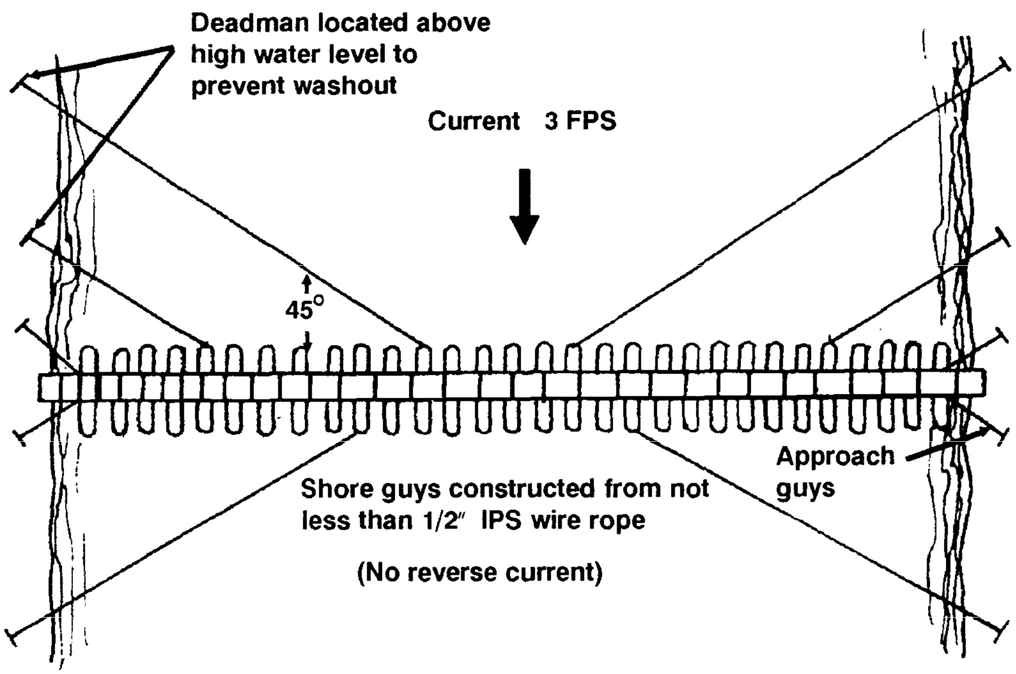
Emplacement

Anchors and lines. Normally, the standard 100-pound kedge anchor is used when installing a kedge anchor system. Standard kedge anchors are provided with all heavy floating bridges. To determine the number of anchors needed, refer to Table 35 when installing an upstream anchorage system and Table 36 when constructing a downstream kedge anchor system. If sufficient kedge anchors are not available, expedient anchors can be constructed. Some guidelines for the construction of expedient anchors are provided in Appendix D. One-inch manila rope is normally used as anchor lines. One line is attached to each kedge anchor. The length of each line must be at least 10 times the depth of the river.

Laying the anchors. The horizontal distance from the ponton or float to the anchors must be at least 10 times the depth of the water, to control the angle of the shank and prevent the anchor from dragging. The following steps should be taken when laying the anchors:

1. Prior to laying the anchors, check to ensure that the anchor line is attached to the anchor using a fisherman's bend knot (see Appendix A). Exercise caution to ensure that the stock of the kedge anchor is at right angles to the shank and locked with the stock key. This prevents the anchor from lying flat on the bottom and failing to engage.
2. Anchors may be laid either from a BEB or from a ponton or raft rigged to a BEB. When laying anchors from a propeller-driven boat,

Typical shore guy system



Note: For a reverse current of 0–3 FPS, shore guys would be placed every 6th bay downstream.

EXAMPLE: Given the following reconnaissance data, design a long-term anchorage system for an M4T6 normal bridge:

River width: 500 feet

Current velocity: 3 FPS

River bottom is composed of rock

No reverse current is expected

SOLUTION: Anchorage system will include–

1. Approach guys: Use 1/2-inch manila rope
2. Upstream system: Use shore guys attached to every 6th float (Table 35)
3. Downstream system: Use shore guys attached to every 10th float (Table 36)

the anchor is usually passed over the bow or gunwale with the boat headed upstream. This decreases the possibility of the line becoming fouled in the propeller.

3. Keep the anchor line neatly coiled so it will pay out freely. Personnel who cast the anchors must take care to stay clear of the rope to prevent entanglement and injury.

4. After the anchor has been cast, allow the boat to drift downstream and apply power to assist the flukes in setting firmly into the streambed. When any anchor is put in the water, it should be set to ensure that it will hold before it is connected to the bridge. If the set anchor holds the BEB stationary when operating at 2,000 revolutions per minute (RPM) in reverse, the anchor will hold its section of the floating bridge. If the anchor fails to hold the stream bottom, it should be retrieved, dropped in another location, and reset.

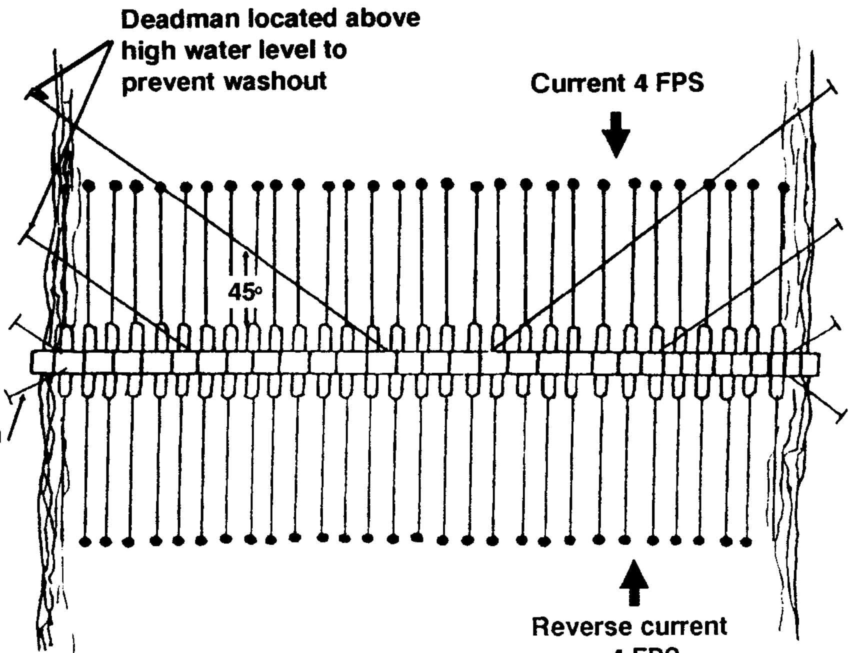
5. After the anchor is firmly set, move the boat downstream to the bay to which the anchor is to be tied and firmly rig the rope to the bridge.

Shore Guy Anchorage

Planning considerations

Shore guys are cables attached from the bridge to deadmen or similar holdfasts on the shore. Shore guys can be used as upstream or downstream anchorage systems provided that the maximum anticipated current (or reverse current for downstream systems) does not exceed 3 FPS. Shore guys may be used for any length of floating bridge provided that a 45-degree angle can be maintained between the shore guy and the bridge centerline.

Typical combination system



Note: Shore guys could be employed every 6th float downstream instead of kedge anchors.

EXAMPLE: Given the following reconnaissance data, design a long-term anchorage system for an M4T6 normal bridge:

River width: 500 feet

Current velocity: 4 FPS

River bottom is composed of silty sand

Reverse current is 2 FPS

SOLUTION: Anchorage system will include –

1. Approach guys: Use 1/2-inch manila rope
2. Upstream anchorage: Combination system (Table 35)
3. Downstream anchorage: Use kedge anchors attached to every float or shore guys attached to every 6th float (Table 36)

Materials

Shore guys normally consist of steel cables attached to deadmen. The cable used for shore guy systems should be 1/2-inch IPS cable or any cable which has a comparable breaking strength. The length of these cables depends primarily upon the length of the bridge and the shore conditions.

Installation

1. When shore guys are used as the upstream anchorage system for abridge, they are emplaced as the bridge is constructed. The cable should be unreeled from the shore and passed out along the bridge. If necessary, station one person at every other float to hold the cable out of the water. The guys are secured to the lifting eyes on the Class 60 bridge and around the balk, and through the balk lugs on M4T6 bridges.
2. Tighten the shore guys that were attached to the bridge during the bridge assembly just enough to hold them taut. After bridge completion, tighten the four approach guys simultaneously to prevent longitudinal movement. Then tighten the shore guys simultaneously to maintain bridge alignment. Shore guys must stay above the water to prevent whipping and accumulation of debris. If necessary, use an A-frame or some other means of intermediate support to raise the guys clear of the water.

Combination Of Kedge Anchors And Shore Guys

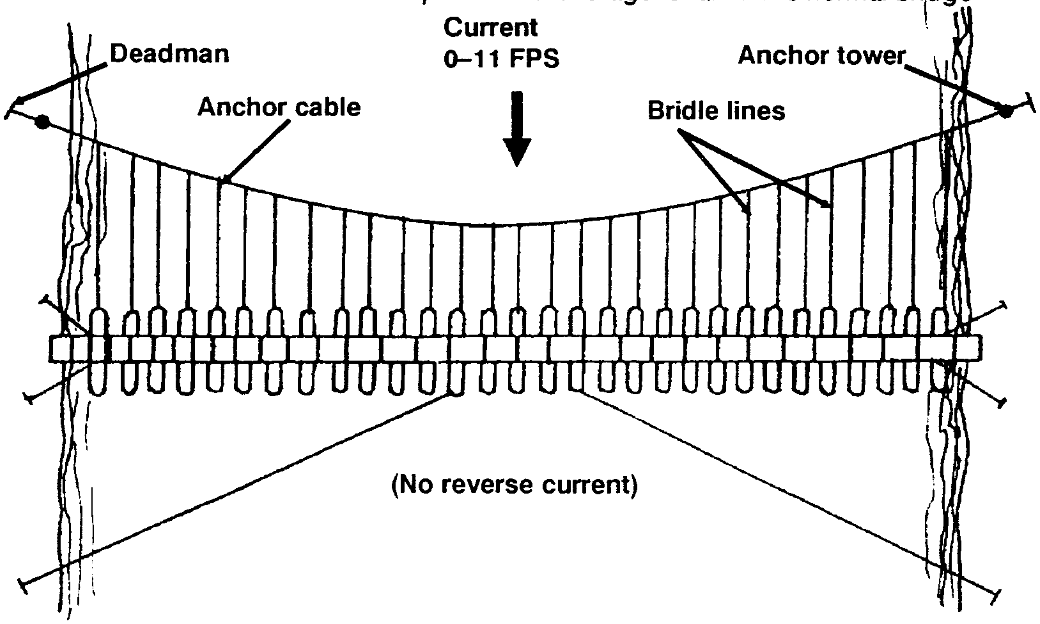
Planning considerations

A combination of kedge anchors and shore guys may be used for upstream or downstream anchorage systems in currents less than or equal to 5 FPS. When constructing a combination system, attach kedge anchors to every float and shore guys to every sixth float. Combination systems can only be used at sites where the river bottom is soft enough to allow the anchors to be set.

Installation

Install combination systems in exactly the manner prescribed for the installation of kedge anchor and shore guy systems. Install the kedge anchors prior to the shore guys so that the

Use of the overhead cable as upstream anchorage for an M4T6 normal bridge



EXAMPLE: Given the following reconnaissance data, design a long-term anchorage system for an M4T6 normal bridge:

River width: 500 feet

Current velocity: 6 FPS

River bottom is composed of solid granite (rock)

No reverse current is expected

SOLUTION: Anchorage system will include—

1. Approach guys: Use 1/2-inch manila rope
2. Upstream anchorage: Overhead cable system (Table 35)
3. Downstream anchorage: Shore guys attached to every 10th float (Table 36)

anchor lines are suspended below the shore guys.

Overhead Cable

An overhead cable system consists of one or more tower supported cables spanning the river parallel to the bridge. Each end of the overhead cable is secured to the shore, preferably through the use of deadmen. Bridle lines are used to connect each bay of bridge to the overhead cable. The cable functions like the cable used in a suspension bridge, except that in its final working position the cable is inclined toward the bridge because of the force of the current on the bridge.

Planning considerations

The overhead cable system can be used as both upstream and downstream anchorage systems. An overhead cable system can hold a heavy floating bridge in currents less than or equal to 11 FPS. The following basic reconnaissance information must be determined in order to design an overhead cable system

- River width
- Current velocity
- Bank heights (near and far shore)
- Depth of the ground water table
- Type of bridge to be supported

It is also important to be aware of the sizes and types of cable available for use as an overhead cable and the dimensions and types of materials that are available for use as deadmen.

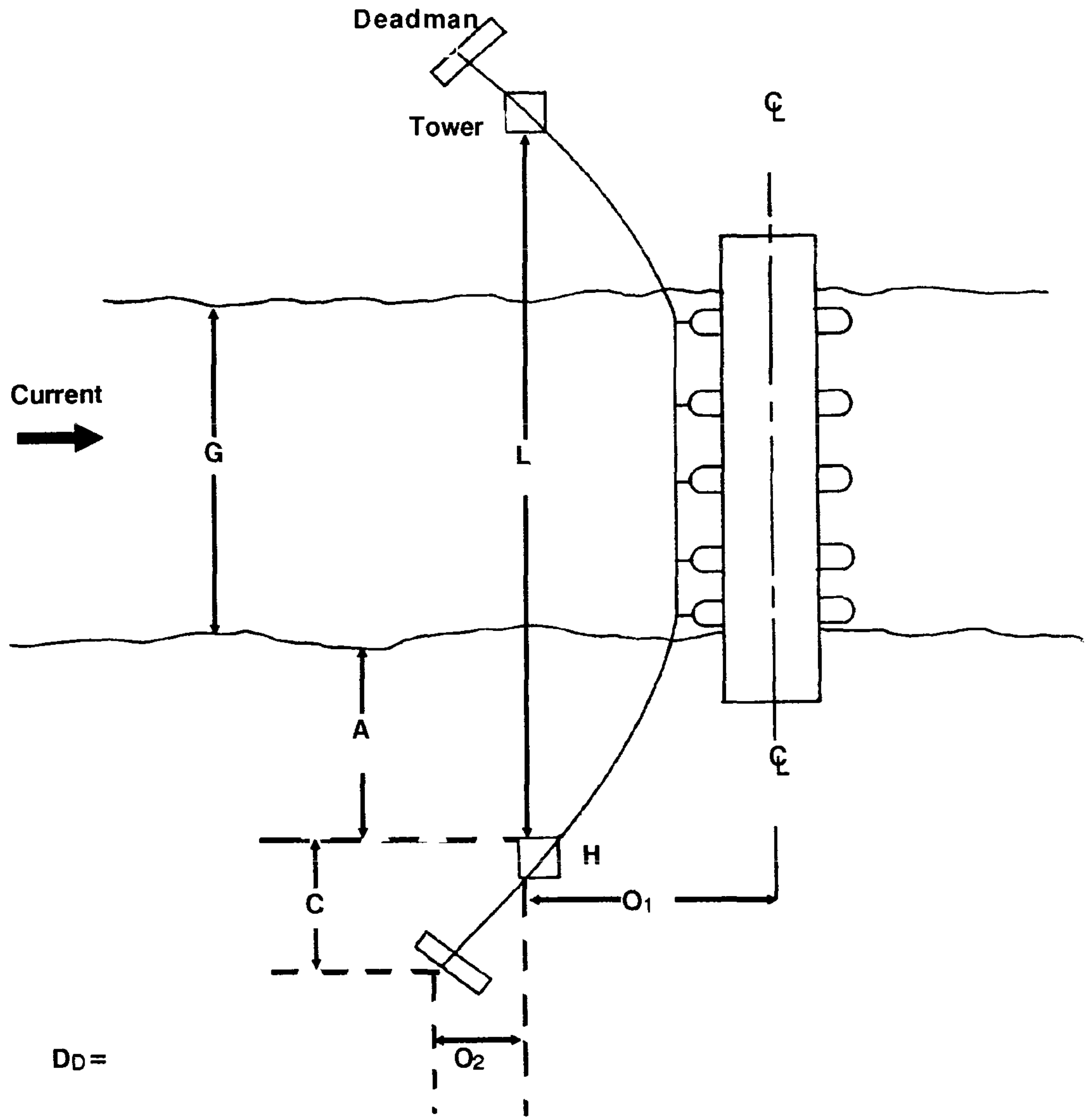
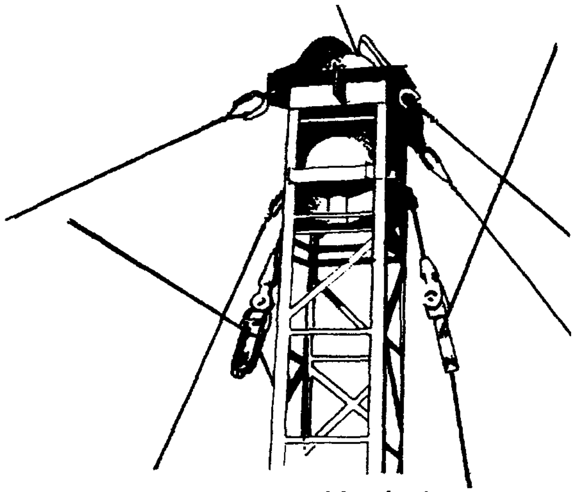


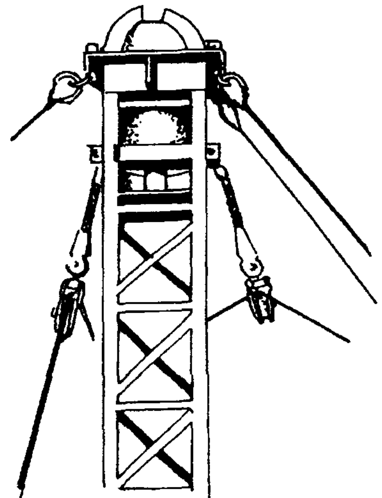
Table 37. Designing an overhead cable system

1. Cable data	
Number of master cables	
Size of master cable(s) (C_D)	
Length of the master cable(s) C_L	
Number of clips at each end of the cable	
Spacing of cable clips	
Initial sag (S)	
2. Tower data	
Actual tower height (H)	
Near shore	
Far shore	
Tower–waterline distance (A)	
Near shore	
Far shore	
Tower–bridge offset (O_1)	
Near shore	
Far shore	
3. Deadman data	
Depth of deadman (D_D)	
Near shore	
Far shore	
Tower–deadman distance (C)	
Near shore	
Far shore	
Tower–deadman offset O_2	
Near shore	
Far shore	
Deadman face (D_f)	
Deadman thickness (D_t)	
Deadman length (D_L)	
Near shore	
Far shore	
Bearing plate thickness (x)	
Bearing plate length (y)	

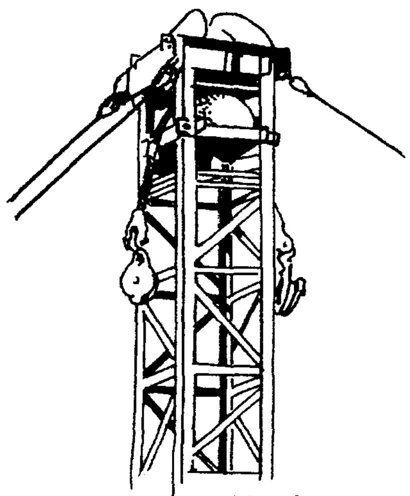
One-, two-, or three-cable system using one set of Class 60 towers



Anchor tower with adapter and three anchor cables



Anchor tower with adapter and two anchor cables



DESIGN OF AN OVERHEAD CABLE ANCHORAGE SYSTEM

Table 37 provides the basic information which must be calculated or determined when designing the overhead cable system. An expedient method of design for the overhead cable system is given in Appendix C. If the assumptions upon which this design sequence is based are invalid or if a better understanding of this design sequence is desired, refer to the following paragraphs.

Cable Design

Size and number of overhead cables

Overhead cable systems may be constructed as one-, two-, or three-cable systems. Single cable systems can be built for bridges as long as 1,200 feet in most cases. Installation of cable spans up to 1,500 feet is possible, but more difficult because of the practical limitations of erection equipment and the cable size and weight. If a cable of sufficient diameter is not available, or if the cable required is too large for the bridle lines and tower fittings, two or three smaller cables may have to be installed using a tower cap adapter. Use Table 38 to determine the size and number of cables required to support Ribbon, M4T6, and Class 60 bridges. Table 39 provides information for light tactical bridges. It is important to understand that both Table 38 and Table 39 are based upon the use of IPS cable. If IPS cable is not used, select an

Table 38. Determination of cable size and number of cables for M4T6, Class 60, and ribbon bridges

Wet gap width (G) (feet)	Type bridge assembly	Size (inches) and number of cables for specified river velocities											
		5 FPS			7 FPS			9 FPS			11 FPS		
		Single	Dual	Triple	Single	Dual	Triple	Single	Dual	Triple	Single	Dual	Triple
200	Normal	1/2	3/8	3/8	5/8	1/2	1/2	3/4	5/8	1/2	7/8	3/4	5/8
	Reinforced	5/8	1/2	3/8	3/4	5/8	1/2	7/8	3/4	5/8	1– 1/8	7/8	3/4
400	Normal	5/8	1/2	1/2	3/4	5/8	1/2	1	7/8	5/8	1–1/4	1	3/4
	Reinforced	3/4	5/8	1/2	1	3/4	5/8	1–1/4	1	3/4	1–1/2	1–1/4	7/8
600	Normal	3/4	5/8	1/2	1	3/4	5/8	1–1/4	1	3/4	1–1/2	1–1/4	7/8
	Reinforced	1	3/4	5/8	1–1/8	1	3/4	1–1/2	1–1/4	7/8	*	1–1/2	1–1/8
800	Normal	7/8	3/4	5/8	1–1/8	7/8	3/4	1–3/8	1–1/8	7/8	*	1–1/2	1–1/8
	Reinforced	1–1/8	7/8	3/4	1–3/8	1–1/8	7/8	*	1–3/8	1	*	*	1–1/4
1000	Normal	1	7/8	3/4	1–1/4	1	7/8	1–1/2	1–3/8	1	*	*	1–1/4
	Reinforced	1–1/4	1	3/4	1–1/2	1–1/4	1	*	*	1–1/8	*	*	1–3/4
1200	Normal	1–1/8	7/8	3/4	1–3/8	1–1/8	7/8	*	1–1/2	1–1/8	*	*	1–3/8
	Reinforced	1–3/8	1–1/8	7/8	*	1–3/8	1	*	*	1–1/4	*	*	*

Notes.

1. All values are based upon Improved Plough Steel cable and a 2 percent initial sag.
2. Asterisks (*) indicate that it is unsafe to construct that system.

Table 39. Determination of cable size for light tactical bridges

Wet gap width (G) (feet)	Current velocity			
	5 FPS	7 FPS	9 FPS	11 FPS
200	3/8″	3/8″	1/2″	1/2″
300	3/8″	1/2″	5/8″	3/4″
400	1/2″	1/2″	5/8″	3/4″
500	1/2″	5/8″	5/8″	3/4″
600	5/8″	5/8″	3/4″	7/8″

Note.
All values are based upon Improved Plough Steel cable and a 2 percent initial sag.

Table 40. Weight and breaking strengths for common cables (cable capacity)

Cable dia (CD)	3/8	1/2	5/8	3/4	7/8	1	1–1/8	1–1/4	1–3/8	1–1/2
Weight (pounds per foot)	.23	.40	.63	.90	1.23	1.6	2.03	2.5	3.03	3.6
Type of cable	**Breaking strength (pounds)**									
IPS	10,000	17,000	26,200	37,400	50,800	66,000	83,000	102,000	123,000	145,000
MPS*	11,000	18,800	28,800	41,200	56,000	73,000	92,000	113,000	136,000	161,000
Plough steel	12,600	21,600	33,200	47,400	64,400	84,000	106,000	130,000	157,000	185,000

Notes.
1. The strength varies slightly with the strand construction and the number of strands.
2. The strength varies approximately with the square of the diameter of the cable. For example: a 3/4" cable is 4 times as strong as a 3/8" cable made of the same materials, $(3/4)^2 \div (3/8)^2 = 4$.

* Mild plough steel

appropriate substitute, based upon a comparison of the breaking strength of the available cables with that of the required IPS cable. Table 40 provides the weight and breaking strength of IPS cable as well as several other common cable types.

Use of cable clips

Both ends of the overhead cable are normally wrapped around a deadman and secured using cable clips. It is essential that the proper number of clips is correctly applied. To determine the number of clips which must be applied to each end of the overhead cable, use the formula:

Number of clips at each end = (3x CD) + 1
where CD is the diameter of the overhead cable, in inches.

These clips should also be spaced according to the cable size. To determine the correct clip spacing (in inches) use the formula:

Clip spacing (in inches) = (6x CD)
where CD is the diameter of the overhead cable, in inches.

When installing cable clips, the base of each clip should bear against the standing (load carrying) end and the U-bolt should bear against the running (loose end). If clips are installed incorrectly, they will cause shearing, excessive wear, breakage, or slippage of the cable. Always use the correct size cable clip to attain maximum holding power.

Length of the overhead cable

In Appendix C, the calculation for the length of the overhead cable (in feet) is given as:

$C_L = L + 250$ feet

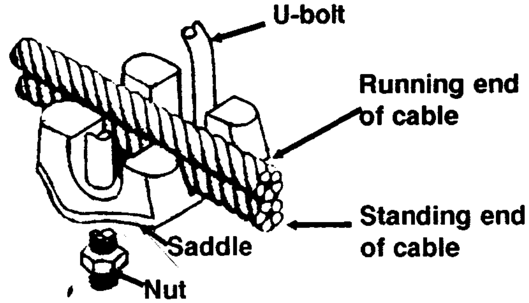
where C_L is the required length of the overhead cable (in feet),

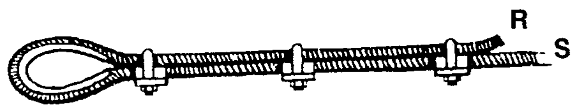
and L is the distance between the anchorage towers (in feet) and is given as:

L = (1.1x Gap) + 100 feet.

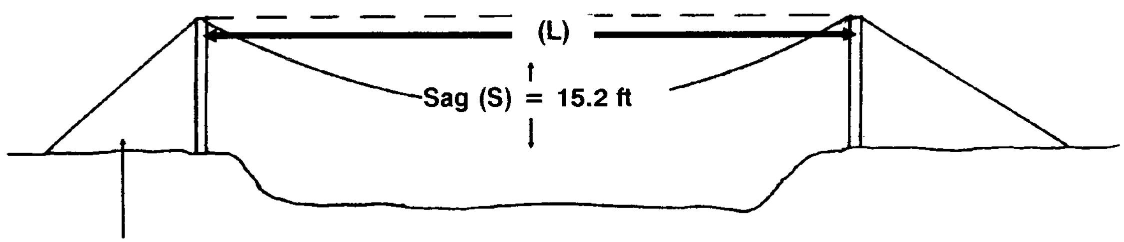
This formula provides an approximate value for the required length of the overhead cable. This approximation is based upon the most severe river and bank conditions and is intended for use as a planning figure only. Normally, there is no need to calculate an exact cable length, but if the designer of a cable system so desires, the formula can be derived from information provided in *TM 5-312*.

Application of cable clips





Initial sag



EXAMPLE: Given the following reconnaissance data, design the cable for an overhead cable system for an M4T6 normal bridge:

River width: 600 feet

Current velocity: 7 FPS

Available cable: 1-, 1 1/2-, and 1 1/4-inch IPS cables

SOLUTION: Number/size cable – Refer to Table 38 on page 115. A single 1-inch cable is sufficient for this system:

Number of clips = $(3 \times C_D) + 1 = 3(1) + 1 = 4$ clips at each end

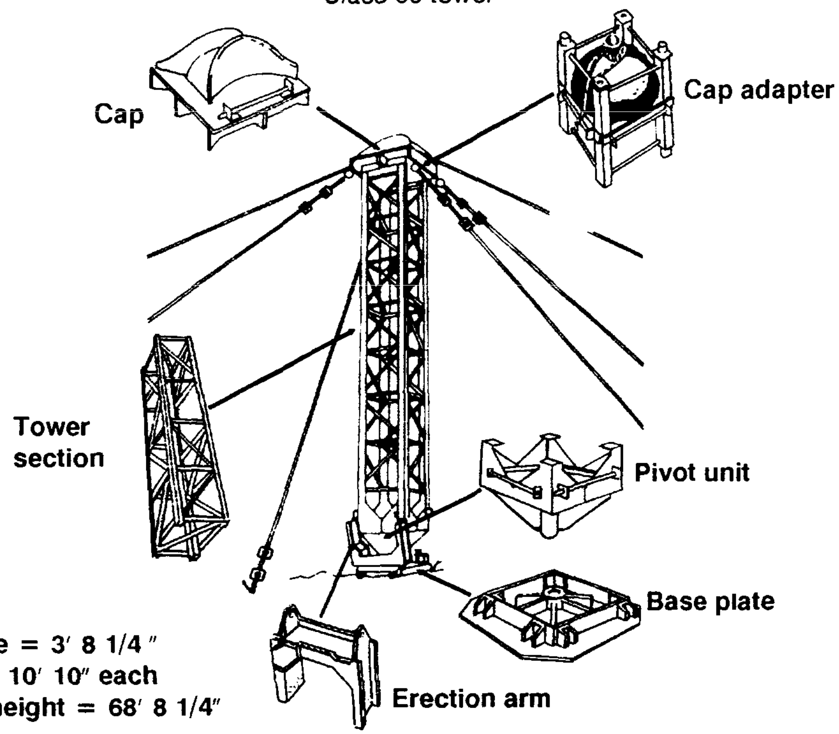
Spacing of clips = $(6 \times C_D) = 6$ inches apart

$L = (1.1 \times 600) + 100 = 760$ feet

$C_L = 760 + 250 = 1010$ feet

$S = 760 \times .02 = 15.2$ feet

Class 60 tower



Cap + base = 3′ 8 1/4″
Sections = 10′ 10″ each
Maximum height = 68′ 8 1/4″

EXAMPLE:

Given the following reconnaissance data, design the tower for an overhead cable system used to anchor an M4T6 normal bridge.

River width: 600 feet

Current velocity: 7 FPS

Bank heights:

Near shore – 10 feet

Far shore – 3 feet

SOLUTION:

1. First, determine the required tower heights.

Near shore: $H_R = 3 + S - BH = 3 + 15.2 - 10 = 8.2$ feet

Far shore: $H_R = 3 + S - BH = 3 + 15.2 - 3 = 15.2$ feet

2. Next, refer to Table 41 to determine actual near and far shore tower heights.

Near shore: H = 14 feet 6 1/4 inches

Far shore: H = 25 feet 4 1/4 inches

Cable sag

The ability of the anchor cable to hold the bridge decreases as the sag in the overhead cable increases. Sag is defined as the distance (in feet) between the cable and the midpoint of a straight line formed by the two cable supports. Prior to connection of the bridle lines to the overhead cable, tension is applied to the cable and the initial sag determined. A 2 percent sag (or less) is desired. Initial sag (in feet) may be computed as:

$S = (.02x\ L)$
where S is the initial sag,
and L is the distance between the towers.

The distance between the towers (L) is determined as:

$L = (1.1 \times G) + 100$ feet
where G is the width of the river, in feet.

An initial sag of 2 percent will usually result in a final sag of 5 to 7 percent once the bridge is connected to the overhead cable.

Tower Design

When installing an overhead cable system, Class 60 towers are used to ensure that the master cable remains at least 3 feet above the water level. The tower components are provided with each set of M4T6 and Class 60 and located in the Ribbon Bridge Supplemental Set. The tower assembly is made up of a tower base, a pivot unit, six tower sections, a tower cap, a cap adapter, and two wire rope slings. If Class 60 towers are not available, Bailey bridge panels can be used to construct an adequate tower. For additional information, see Appendix B.

Tower height

Required. To determine the size of the tower which must be built, it is first necessary to calculate the required tower height. Because the purpose of the tower is to elevate the overhead cable to a height at least 3 feet above the water level, the formula for the required tower height (in feet) is:

$$H_R = 3ft + S - BH$$

where H_R is the required tower height in feet,
S is the initial sag,
and BH is the bank height in feet.

Because the height of the bank is used in this calculation, determine the required tower height separately for both the near shore and the far shore (if the bank heights of both shores are not the same).

Actual. Once the required tower height (in feet) is calculated, the actual height of each tower (near and far shore) can be determined. When using the Class 60 tower, it is possible to bolt the tower cap directly to the pivot unit to obtain a tower height of 3 feet, 8 1/4 inches. This is the minimum possible tower height. The tower height may be increased by adding up to six of the 10-foot, 10-inch tower sections. Table 41 provides a list of available tower heights.

To determine the actual tower height, compare the required tower height to those available tower heights in Table 41. Always construct the smallest tower which has an actual height greater than or equal to the required tower height.

Tower location

Distance from the tower to the waterline. Before erecting the towers, determine exactly where on each shore to place the towers. Both towers are placed an equal distance from the waterline. For planning purposes, determine this distance (A), in feet, by using the formula:

$$A = \frac{L-G}{2}$$

where **L** is the distance between towers in feet and **G** is the river width in feet..

This calculation, basically, centers the two towers on the river.

Distance from the bridge centerline to the tower. When using an overhead cable system as an upstream anchorage system, the tower is placed some distance upstream from the bridge centerline. Conversely, if the overhead cable system is used as a downstream anchorage system, the tower is located some distance downstream from the bridge centerline. This distance, the Bridge to Tower Offset (O_1) can be calculated as follows:

- If the Bank Height (BH) is less than or equal to 15 feet then:
  $O_1 = H + 50$ feet
  where His the actual tower height in feet
- If the Bank Height (BH) is greater than 15 feet then:

  $O_1 = H + BH + 35$feet
  where H is the actual tower height in feet and BH is the actual bank height in feet.

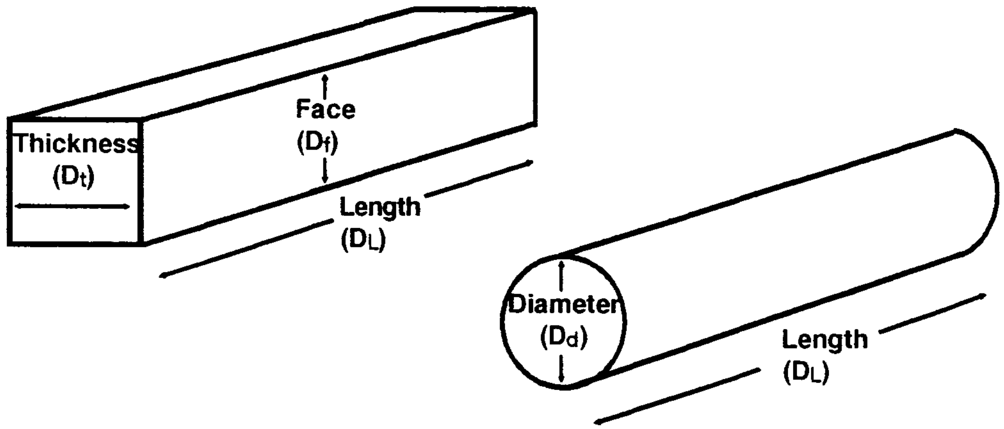
This distance provides a suitable slope for the cable running from the bridge to the tower.

Note. If the near or far shore bank or tower heights differ, this step must be performed separately for each shore.

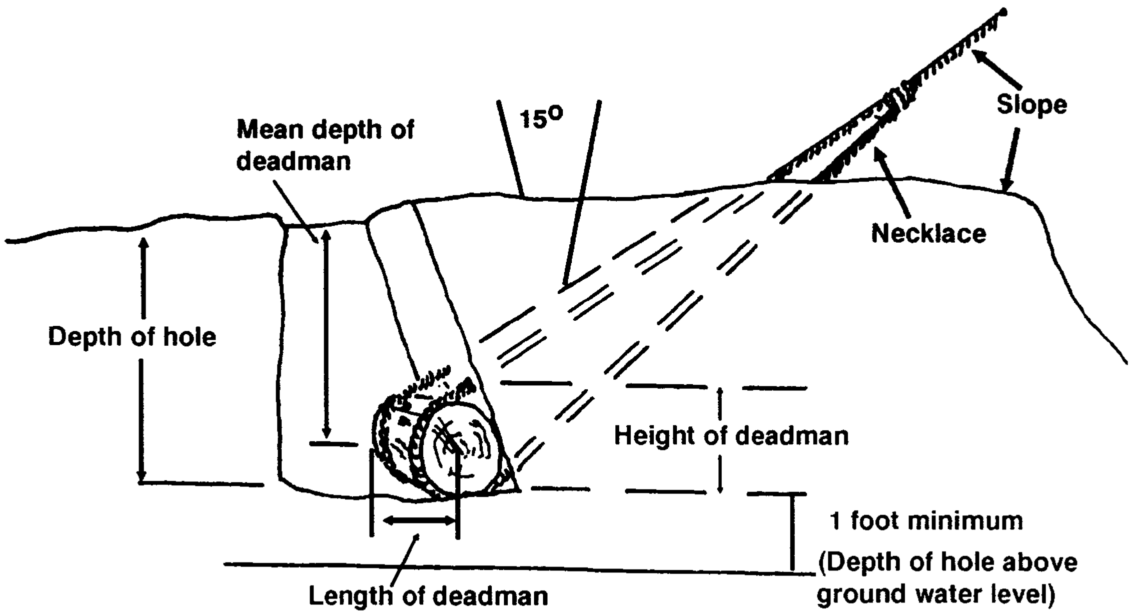
Table 41. Possible tower heights

Number of tower sections	Tower height (H)
Cap, base, and pivot unit	3 ft 8 1/4 in
With 1 tower section	14 ft 6 1/4 in
With 2 tower sections	25 ft 4 1/4 in
With 3 tower sections	36 ft 2 1/4 in
With 4 tower sections	47 ft 1/4 in
With 5 tower sections	57 ft 10 1/4 in
With 6 tower sections	68 ft 8 1/4 in

Determination of deadman dimensions



Depth of deadman



Deadman Design

The use of a deadman on each shore is the preferred method of securing the overhead cable(s). These deadmen provide the holding power for the entire overhead cable system. Because of this, accurate deadman design is critical. Construct deadmen using logs, rectangular timber, steel beams, or similar objects, buried in the ground with a guy line or sling attached to the deadman's center. The holding power of a deadman is affected by the frontal bearing area, mean (average) depth, angle of pull, deadman material, and soil conditions.

Available materials

The first step in designing a deadman is to identify the dimensions of all available materials. Generally, select the timber with the largest timber face or a log with the greatest diameter. Use the largest dimension of the proposed deadman as the deadman face (D_f). The smaller dimension is defined as the deadman thickness (D_t).

Depth of deadman

To determine the depth that a deadman should be buried, three rules must be considered

1. There must be at least 1 foot of undisturbed soil between the ground water level and the bottom of the deadman. Therefore, the maximum mean deadman depth (D_{Dmax}) is defined as:

$$D_{Dmax} = GWL - 1ft - \frac{(D_f)}{2}$$

where GWL is the depth of the ground water level in feet.
D_f is the size of the deadman face in feet, and D_{Dmax} is the maximum mean depth of

the deadman (the maximum depth that the center of the deadman can be buried) in feet.

2. The minimum mean depth of a deadman is 3 feet. There is a real danger of the deadman being pulled out of the ground at depths of less than 3 feet.

3. The maximum mean depth of a deadman is 7 feet. Beyond this depth, the advantage achieved in holding power is offset by the difficulty in emplacing the deadman.

To determine the actual mean depth of deadman (depth to the center of the deadman), calculate D_{Dmax} using the formula given above. Compare this value to the minimum and maximum values given in rules 2 and 3, and adjust the depth as necessary.

Length of deadman

Deadmen are designed to have lengths which enable them to resist the breaking strength of the cable attached to them. The required length and thickness are based on allowable soil bearing with 1 foot of length added to compensate for the width of the cable trench. The formula for the determination of deadman length D_L is:

$$D_L = \frac{CC}{(HP \times D_f)} + 1$$

where CC is cable capacity (breaking strength)
HP is the required holding power of the deadman.
D_f is the deadman face in feet (or log deadmen, use log diameter in feet).

This is the general formula for the determination of the required deadman length in all circumstances. In Appendix C, the values for CC and HP have been divided by 1,000 for ease of

Table 42. Holding power of deadmen in loamy soil

Required holding power (HP) in lb/square foot

Depth of deadman (D_D) in feet	Tower to deadman slope 1:1 (45°)	1:2 (26.5°)	1:3 (18.5°)	1:4 (14°)
3	950	1,300	1,450	1,500
4	1,750	2,200	2,600	2,700
5	2,800	3,600	4,000	4,100
6	3,800	5,100	5,800	6,000
7	5,100	7,000	8,000	8,400

Notes.
1. For hardpan or rock, multiply the HP by 5.
2. For fine-grained soils with high moisture content, multiply the HP by 1/2.

Estimation of tower to deadman slope

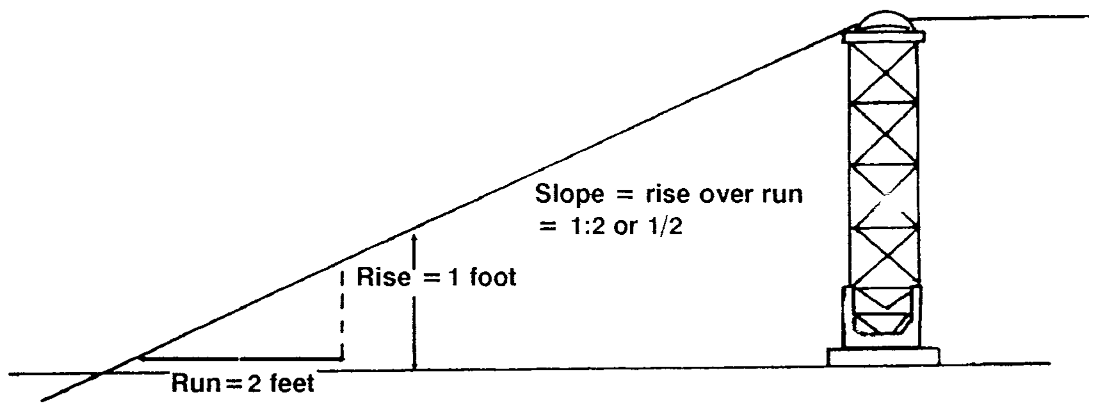


Table 43. Determination of the deadman offset factor (O_2)

Type of assembly	Deadman offset factor (O_2) Current velocity				
	3 FPS	5 FPS	7 FPS	9 FPS	11 FPS
Normal	.09	.11	.14	.17	.19
Reinforced	.11	.14	.17	.19	.23

calculation. Actual breaking strengtns (CC) or cables were provided in Table 40 on page 116. The actual holding power of deadmen in loamy soil is provided in Table 42.

Note: Table 42 assumes the deadman will be buried in loamy soil. For rock or hardpan soil, multiply the values in Table 42 by a factor of 5. For fine-grained or sandy soil, multiply these values by a factor of 1/2.

The tower to deadman slope, used in Table 42, represents an approximation of the slope of the cable running from the tower to the deadman, as shown on page 121. Since this value cannot be accurately measured until the exact location of the deadman is known, an estimation is made. The tower to deadman slope should fall between a 1:1 slope (45 degrees) and a 1:4 slope (14 degrees). If it is not possible to obtain an accurate estimate, then assume the worst case (1:1) slope.

Deadman thickness

After calculating the required length of the deadman, check the thickness of the deadman to ensure that the deadman will not break due to an insufficient length to thickness ratio.

For timber:

$\frac{D_L}{D_f}$ must be less than or equal to 9.

For logs:

$\frac{DL}{\text{diameter}}$ must be less than or equal to 5.

If the length to thickness ratio is exceeded, decrease the length requirements. This can be accomplished by one of the following methods:

- Increase the mean depth of deadrnan (D_D).
- Increase the tower to deadman slope ratio (the cable should become more horizontal).
- Increase the thickness of the deadman by selecting a deadman with a greater thickness or by using two timbers, placed back-to-back.

Tower to deadman distance

The actual distance (in feet) between the tower and the deadman can be described by the formula:

$$C = \frac{H + D_D}{\text{slope}}$$

where H is the actual tower height in feet, DD is the mean depth of deadman in feet, and the slope refers to the tower to deadman slope ratio.

Given that the minimum tower to deadman slope is 1:1, the minimum value for C is therefore described as:

$$C_{min} = H + D_D$$

Since the maximum tower to deadman slope ratio is 1:4 (or 1/4), the maximum value for C is:

$$C_{max} = 4x(H + D_D)$$

Place the deadman at any distance from the tower, as long as that distance falls between these minimum and maximum values. Once the deadman is positioned, make a check of the tower to deadman slope to ensure that the actual slope falls between the criteria given (1:1 and 1:4).

Tower to deadman offset

Just as it was necessary to calculate the distance to place the tower upstream from the bridge centerline, it is now necessary to determine the distance to place the deadman upstream from the tower. This distance is called the tower to deadman offset, or O_2. To calculate, use the formula:

$$O_2 = (C \text{ x } O_2 \text{ feet})$$

where O_2 feet is a factor determined from Table 43, and C is the tower to deadman distance (in feet).

A slightly more accurate means of positioning the deadman is to determine the exact angle at which the deadman should be placed in relationship to the tower (see Table 44) and place the deadman at the calculated distance (C) along that angle. The slight difference between the two methods is negligible to the extent that the difference will not cause the system to fail.

Bearing plate design

The final step is to design a bearing plate for each deadman. Whenever a deadman composed of wood is used, apply a bearing plate to prevent the cable from cutting into the wood. The two types of bearing plates are flat and formed, each with its particular advantages. The flat plate is easily fabricated. The formed bearing plate can be made of a thin piece of steel.

Flat. Given the size of the deadman face and the diameter of the overhead cable, flat bearing plates can be designed using Table 45 on page 1.24.

Formed. Given the size of the deadman face and the diameter of the overhead cable, the dimensions for a formed bearing plate can be determined using Table 46 on page 125.

INSTALLATION OF AN OVERHEAD CABLE ANCHORAGE SYSTEM

When constructing an overhead cable system to be used as the primary (upstream) anchorage system for a bridge, construct this system at the same time as the bridge. As bridge bays are brought and connected to the bridge, connect them to the overhead cable using bridle lines. Usually, one engineer platoon has sussicient personnel to construct a complete single cable overhead anchorage system. When practical, the work on the far shore should progress simultaneously with the work on the near shore.

Table 44. Alternate means of determining deadman offset

Type of assembly	Deadman offset angle (Φ) Current velocity				
	3 FPS	5 FPS	7 FPS	9 FPS	11 FPS
Normal	5°	6.5°	8°	9.5°	11°
Reinforced	6.5°	8°	9.5°	11°	13°

Design of formed and flat bearing plates

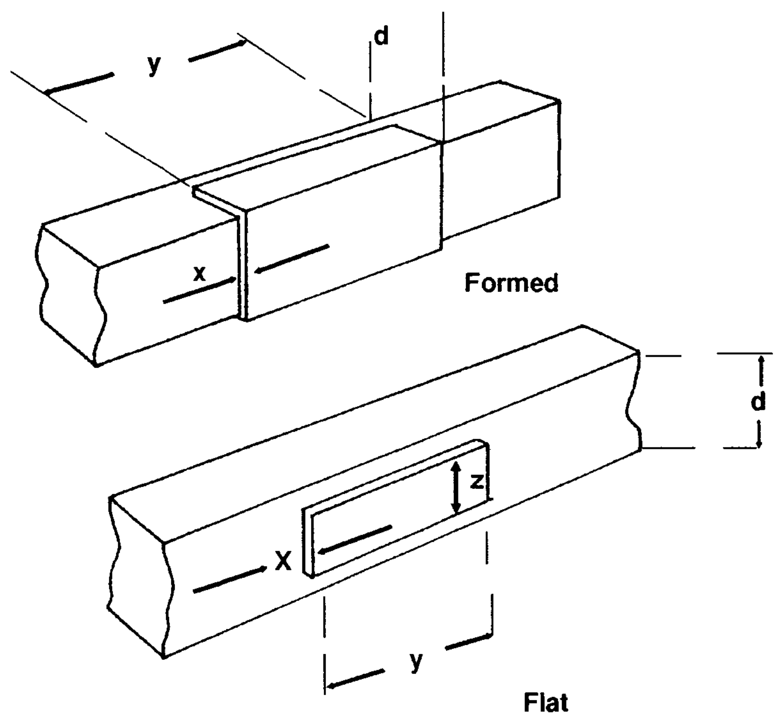
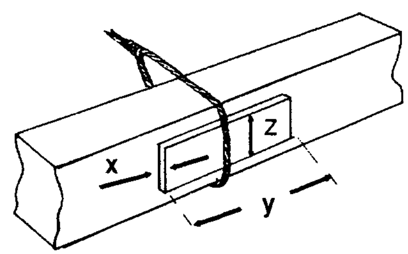


Table 45. Determination of bearing plate dimensions x, y, and z (in inches) for flat bearing plates

Deadman face (D_f)		Cable size (C_D)								
		3/8″	1/2″	5/8″	3/4″	7/8″	1″	1–1/8″	1–1/4″	1–1/2″
8"	x	7/16″	7/8″	1–1/4″						
	y	4″	8″	11″						
	z	6″	6″	6″						
10"	x	7/16″	11/16″	1″	1–3/8″					
	y	4″	6″	9″	12″					
	z	8″	8″	8″	8″					
12"	x	7/16″	9/16″	13/16″	1–1/8″	1–7/16″				
	y	4″	5″	7″	10″	13″				
	z	10″	10"	10″	10″	10″				
14"	x	7/16″	7/16″	11/16″	7/8″	1–1/4″	1–9/16″	2″		
	y	4″	4″	6″	8″	11″	14″	18″		
	z	12″	12″	12″	12″	12″	12″	12″		
16"	x	7/16″	7/16″	9/16″	13/16″	1–1/8″	1–3/8″	1–11/16″	2–1/8″	
	y	4″	4″	5″	7″	10″	12″	15″	19″	
	z	14″	14″	14″	14″	14″	14″	14″	14″	
18"	x	7/16″	7/16″	7/16″	11/16″	7/8″	1–1/4″	1–9/16″	1–13/16″	
	y	4″	4″	4″	6″	8″	11″	14″	16″	
	z	16″	16″	16″	16″	16″	16″	16″	16″	
20"	x	7/16″	7/16″	7/16″	11/16″	7/8″	1–1/8″	1–3/8″	1–11/16″	
	y	4″	4″	4″	6″	8″	10″	12″	15″	
	z	18″	18″	18″	18″	18″	18″	18″	18″	
24"	x	7/16″	7/16″	7/16″	9/16″	11/16″	7/8″	1–1/8″	1–3/8″	1–7/8″
	y	4″	4″	4″	5″	6″	8″	10″	12″	17″
	z	22″	22″	22″	22″	22″	22″	22″	22″	22″



Note.
The values in this table are based upon the use of Improved Plough Steel (IPS) cable, where:
x = bearing plate thickness
y = bearing plate length
z = bearing plate face

Table 46. Determination of bearing plate dimensions x, y (in inches) for formed bearing plates

Deadman face (D_f)		Cable size (C_D) 3/8"	1/2"	5/8"	3/4"	7/8"	1"	1–1/8"	1–1/4"	1–1/2"
6"	x	1/8"	3/16"							
	y	4"	7"							
8"	x	1/8"	1/8"	3/16"						
	y	3"	5"	8"						
10"	x	1/8"	1/8"	1/8"	1/4"					
	y	2"	4"	7"	10"					
12"	x	1/8"	1/8"	1/8"	1/8"	1/4"				
	y	2"	4"	6"	8"	11"				
14"	x	1/8"	1/8"	1/8"	1/8"	1/8"	1/4"	5/16"		
	y	2"	3"	5"	7"	9"	12"	15"		
16"	x	1/8"	1/8"	1/8"	1/8"	1/8"	3/16"	1/4"	3/8"	
	y	2"	2"	4"	6"	8"	11"	14"	17"	
18"	x	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	3/16"	1/4"	
	y	2"	2"	4"	6"	7"	10"	12"	15"	
20"	x	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	3/16"	3/8"
	y	2"	2"	3"	5"	7"	9"	11"	13"	19"
24"	x	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/4"
	y	2"	2"	3"	4"	6"	8"	9"	11"	16"
30"	x	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
	y	2"	2"	3"	4"	5"	6"	7"	9"	13"
36"	x	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
	y	2"	2"	2"	3"	4"	5"	6"	8"	10"

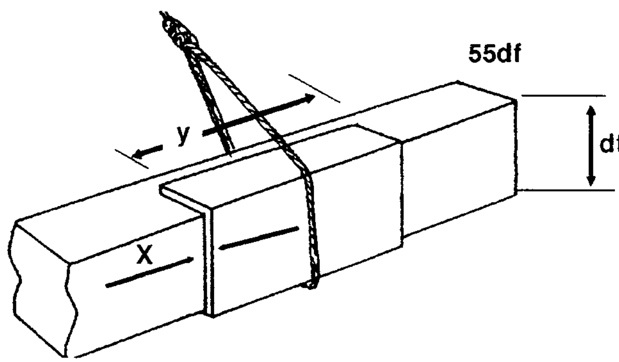


Table 47. Organization for construction of overhead cable system

Task	Crew size NCO	EM
Far shore:		
Install deadman	1	3
Erect tower	1	8
Adjust cable to tower and deadman	1	2
Install approach guys	1	2
Near shore:		
Install deadman	1	3
Erect tower	1	8
Adjust cable to tower and deadman	1	2
Install approach guys	1	2
Over the water:		
Transport cable to the far shore	1	2
Attach bridle lines	1	4

Organization

Table 47 on page 125 provides a list of tasks to accomplish when constructing an overhead cable system. A suggested crew size for each task is also given.

Installation of Deadman

1. Cut deadman to length and attach bearing plates as specified by the design procedure.
2. When installing a deadman, dig a hole or trench perpendicular to the cable to be attached to the deadman. Place the deadman in this hole. Dig a sloping trench, which has the same slope as the cable, in front of the hole in which the deadman is placed. This will allow the cable free access to the deadman as shown on page 120.

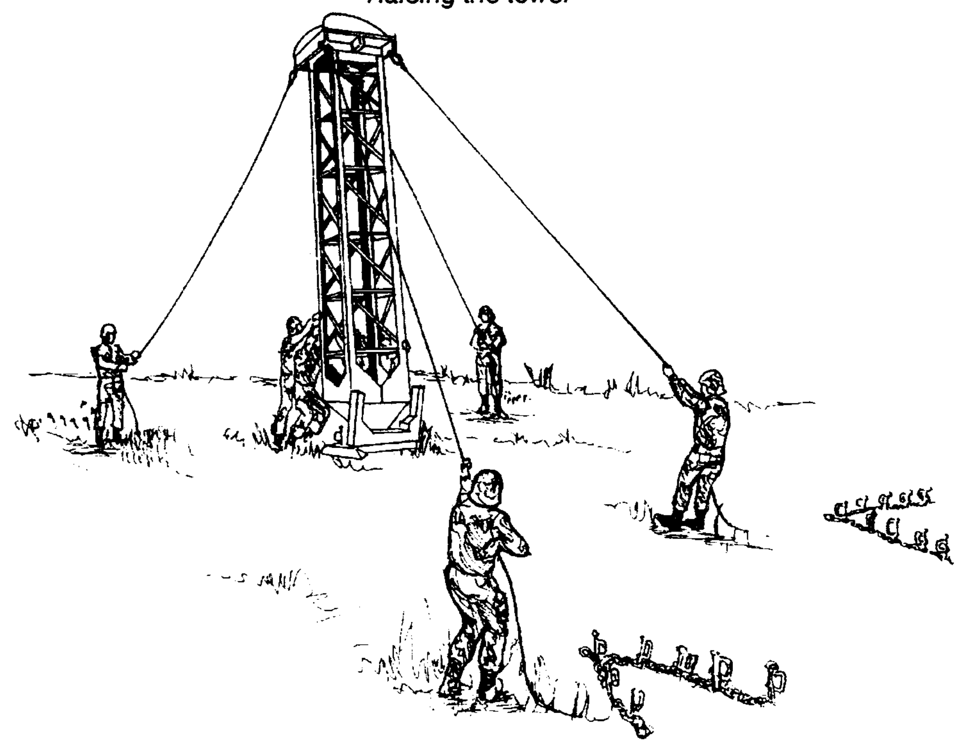
Erection of Towers

1. To assemble the anchor tower, anchor the tower base, rig the guy lines, and provide deadmen or holdfasts for the tower guy lines. Begin installation of the deadman to which the overhead cable will be attached prior to tower erection.
2. Install tower base plates and chain holdfasts.
3. Connect the pivot unit, the required number of tower sections (from the tower design), and the tower cap. Bolt the tower cap to the top tower section. The tower cap has a 3-inch saddle which must be aligned to receive the overhead cable. For multiple cable systems, ensure that the two-cap adapter with two wire rope slings is attached to the top tower section.
4. Before raising the tower, secure the guy lines to the tower cap. Take care not to tangle or foul these guy lines. Place the erection arm in the pivot unit and pin it to the tower base to keep the pivot unit in the base socket.
5. Raise the tower. For taller towers, some lifting device may be needed. any crane, M728 combat engineer vehicle, or M88 recovery vehicle can be used.
6. Adjust the tower guy lines as required.

Installing the Overhead Cable

1. Emplace anchor cables by mounting the cable reel on the near shore and tow the free end of the cable across the river using a BEB. If the stream bottom is hard and reasonably clear of shelf rocks and snags, this method is most effective. The use of intermediate floating supports in areas where a large number of potential snags exist on the river bottom, may be of good use. Care must be taken when using intermediate floats, particularly in rivers with a swift current, to ensure that the boat can overcome the drag developed by towing the cable.
2. Once the cable is ready for attachment to the deadman, place the cable under the deadman and around it. This reduces the

Raising the tower



upward and out of the hole. If the cable cuts into the ground place a log or board under the cable at the outlet of the sloping trench.

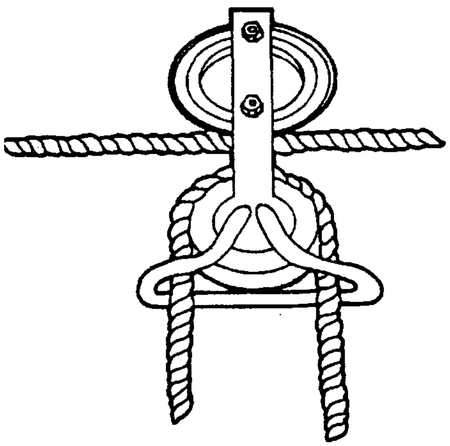
3. Measure and mark the initial sag distance from the point of support on each tower. Establish a line of sight between the marks. Tighten the cable until its lowest point touches the line of sight. This adjustment must be made before the bridge is connected to the cable. Tighten cable clips frequently as more strain is placed on the cable when bridle lines from the floats are attached. After the cable has been placed in service and is under tension, tighten the cable clips again to compensate for any decrease in cable diameter caused by the load and ensure equal distribution of load between the clips.

4. Use the cable clips to secure the cable. Attach these clips above the ground for ease of tightening and maintenance.

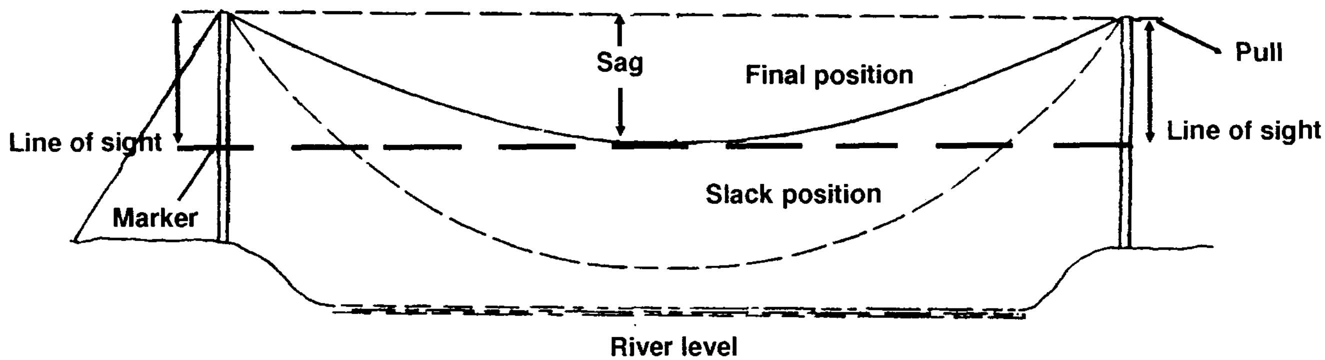
Attachment of Bridle Lines

Once the overhead cable is secured, the bridle line crew can begin connecting the bridle lines from each float to the overhead cable. Bridle lines are normally 32-foot-long sections of 1-inch manila rope and are attached to the pontons in the ponton assembly area. Use bridle line connectors to attach the bridle lines to the overhead cable.

Bridle line connector



Measurement of initial sag



Note: Vertical distances are exaggerated.