Techniques of Water-Resources Investigations of the United States Geological Survey

Chapter A21

STREAM-GAGING CABLEWAYS

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Book 3

APPLICATIONS OF HYDRAULICS

on the cable-car storage side. The Occupational Safety and Health Act (OSHA) requires a safety railing on all platforms over 4 ft above ground level. Detailed OSHA guidelines are contained in 29 CFR (Code of Federal Regulations), pts. 1910.23 and 1910.27.

In some cases, walkways to gage shelters or down banks are required. Standard A-frame plans include properly designed platforms and railings. However, most walkways are site unique and are designed for each location. Strength and durability should be considered in the design. Galvanized steel provides long-term, low-maintenance performance. Walkways and steps should be of an open-grate, skid-resistant material. Preformed, skid-resistant, aluminum walkway material is commonly available, but caution is advised in attaching it to other metals because of galvanic action, which may rapidly deteriorate the aluminum. Wooden walkways, platforms, and ladders are discouraged, except as required for environmental or esthetic reasons. All wood should be pressure treated with preservative meeting the American Wood-Preservers' Association (1990) standard C1, designated as ACZA or CCA–C, and having retention (PCF value) of 0.40 lb/ft^3 or greater. This information should be stamped on the wood or contained in a tag attached to each individual piece. Pressure-treated wood should not be painted. Fiberglass grating and support members that are light and long lasting are available.

GROUNDING FOR LIGHTNING PROTECTION

Very few USGS cableways have been grounded in the past, and lightning-induced structural damage has been negligible. Most USGS cableways use concrete anchors to provide cable tension. This mass of concrete with a long steel U-bar attached to the cable, in effect, serves as an effective ground, known as the "Ufer" ground. The Ufer technique uses foundation reinforcing bars and the moisture-retaining properties of concrete as grounds. The diameter and length of the U-bars used in USGS cable anchorages are usually adequate for carrying the energy of average lightning strikes to ground. Increased protection can be obtained by attaching the standard U-bar to anchorage reinforcement bars.

The advent of solid-state electronic sensing and recording and transmission devices in gaging stations has increased the need to provide suitable grounding procedures for instrument shelters and the electronic instrumentation. The procedures involved in protecting this instrumentation are beyond the scope of this manual. However, many cableways are near instrument shelters, and a lightning strike on the cableway system could indirectly damage electronic equipment. In these locations, or in areas of abnormally heavy lightning strikes, additional grounding procedures may be desirable. Grounding rods and wire grounds are inexpensive and effective methods of providing protection. Numerous reference materials are available that provide detailed instructions on installation procedures for a variety of lightning-protection systems. The Standard of Practice LPI–175 (Lightning Protection Institute, 1987) provides detailed procedures.

ANCHORAGES

Anchorages are used to maintain tension in the cable. In the case of a steeply sloping topography, the anchorage may be attached directly to a cable. Most frequently, anchorages are located behind a cable support structure such as an A-frame. Anchorages must be designed to withstand safely all forces transmitted by the cableway with an appropriate design factor. Several types of cable anchors have been used and are described in this section.

CONCRETE MASS ANCHORS

Concrete mass anchors (gravity anchors) are most frequently used by the USGS. A properly designed and installed concrete anchor will last indefinitely with minimal maintenance. This type of anchor is strongly recommended. High-quality concrete can now be delivered and mixed on site nearly everywhere. However, transporting the concrete from the truck to the cableway site may require innovation on the part of the local construction crew. Even if this process is relatively costly, long-term durability and low maintenance over many years make this type of anchor desirable.

Concrete must meet ACI–318 (American Concrete Institute, 1984) and ASTM C–94 specifications. Concrete for anchors must have a minimum compressive strength of 3,000 lb/in^2. Reinforcing steel must have a minimum yield strength of 40,000 lb/in^2.

The size and shape of this type of anchor depend on the bearing and shear strength of the soil. Design considerations include the load (tension) acting on the end of the cable calculated vertically and horizontally, the coefficient of friction between concrete and various soils, the bearing strength of various soils, the weight of the concrete, and design factors against overturning and material yield stress.

In cases of submergence during high water, a buoyant effect occurs. This buoyancy dictates the use of heavier anchors. The anchor designs that follow provide for a factor of 2 for moist soil conditions and 1.5 for saturated soil conditions.

The angle of the cable from the horizontal affects the forces acting on the anchor and is therefore a significant factor in determining the size of the anchor. As the cable angle increases, the load acts downward on the A-frame and footings, and tension in the backstay increases. Angles greater than 45° are not recommended. Should angles greater than 45° be required, individual designs for footings, support structures, anchors, and backstays must be made.

The strength of various cable materials varies widely within a given cable diameter. Therefore, standard anchorages have been developed for cables of various design loads.

Standard designs for concrete mass anchors are given in figures 24 and 25 for attachment angles of 30° and 45°. Anchorage dimensions for various cable design loads are given in table 4. Spacing of reinforcing bars should be prorated depending on size but should not exceed 18 in. between bars. Placing of boundary reinforcement is critical and should never be less than 3 in. from outside surfaces. All reinforcing bars must meet ASTM specification A–615 for deformed bars designated Grade 40 or greater. U-bars in concrete anchors must always be placed in a vertical plane to minimize fatigue induced by cable vibration.

SIDEHILL ANCHORS

A sidehill anchor is a modification of a mass anchor and is designed to be built into a sloping streambank. The shape of the anchor and weight of soil on top of the concrete increase resistance to horizontal movement. The anchor must be completely buried, with the exception of the U-bar area, to work as designed. Standard designs are shown in figures 26 through 30 for design loads of 10,000 through 30,000 lb for soil type A only.

Sidehill anchors can be used only on stable slopes that have good soil and no possibility of submergence. Excavation and backfilling must be performed carefully to maintain maximum soil-bearing strength. Backfill must be placed and compacted in 3- or 4-in. layers.

T-ANCHORS

A T-anchor is a combination mass anchor and "deadman" anchor. T-anchors are not recommended for general usage. These anchors have been used in locations where concrete placement is difficult. Excavation must be carefully undertaken to minimize soil disturbance. The placement of the forms and reinforcement bars must be precise and is therefore costly. The U-bar and main stem of the anchor must be in exact alignment with the cable. Misalignment will cause a rotational moment on the transverse load-bearing component, which then could cause cracking and a resultant strength loss. T-anchor design has been considered only for 30° applications and should never be used in locations where submergence of the anchor is likely to occur. Installations at 45° will require a deeper and larger design, which would not be practical. Standard designs are shown in figures 31 and 32. Anchorage dimensions are given in table 5 for design loads of 10,000 to 30,000 lb. U-bar diameters are shown in table 2; length and shape are shown in figure 31.

ROCKS AS ANCHORS

Rock anchors are used in locations where solid rock formations are available. A rock anchor can be a steel U-bar or single-bolt-type device that either (1) is grouted into rock with expanding cement grout, epoxy or polyester resin, or other material that expands on setting or (2) incorporates a wedge-shaped expansion device that tightens as force is applied. Should the rock crack, as a result of freezing, by a change in the bond between the rock and the steel bar due to alternate loading, or by a sudden change in loading direction as a result of wind loading or a stream-gager's sounding line snagging a floating object, the connection may lose some of its strength. Many existing anchors were installed by using poured sulfur; however, this technology has generally been replaced with various resin materials.

Rock anchors generally are installed in a vertical position so that the cable tension pulls at or near 90° to the axis of the anchor. In some cases, two or more anchors are installed several feet apart, and the cable is attached to them with a metal bar or cable bridle. The design of a multianchor system requires a careful engineering analysis of all forces and selection of adequate auxiliary hardware.

Vertically installed rock anchors transmit cable tension to the rock by shear forces. Therefore, larger diameter U-bars are required than for concrete anchors. A design factor of 2 is used. Anchors should extend into solid rock for at least 3 ft, preferably 4 to 5 ft. The hole in the rock should be drilled to at least 2 in. in diameter and at least 1/2 in. larger than the U-bar or bolt diameter to allow for drilling misalignment and to allow penetration of the bonding material.

The anchor should be fabricated so that its strength is not reduced. Galvanizing of the exposed part is recommended. Grouting or epoxy or polyester resin installation must be done by experienced personnel, following the manufacturer's instructions completely. The success and safety of rock type anchors are dependent on proper installation and bonding and an accurate assessment of the stability and strength of the rock. A typical vertically installed rock anchor is shown in figure 33.

Horizontal rock anchors have been used where the cable tension pulls in a straight line. Because this type of rock anchor is in tension, it is more difficult to install and is more susceptible to failure. It is recommended that the site-evaluation, design, and installation of this type of anchor be contracted to a qualified specialist such as a mining engineering consultant. A horizontal rock anchor is shown in figure 34.

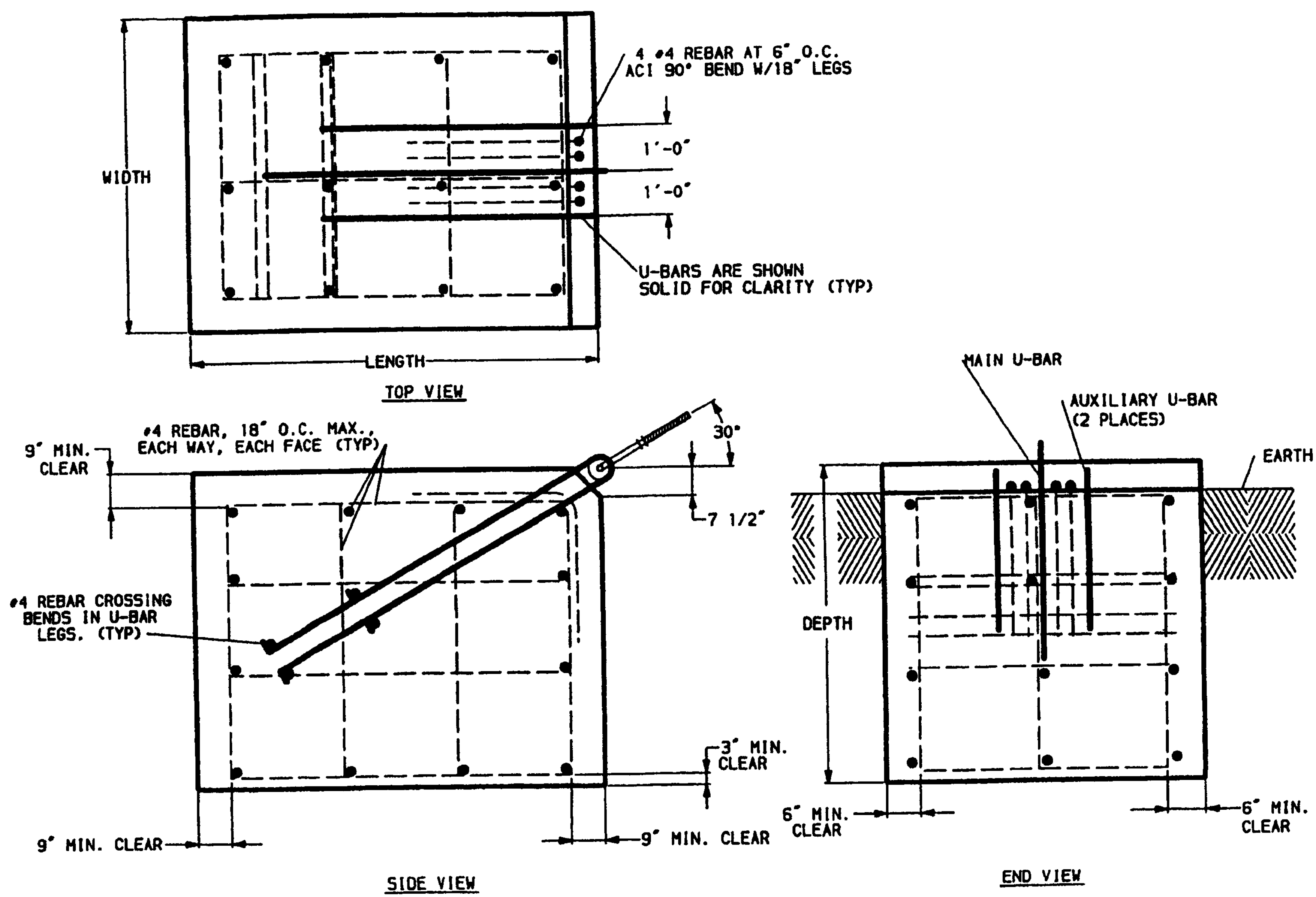


Figure 24. Anchorage for cableway positioned at 30°. O.C., on center; ACI, American Concrete Institute; TYP, typical placement; O.C. MAX, on center maximum; MIN. CLEAR (TYP), minimum clearance (typical placement).

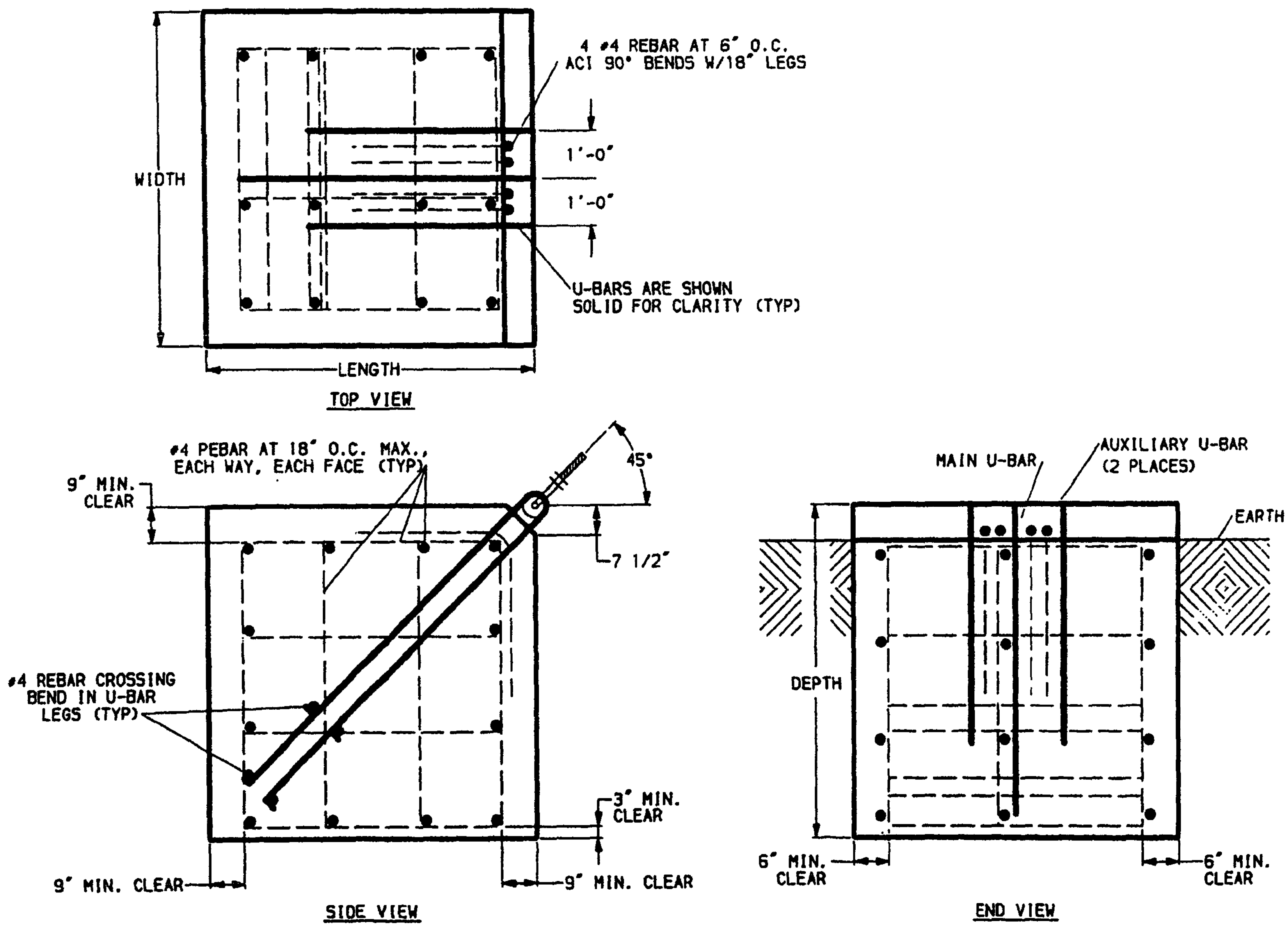


Figure 25. Anchorage for cableway positioned at 45°. O.C., on center; ACI, American Concrete Institute; TYP, typical placement; O.C. MAX, on center maximum; MIN. CLEAR (TYP), minimum clearance (typical placement).

Table 4. Anchorages for 30° and 45° cables.

Soil type	Cable design load[1] (lb)	Anchorage dimensions Length (ft)	Width (ft)	Depth (ft)	Concrete quantity (yd^3)
		Anchorages for 30° cables			
A	10,000	6.75	5.00	4.75	6.0
	15,000	7.75	5.50	5.50	8.7
	20,000	8.50	6.00	6.00	11.4
	25,000	9.00	6.25	6.25	13.0
	30,000	9.50	6.75	6.75	16.0
	40,000	10.50	7.25	7.25	20.5
B	10,000	7.00	5.75	6.00	9.0
	15,000	7.75	6.50	6.75	12.6
	20,000	8.00	7.25	7.25	15.6
	25,000	8.50	8.00	8.00	20.2
	30,000	9.50	8.25	8.25	24.0
	40,000	10.50	9.00	9.00	30.0
		Anchorages for 45° cables			
A	10,000	6.25	5.00	5.00	5.8
	15,000	7.00	5.50	6.00	8.6
	20,000	7.50	6.00	6.50	10.9
	25,000	8.00	6.50	7.00	13.5
	30,000	8.50	6.75	7.50	16.0
	40,000	9.25	7.50	8.25	21.2
B	10,000	7.00	5.50	6.00	8.6
	15,000	8.00	6.25	7.00	13.0
	20,000	8.50	7.00	7.50	16.6
	25,000	9.00	7.50	8.00	20.0
	30,000	9.50	8.00	8.50	24.0
	40,000	10.25	8.75	9.50	31.6

[1]Cable design load from table 1 or manufacturers' specifications.

TREES AS ANCHORS

Trees have been used as anchors for cableways in the past. Use of trees as anchorages will be covered here only for limited applications where large healthy trees are available and installation of concrete anchors is difficult. When a tree is used as an anchorage, it may be subjected to only a horizontal force or, if the cable first passes over a structural support such as an A-frame or another tree, to both vertical and horizontal forces. Because the physics of tree root to soil have not been quantified mathematically, calculation of permissive loads on a particular tree is impossible. Differing species have root systems with substantially differing holding strength. Soil types, moisture content, and distance above ground (bending moment) that a cable is attached also affect a tree's stability.

If a tree is used, it must be a large, live, mature tree with a solid root system located in stable soil. Core borings should be obtained if disease or decay is suspected. Since considerable judgment is required to ensure a safe installation, the design and construction should be performed only by personnel with experience in using trees as cable anchors. Consultation with an experienced forester to evaluate a tree's health and stability may be required.

BURIED DEADMEN

The use of buried timber or steel "deadmen" was once commonplace, but it is now against USGS policy to use deadman anchors because deterioration of cable and anchor material may be rapid and unobservable. Existing deadmen should be replaced with concrete anchors.

AIRCRAFT WARNING DEVICES

Aircraft warning markers usually are not required. However, some cableway locations are in remote areas where aircraft density is high and installation of markings may be desirable. Current regulations on appropriate and approved marking devices should be obtained from the FAA.

Orange spherical markers are usually suitable for USGS cableway marking. A 3/8-in. 6 ×19 IWRC or similar wire rope is adequate support for spans to about 500 ft. For greater spans, use a 1/2-in. wire rope. The support cable, sometimes referred to as a messenger cable, should be mounted about 3 ft above the main cable. This cable should have about the same sag as the main cable. An aircraft warning system places additional dead and live loads on the cable support components and anchorages and must be included as part of the design. Additional backstays and U-bars may be required. Markers should be spaced about 200 ft apart or as otherwise directed by current FAA regulations. There are no standard plans for modifications to support structures such as A-frames for aircraft warning markings.

Painting of cable supports for aircraft warning is not required except in unusual circumstances. Contact the FAA for guidance as required.

CABLE CARS

Two styles of manually propelled fabricated aluminum cable cars are commonly used by the USGS. One is a sit-down-type car with space for two field persons. The sit-down style is 60 in. long, 21 in. wide, and approximately 55 in. from footrest to cable. The other is a standup-style car, 52 in. long, 27 in. wide, and 73 in. from floor to cable. Two persons can work in the standup cable cars. Both cable car types are provided with an integral reel mount, which will accept all standard sounding reels. Both models are equipped with a follower brake to hold the car in place dur-

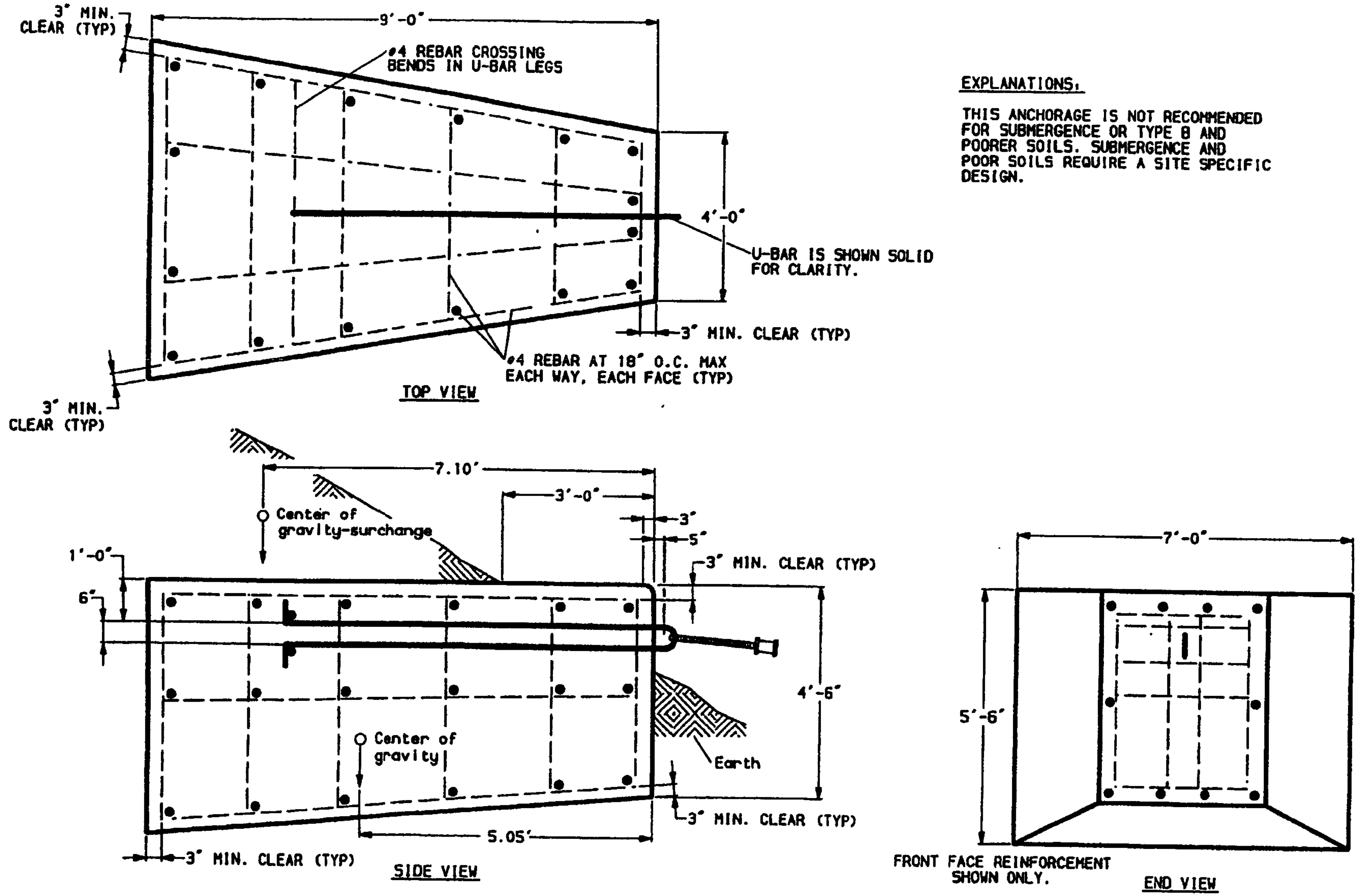


Figure 26. Sidehill anchorage for 10,000-lb design load. O.C. MAX, on center maximum; MIN. CLEAR (TYP), minimum clearance (typical placement).

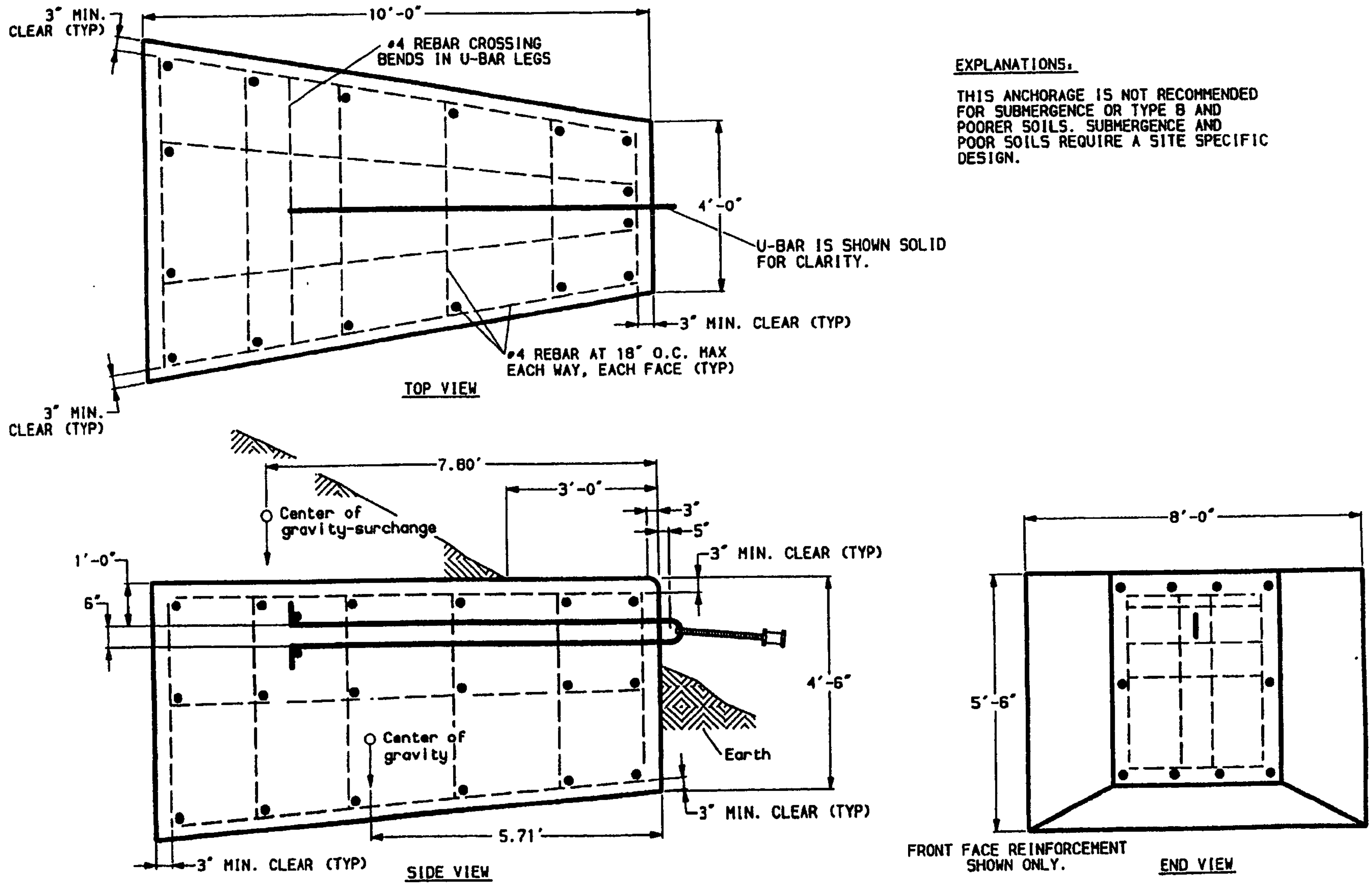


Figure 27. Sidehill anchorage for 15,000-lb design load. O.C. MAX, on center maximum; MIN. CLEAR (TYP), minimum clearance (typical placement).

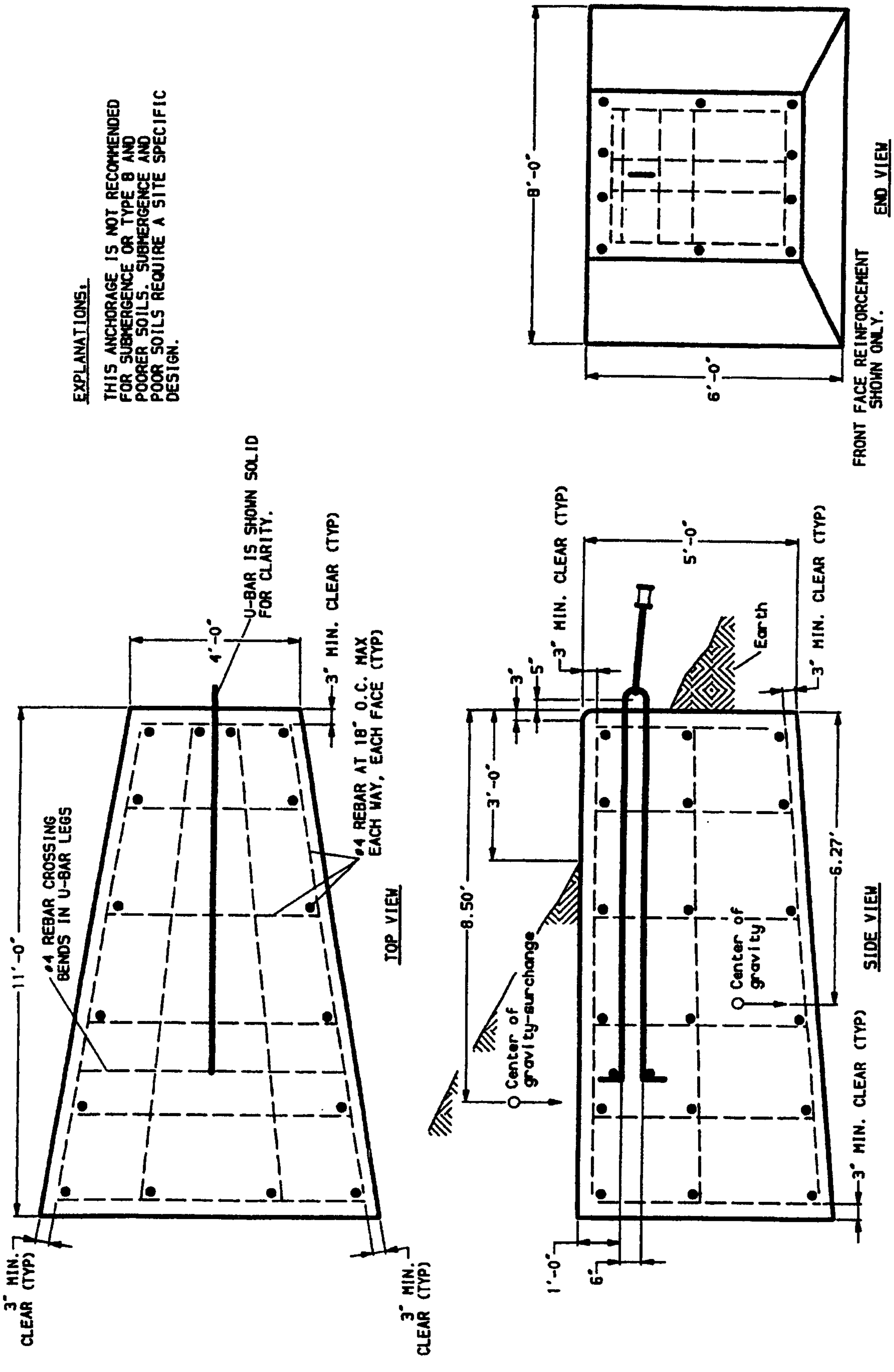


Figure 28. Sidehill anchorage for 20,000-lb design load. O.C. MAX, on center maximum; MIN. CLEAR (TYP), minimum clearance (typical placement).

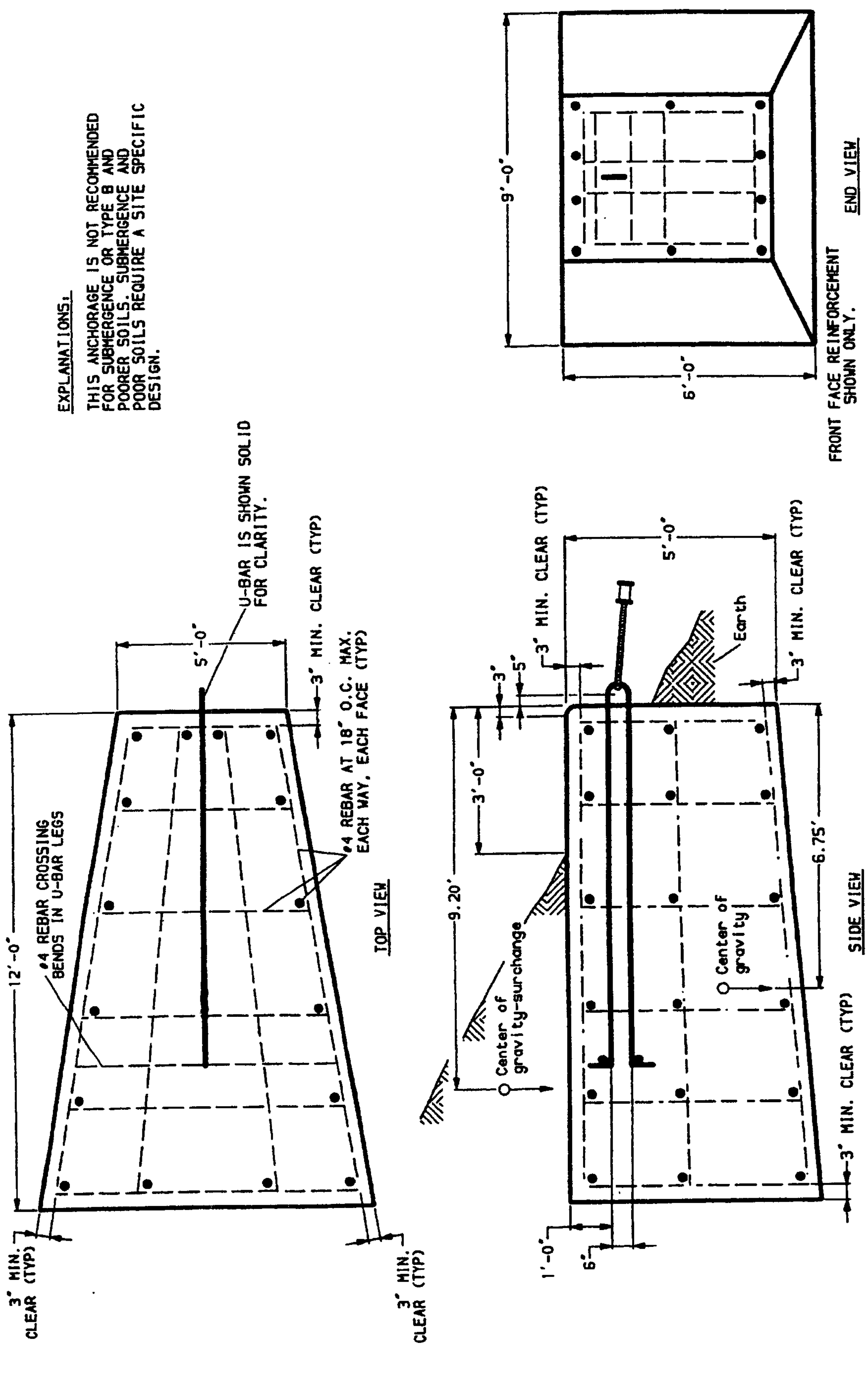


Figure 29. Sidehill anchorage for 25,000-lb design load. O.C. MAX, on center maximum; MIN. CLEAR (TYP), minimum clearance (typical placement).

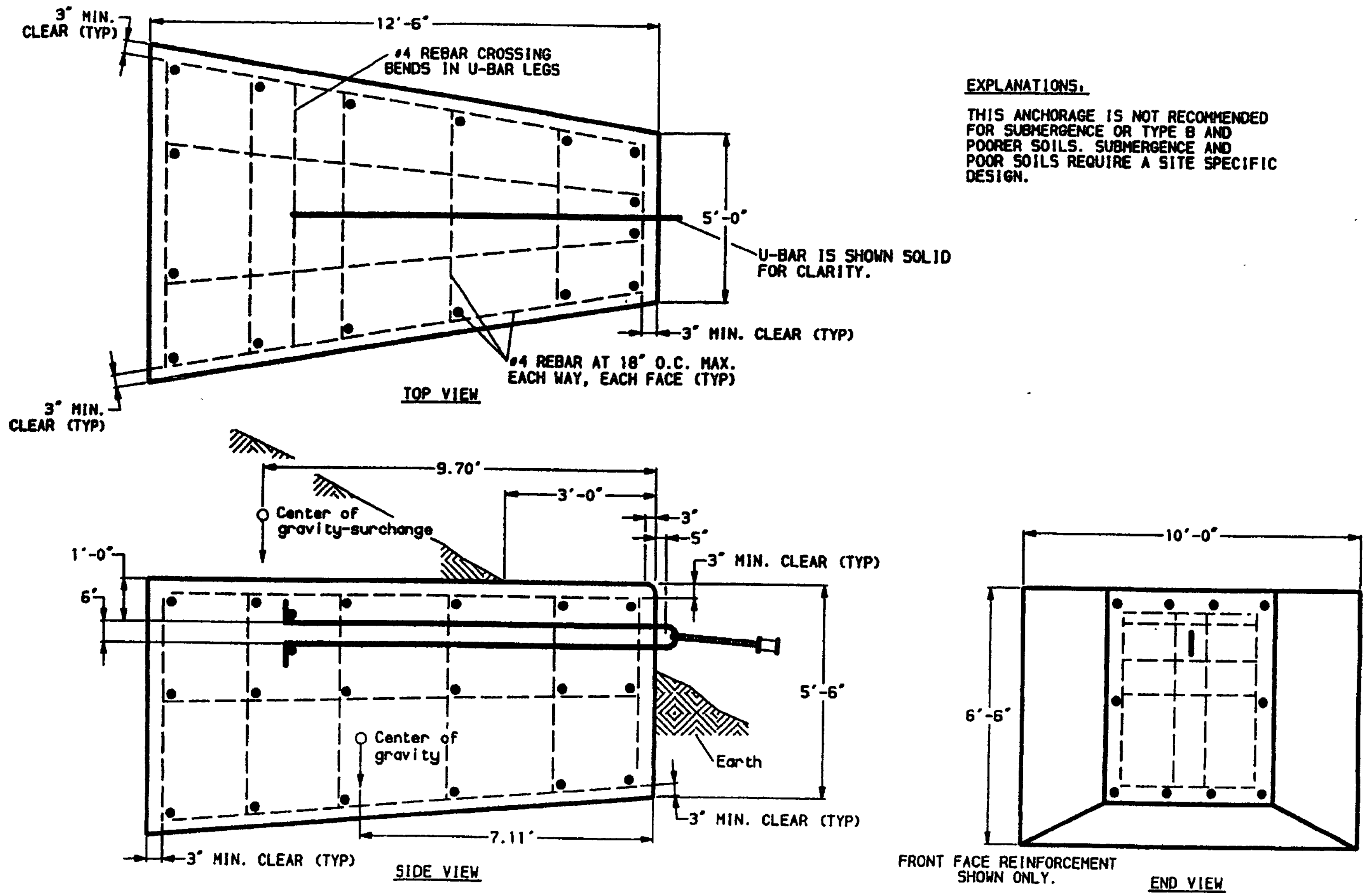
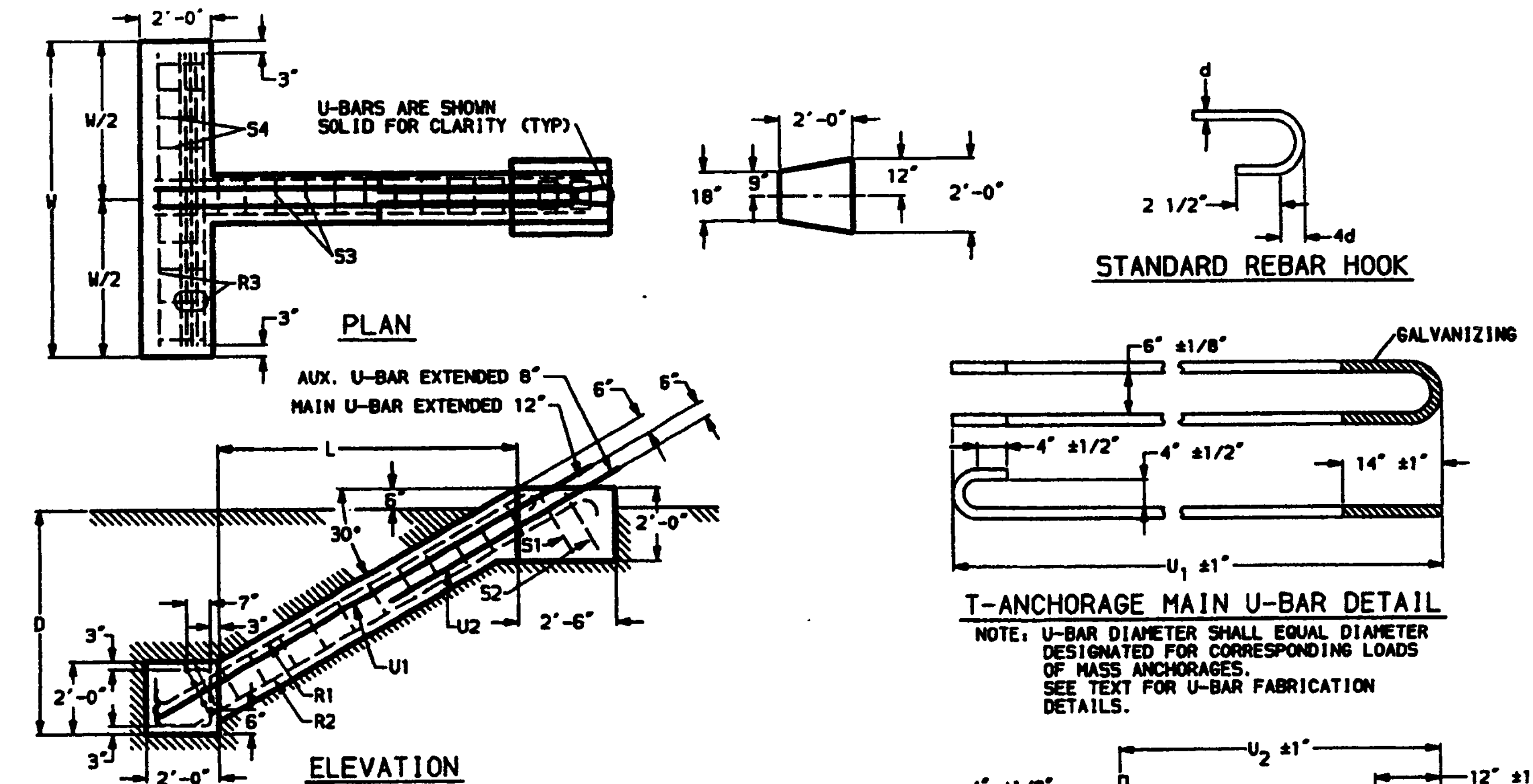


Figure 30. Sidehill anchorage for 30,000-lb design load. O.C. MAX, on center maximum; MIN. CLEAR (TYP), minimum clearance (typical placement).



EXPLANATIONS: STEEL REINFORCEMENT SPECIFICATIONS

1. ALL MAIN REINFORCEMENT #6 REBAR. ALL TIES #3 REBAR.
2. LENGTH - CALCULATED AS FOLLOWS USING LENGTH (L) AND WIDTH (W) FROM TABLE 5.
   - U1 = 1.155L + 4.2 FT
   - U2 = 0.577L + 3.7 FT
   - R1 = 1.155L + 3.2 FT
   - R2 = 1.155L + 5.0 FT
   - R3 = W - 0.5 FT
   - S1 = TIE WITH STANDARD 180° HOOKS REBAR LENGTH = 5 FT
   - S2 = TIE WITH STANDARD 180° HOOKS REBAR LENGTH = 4.8 FT
   - S3 = TIES AT 12" O.C. (TYPE T2 CRSI MSP-1-86) REBAR LENGTH = 5.3 FT/TIE
   - S4 = TIES AT 12" O.C. (TYPE T2 CRSI MSP-1-86) REBAR LENGTH = 7.3 FT/TIE
3. SEE T-ANCHORAGE STEM AND FLANGE DETAILS ON THE FOLLOWING PAGE.

Figure 31. T-anchor. AUX, auxiliary; TYP, typical placement; O.C., on center.

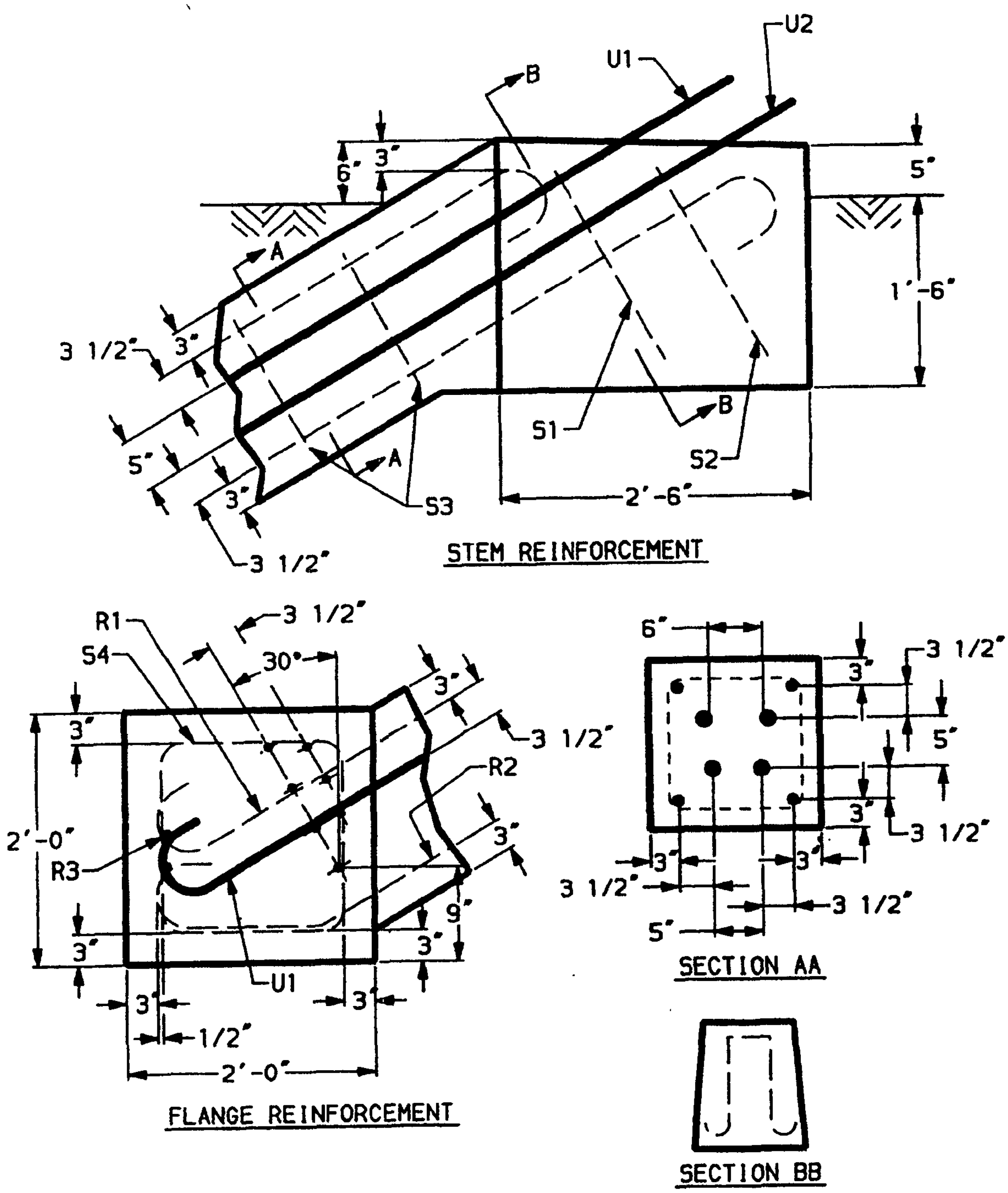


Figure 32. T-anchor details. See figure 31 for explanation of symbols used.

ing observations or sampling procedures. Several styles of car pullers are available. Exterior mounting brackets for water-sample bottles are available for both styles of cable cars.

All cable cars and accessories mentioned above are available to the USGS and other Federal agencies through the HIF. Battery- and gasoline-powered cable cars are sometimes used at sites located on large rivers that are frequently and extensively monitored. The HIF has designed a gasoline-powered cable car with a hydraulic pump that drives two hydraulic motors, one that moves the cable car along the cable and another that operates a type E sounding reel. This cable car is available from the HIF on special order.

Table 5. T-anchor dimensions.

Cable design load[1] (lb)	Dimension (ft)		
	Depth	Width	Length
Soil type A			
10,000	6	6	7.8
15,000	6	8	7.8
20,000	7	8	9.5
25,000	7	10	9.5
30,000	8	10	11.25
Soil type B			
10,000	6	8	7.8
15,000	7	10	9.5
20,000	8	11	11.25
25,000	9	13	13
30,000	9	16	13

[1]Cable design load from table 1 or manufacturers' specifications.

CONSTRUCTION

Construction of cableway systems must be carried out by using sound construction and safety practices. USGS personnel have been injured while building or maintaining cableways. Most incidents involved poor training, inadequate or makeshift equipment, or carelessness. It is not the intent of this publication to teach a course in engineering design or construction practices, and the following information is provided only for informational purposes for those with limited experience in constructing this type of structure.

EXCAVATING FOR ANCHORS AND SUPPORT STRUCTURES

Most excavation for typical A-frame footings and anchors is done by power equipment. Small backhoes of the type frequently mounted on industrial or farm tractors are best suited for this work because of their mobility. In general, the bearing strength of soil decreases when disturbed;

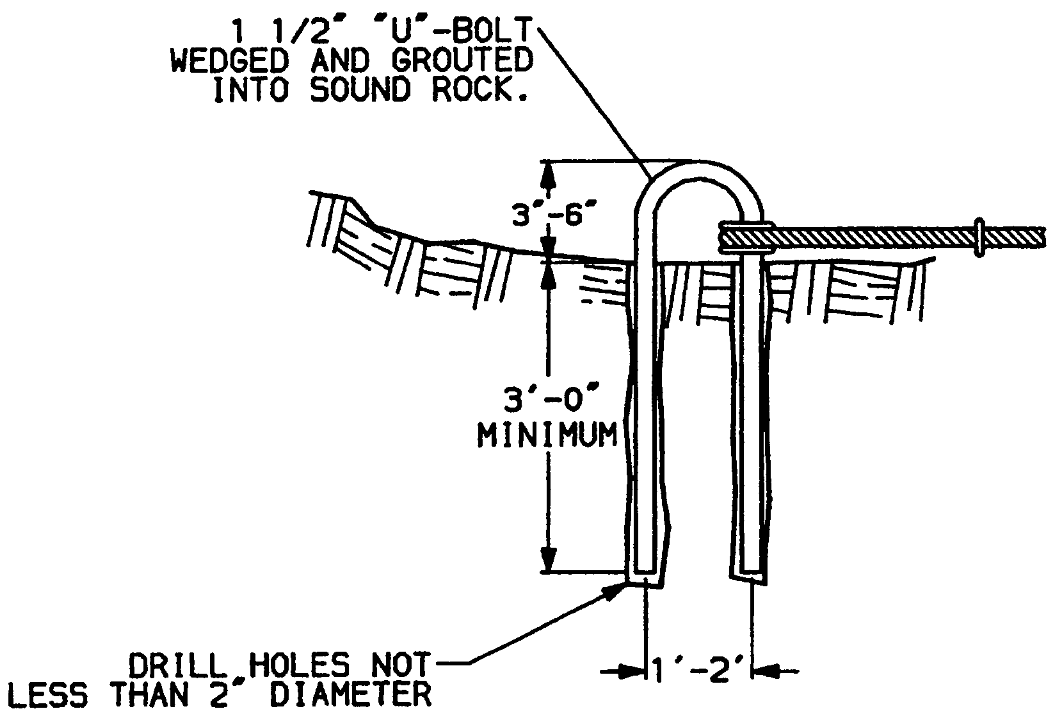


Figure 33. Vertical rock anchor. Drill holes in rock at least 2 in. in diameter or 1/2 in. larger than anchor diameter. Width normally measures between 6 and 12 in. Anchor diameter (in inches) for cable working load (in pounds) = 1 1/2 in., 10,000 lb; 1 5/8 in., 15,000 lb; 1 7/8 in., 20,000 lb; 2 in., 25,000 lb; 2 1/8 in., 30,000 lb; 2 1/4 in., 40,000 lb.

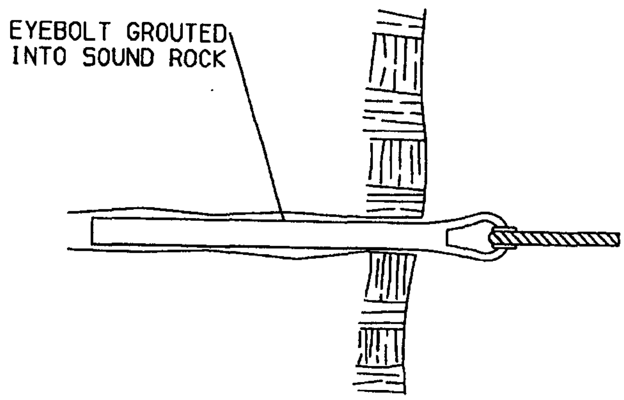


Figure 34. Horizontal rock anchor.

therefore, it is essential to dig as close to the desired dimensions as possible. In the case of concrete anchor blocks, a carefully dug rectangle may require a concrete form only for the top foot or so to provide for the above-ground portion. However, it is sometimes desirable in such cases to line the sides of the hole and adjacent ground with plastic sheeting before placing the forms and pouring the concrete to prevent dirt from falling into and contaminating the concrete. A careful and attentive backhoe operator and a little hand shoveling can result in a considerable savings of time and materials.

The use of cylindrical forms for A-frame footings is cost efficient since it minimizes excavation and labor intensive form construction. Cylindrical cardboard form materials are available commercially in a variety of sizes and can be easily cut as needed in the field. Steel culvert pipe makes an excellent form, and A-frame anchor bolts can be welded in exact positions before being taken to the site. (Neither type of form material is removed after pouring.) Careful attention to vertical and horizontal control in construction layout surveys is necessary to ensure that all components are exactly located.

The size and placement of steel reinforcement are critical to the strength of concrete structures. Concrete has excellent strength in compression but little strength in tension. Therefore, the integrity of concrete anchors depends primarily on the tensile strength of the reinforcement steel and proper bonding to the concrete.

Any space that has been excavated around formed concrete must be carefully replaced by mechanical compacting or by "puddling" before erection of A-frames and cable. Puddling involves pouring water into the void between the cured concrete and the excavation and carefully hand backfilling and tamping to ensure a soil condition as close as possible to original soil conditions.

PREPARING CONCRETE FOR ANCHORS AND SUPPORT STRUCTURES

Concrete is best procured from a local "ready-mix" vendor. Onsite hand mixing often results in a low-strength product and, in most cases, is not cost effective. In inaccessible locations, innovation may be necessary to transport concrete from the mixer-truck to the forms. If a long delay is expected, request a slow-setting mix. A temporary cableway or a cableway that is to be replaced may be used to transport concrete to a location on the far side of a stream. A washed-clean front-end bucket on a tractor may be used or, in some cases, a helicopter may be required.

Concrete for footings and anchorages must have compressive strength of 3,000 lb/in^2 (5 sacks/yd). All concrete should meet ACI–318 (American Concrete Institute, 1984) and ASTM C–94 and specifications. All concrete should be poured within 60 minutes after water has been added. When pouring concrete in forms, not more than 12 to 18 in. shall be poured before concrete is consolidated into all corners and around all reinforcing bars. Care must be taken to avoid disturbing the position of the reinforcing or U-bars. The process of consolidation or compaction of concrete must be done during and immediately after pouring. Mechanical vibrators are recommended; however, on small pours, hand spading (rodding) is acceptable as long as it is done thoroughly and carefully. The entire operation of depositing and consolidating the concrete must be conducted such that the finished concrete is smooth, dense, and free from honeycombs and pockets of segregated aggregate. Once started, no pour should be interrupted for more than 30 minutes. Water should never be added to the concrete mix to make it flow better because its addition seriously reduces the strength of the final product. Concrete should not be poured if below-freezing temperatures are expected within 48 hours, unless heated concrete is used or other means are available onsite to protect the curing concrete. All freshly poured concrete should be kept moist and should be protected from rapid drying by waterproof paper, plastic sheeting, wet burlap, or straw. Concrete poured during extremely hot or below-freezing conditions requires appropriate protection.

Concrete achieves approximately 75 percent strength in 7 days and approximately 100 percent strength in 28 days. Therefore, erection of A-frames and cables should never be started in less than 7 days. A longer curing time is preferable. A variety of readily available admixtures will retard or increase the setting and curing time of concrete. High, early-strength concrete achieves nearly full strength in 3 days; however, special curing procedures are required due to the large amounts of heat generated. All admixtures must meet applicable ASTM specifications (C–260 or C–494). Special mixtures should be agreed upon with the concrete supplier prior to formulation and delivery.

All placement of reinforcing bars and U-bars must be completed prior to starting a pour. The placement of anchor bars and A-frame attachment bolts in concrete must be done carefully to ensure proper connection with the steel components of the system. Reinforcing and U-bars must be free of loose rust and scale, petroleum products, or excessive dirt, any of which will significantly reduce concrete bonding. Misalignment of U-bars in concrete anchors will result in added stresses to the U-bars if the U-bars are not set at the proper angle. Even a slight misalignment of A-frame anchor bolts will result in a poor or impossible attachment to the steel A-frame. A convenient way of maintaining the proper spacing of anchor bolts is to weld the bolts for one leg of an A-frame together with reinforcing bars at the exact spacing. The bolt "cluster" is then inserted into the wet concrete as a unit. Alignment for bolt clusters for the legs of both A-frames can be maintained by drilling appropriate bolt holes in a 1- by 12-in. board, long enough to extend between the two pedestals. U-bars must always be placed vertically and at the same alignment angle as the cable. Proper placement is necessary to transmit tension forces to the entire concrete anchor.

Personnel preparing form work, installing reinforcement, and positioning anchor bolts and U-bars should have experience in construction carpentry and must follow design instructions. Concrete should have a smooth and level finish with a slight pitch to encourage water to drain away from metal connections such as A-frames and U-bars on anchors.

In locations where soil instability is suspected, inserting a gaging station reference mark or a bolt slightly above the concrete surface serves as a reference point and also allows measurements to be taken over time to determine if movement of any components has occurred.

INSTALLING ROCK ANCHORS

The installation of rock anchors must be done with great care to ensure adequate holding strength. Anchors should not be installed near fractures or near the edges of the rock formation. Installation of mechanical expansion anchors must follow the manufacturer's instructions. U-bar anchors require precise drilling of two parallel holes to accommodate the two legs of the bolt. Drill size must be selected to allow adequate clearance for grout or epoxy bonding materials. Vibrating the anchor will assist in working the bonding material along the entire anchor axis. Proper setting time is necessary prior to tensioning.

INSTALLING TREE SUPPORTS OR ANCHORS

The construction of cableways using trees as anchors or support structures should be performed only by persons who have had experience with such designs. When a tree is incorporated into the design of a cableway, it must be a large, live, mature tree with a solid root system located in stable soil. If there is any reason to suspect that a tree is diseased or decaying, core borings should be obtained. Careful consideration of all factors must support the tree's suitability for use.

The main cable may be looped directly around the tree, or a separate cable sling may be looped around the tree and attached to the main cable with a turnbuckle or other appropriate fittings. Wooden bearing blocks (often called lagging), such as hardwood 2 x 4's, should be placed between the tree and cable to protect both the cable and the tree. The cable should be loose enough to allow for the growth of the tree. If a sheave or other attachment hardware is used to attach the cable to a tree, it must be installed in a manner to adequately carry the load and not injure the tree.

ERECTING A-FRAMES AND CABLE

The construction of a cableway must be done by experienced personnel who emphasize safe practices. Safety shoes, hard hats, and heavy work gloves should be worn. No member of the crew should work in any location that would be unsafe in the event of a slippage or failure of a cable or component.

Preparation of a cable is essential to prevent unraveling and subsequent loss of strength. Seizing is the procedure of making a secure binding at the end of a wire rope to prevent unraveling. If a wire rope unravels, it will lose strength several feet from the point of disturbance. Wire rope should be seized prior to being cut. Seizing with wire wrappings has been the traditional method; however, stainless steel crimp-type hose clamps are noncorrosive and an effective means of seizing wire rope. If wire seizing is used, the wire should be soft annealed rustproof wire or strand, about 0.075 in. in diameter for most main cable applications. Correct placement techniques are shown in figure 35.

Once a wire rope is properly seized, it should be cut, preferably with a shearing-type cutter. A number of portable manual cutters that will meet most USGS needs are commercially available. A hammer-type cable cutter is shown in figure 36. Wire rope should not be cut with acetylene torches; using a torch tends to weld together the individual wires and inhibit movement in the wire rope, reducing its strength.

The erection of A-frames about 15 ft or less and cable spans of 400 to 500 ft long can usually be performed by a 3- or 4-person team without power equipment. Larger installations may require the use of power equipment. Backhoes usually are appropriate for lifting the A-frame into place and pulling the cable tight.

Usually the A-frames are aligned and bolted into place first, with the A-frame pointing to the river. In the case of A-frames without pivoting legs or I-beam supports, the sup-

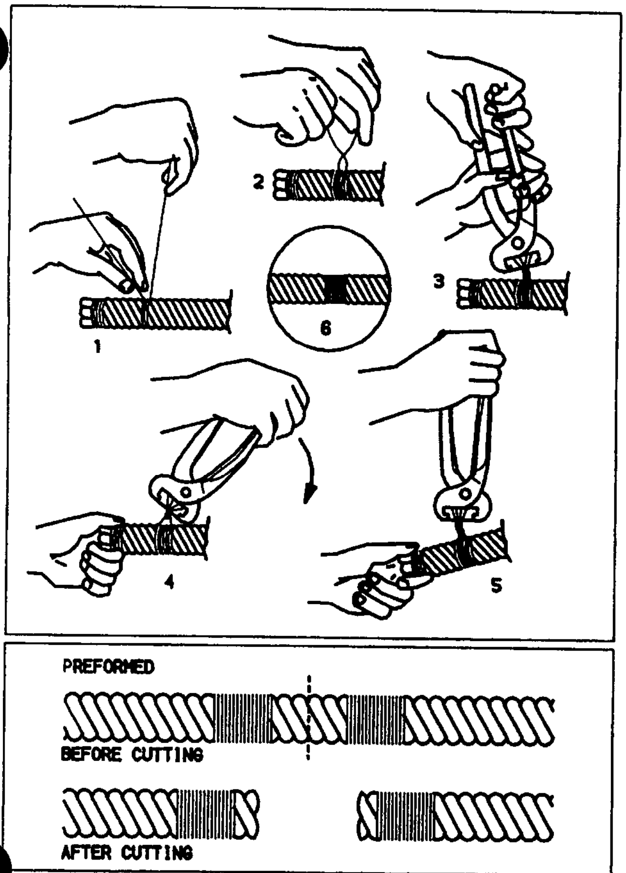


Figure 35. Wire-rope seizing technique and final product.

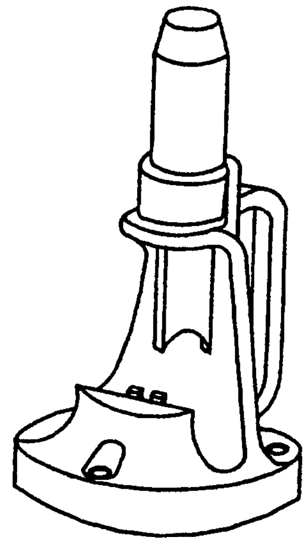


Figure 36. Hammer-type cable cutter.

ports must be erected and guyed in position before the cable is installed. For pivoting structures, the cable can be pulled across the stream and raised as the A-frames are lifted into position.

Pulling a cable across a large or deep river is best accomplished by first pulling a fiber rope across the river with a boat and then pulling the steel cable with the rope. Usually, the cable is attached on the less accessible side first. The cable and turnbuckle are assembled, and the cable is laid over the sheave or bearing block of the A-frame. The A-frame is then pulled to a nearly upright position and guyed. Usually the second side is handled by lifting the A-frame into position before end connections are made to the main cable; if exact measurements are made, the end connections can be done prior to lifting the A-frame into place.

Raising and tightening a main cable present the most dangerous parts of the construction process because of the large amount of energy involved. It is strongly recommended that, prior to this activity, the construction crew take a brief break and carefully review assignments, personnel positions, and safety procedures. Also, all connections and lifting equipment should be double checked prior to final tensioning.

CAUTION.—Various block and tackle, cable hoists (come-a-longs), and chain hoists are used to erect A-frames and tighten cables. Make certain that the lifting devices being used are rated for the loads involved. Always use a cable grip of the proper type and size to attach the lifting device to the main cable to prevent damage to the cable or avoid slippage or failure during lifting. Common sense and caution are critical. A 1/4-in. cable hoist is not capable of tightening a l-in. steel cable. Double check connections to the main cable when chains are used to assist in the lifting. Make sure that all pulls are straight. Make sure that all personnel are clear, should something go wrong as the cable is pulled up.

The following method is recommended for tightening a wire rope and fastening it to its anchorage. With one end of the hoisting device hooked to the anchor and the other to the main cable, take up the cable to slightly tighter than unloaded sag. Fasten the turnbuckle to the anchor and place a thimble in the cable end. The turnbuckle should be in its fully extended position. Pass the end of the main wire rope around the thimble and install clips to achieve maximum holding power. See figure 37 for proper clip placement. Follow the directions listed below to attach the U-bolts to the cable.

1. Turn back the specified amount of rope from the thimble. Apply the first clip approximately one base width (width of clip saddle) from the dead end of the wire rope (U-bolt over dead end, live end rests in clip saddle). Tighten nuts evenly to recommended torque.

Table 6. Recommended number of clips, torque, and dead-end turnback for wire rope.

Wire rope diameter (in.)	Minimum number clips	Torque[1] (ft-lb)	Minimum turnback (in.)
7/16	2	65	7
1/2	3	65	12
9/16	3	95	12
5/8	3	95	12
3/4	4	130	18
7/8	4	225	19
1	5	225	26
1 1/8	6	225	34
1 1/4	7	360	44

[1]From Wire Rope Technical Board, 1981.

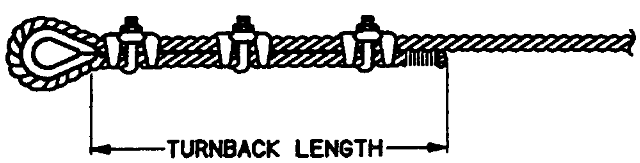


Figure 37. Correct way to attach wire rope clips.

2. Apply the next clip as near the loop as possible. Install nuts firmly but do not tighten.

3. Place additional clips, as required, equally spaced between the first two. (Spacing between clips should be 1 to 2 base widths.) Install nuts firmly but do not tighten; back off lifting device to place a slight tension on the wire rope, and tighten all nuts evenly on all clips to recommended torque.

4. Release lifting device, placing full tension on connection, and retorque all nuts. Rope will stretch and be reduced in diameter when loads are applied. Inspect periodically and retighten to recommended torque. (A light application of spray paint over the cable and wire rope clips provides a visual indication of slippage.)

Recommendations for the minimum number of clips, torque, and dead-end turnback are given in table 6.

A-frame backstay cables are installed and tightened with the A-frame in a plumb position. Final sag adjustment should be made after the cable car is installed and several trips have been made across the cableway with a loaded car to stretch the cable and set bends and clips. One method to check sag easily is to paint a line on both A-frames at a distance from the sheave corresponding to the proper unloaded sag, then sight from one A-frame to the other with a hand level. This procedure is also applicable to structures where cable supports are at differing elevations.

It is necessary to mark the cableway to provide a width reference for discharge measurements. This is commonly done by stretching a tag line or steel tape between A-frames and painting marks at selected intervals with brightly colored paint. A convention of single marks at 5- or 10-ft intervals, double marks at 50 ft, and triple marks at 100 ft is usually used.

INSTALLING GROUNDS

GROUNDING RODS

Grounding rods can be installed for attachment to the main cable, backstay cables, and steel A-frames or other support structures. For cable grounding, drive a standard 10-ft by 5/8-in., copper-clad grounding rod into the earth under the main cable, streamward from the anchorage. Drive the grounding rod about 1 ft below ground level. Clamp a piece of 1/4- to 1/2-in. galvanized wire rope with galvanized wire rope clips to the main cable above all clamps and attachment hardware. With gentle bends, clamp this cable to all backstay cables and arc it toward the grounding rod. Just above the ground level, cut the galvanized wire rope and securely clamp it to a piece of No. 2 copper lightning-conductor cable. Clamp this cable to the grounding rod by using a commercial, bronze grounding clamp. (This procedure reduces damage to the main cable from electrochemical reaction of dissimilar metals.) All connection surfaces should be clean and free of corrosion and coatings. Drive a similar ground rod midway between the A-frame legs and under the A-frame. Solidly connect a No. 2 copper lightning-conductor cable to each leg of the A-frame and to the grounding rod. Connect the two grounding rods with No. 2 copper lightning-connector cable. The grounding rods and connecting wire should be about 1 ft below the surface of the earth. Drive the ground rods full length into solid earth. All bends in the grounding wires should be gradual with no bends less than 8 in. in radius. All cable and components must meet Lightning Protection Institute (1987) requirements.

WIRE GROUNDS

An alternative grounding system uses several 40- to 50-ft lengths of wire buried at least 6 to 12 in. below ground and, preferably, below frost level. Running the wire from the main cable and the A-frames toward the river usually provides the best ground because of the likelihood of increased soil moisture. No. 2 copper lightning-protection cable should be used. Follow all connection procedures described for grounding rods. Extraneous metal objects such as wire fences or antennas should not be connected to cableway systems.

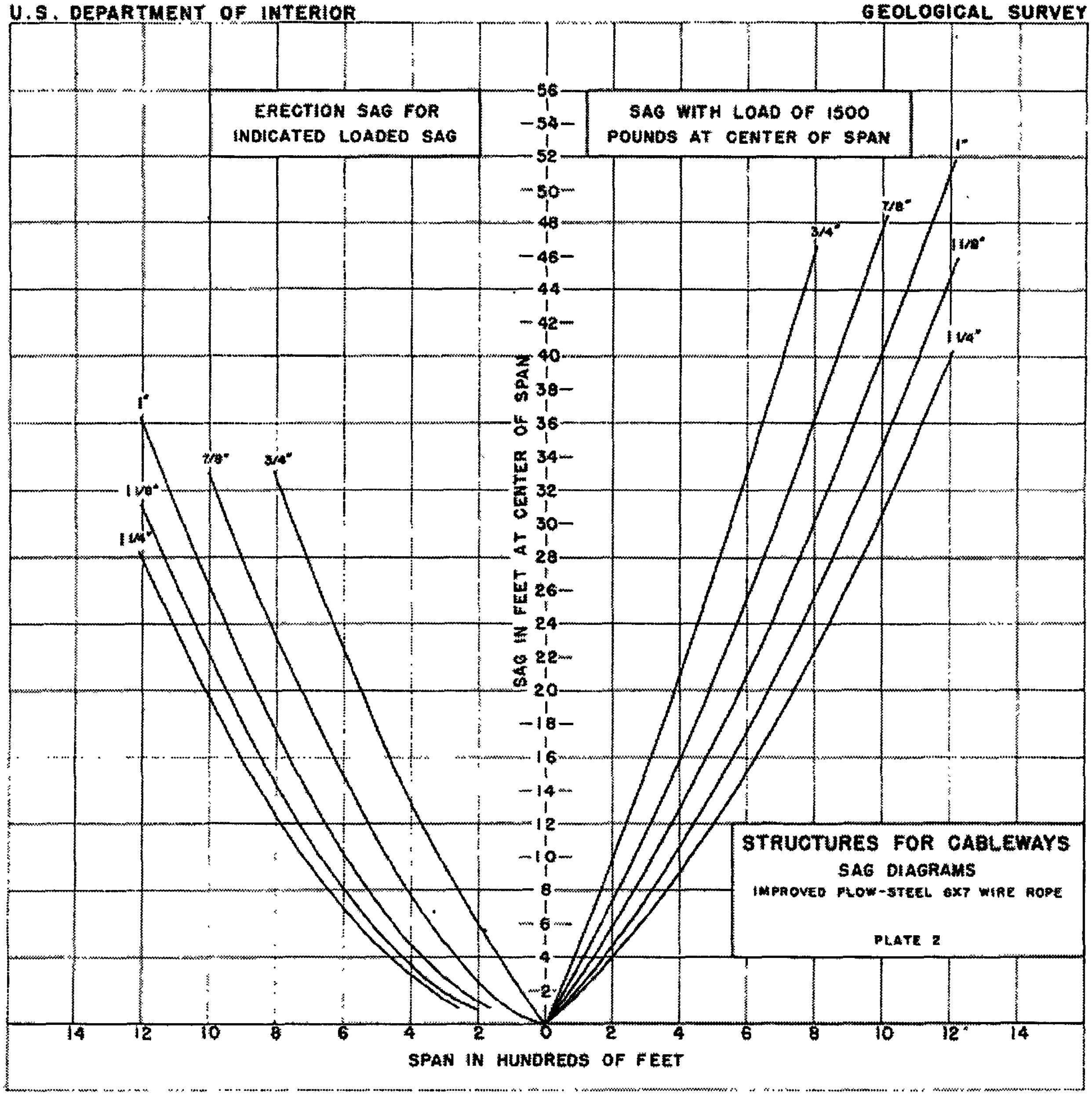


Figure 38. Sag diagram for improved plow steel 6 × 7 wire rope (cable) (from Pierce, 1947, p. 16a).

There is no effective means of protecting operating personnel from the hazards of lightning strikes. Use of cableways during periods of lightning storms is discouraged.

CABLEWAYS CONFORMING TO CIRCULAR 17 SPECIFICATIONS

Design criteria used in this manual differ slightly from those used in earlier cableway manuals. The type and strength of available cable materials have changed since USGS Circular 17 (Pierce, 1947) was prepared, and heavier equipment is now being used.

Many of these earlier structures will be maintained in service for some time. Sag diagrams from Circular 17 are included herein and should be used for determining proper sag adjustments for cableways built in accordance with guidelines from Circular 17 (figs. 38 and 39).

Many existing cableways may be retrofitted with new higher strength cable in the future. The heavier design loads recommended in this manual and the reduced sag and

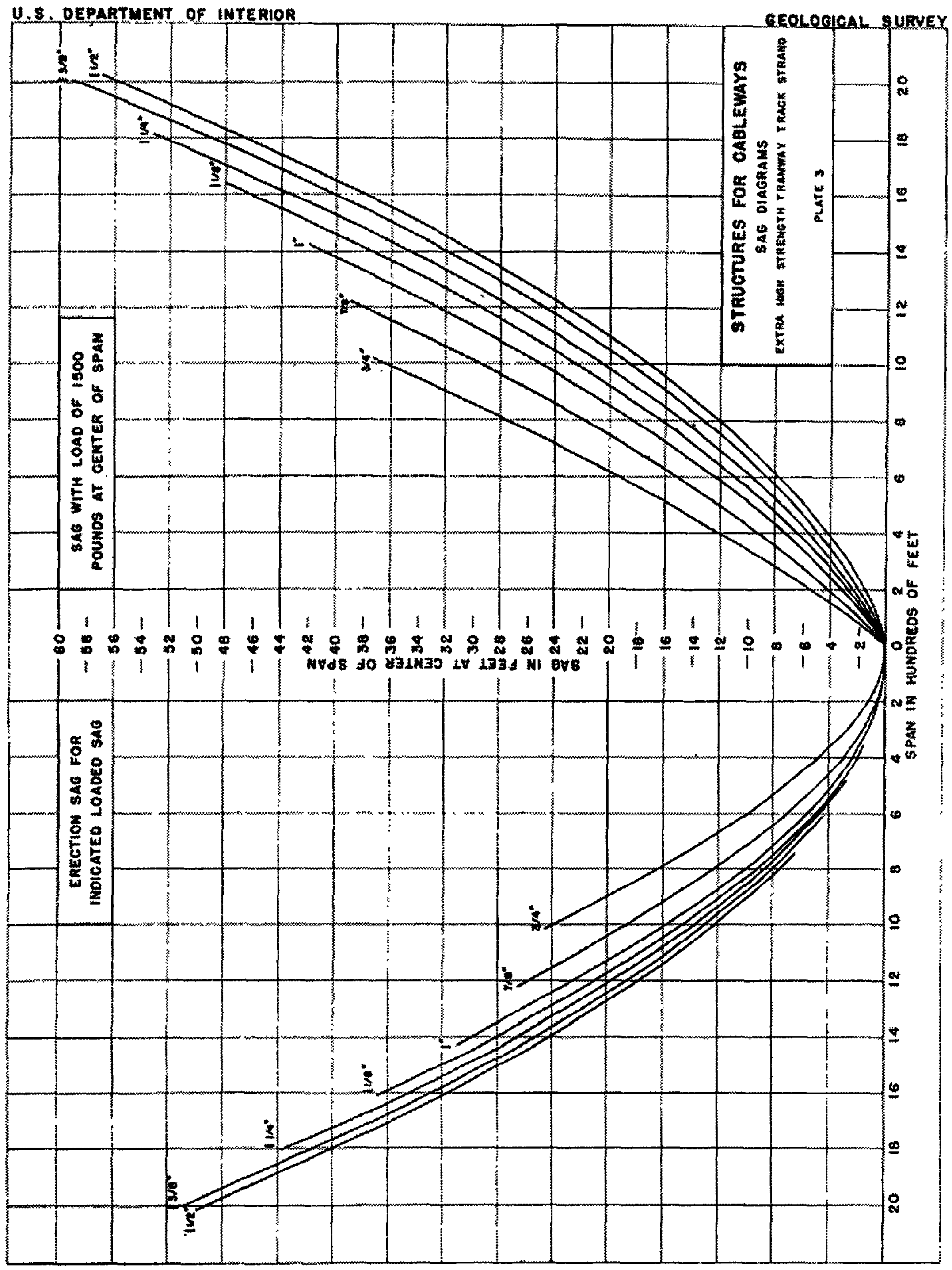


Figure 39. Sag diagram for extra high strength tramway track strand of various diameters (from Pierce, 1947, p. 16b).

higher-strength characteristics of present cable may result in a larger tension force acting on the existing anchorage. Careful inspection and evaluation of existing anchorages and attachment hardware, cable supports, and footings are necessary to determine adequacy of these components to meet increased loads. Complete inspection is also necessary to ensure that strength-limiting deterioration has not occurred. In many cases, replacement of entire systems will be necessary.

Inspection, evaluation, and redesign must be performed and documented by using the guidelines described in this report.

DOCUMENTATION

After a cableway installation is complete, all vital dimensions must be recorded for inclusion in USGS WRD District files and Field Station Description (USGS Form 9–197). Documentation should include the size and depth of the footings, the size of the anchors, the manufacturer and type of cable, and a diagram showing dimensions between components. A copy of the design information, including any special considerations, should always be retained. Any changes or repairs to the structure should be added as they are made.

As much information as possible should be obtained on existing structures. Careful field measurements of cable diameter and type, anchorage dimensions, and related information are important for evaluating the safety of old structures. Reliable information about existing anchors and footings is needed to determine whether they can safely be reused with new supports and (or) cables.

SECURITY

Cableways frequently are the target of vandals. This vandalism may involve breaking locks and using the cable cars to cross streams or just damaging the structure. Cable cars should always be locked when not in use. In most cases, a piece of chain about 4 ft long wrapped around the A-frame or anchor and a standard or high-security USGS padlock will be adequate. The preferred chain is 3/8- to 1/2-in. case-hardened and rustproofed. It is nearly impossible to saw through case-hardened chain and the USGS high-security padlock. However, vandals may cut the chain with large bolt cutters. Several types of special locking devices and lock shields have been tried with some success. "Danger—Keep Off" warning signs should be attached to all cableways.

In some areas subject to frequent vandalism, enclosing the entire anchor, A-frame, and cable car with a heavy-duty, chain-link fence protects the USGS's property and minimizes potential liability for persons injured by misused equipment.

INSPECTION AND MAINTENANCE

Casual inspection and incomplete maintenance of a cableway structure may result in shortening its useful life and jeopardizing the safety of personnel using the system. Inspection personnel must have a knowledge of materials and forces acting on the systems and be properly trained in field inspection techniques. Maintenance personnel must also receive training in proper procedures. One of the major factors in deterioration of cableway systems is the improper selection of fabrication materials and subsequent preservation of components. Guidance on painting and preservation is given in appendix III.

Experience indicates that the majority of cableway system deficiencies are in the footing to A-frame attachment, backstay system, and improperly installed wire rope clips.

Every cableway system shall be inspected at least once each year, and new or modified structures should be inspected after the first several uses. The inspections shall be performed by a qualified person, and an inspection report, in approved USGS format, must be completed, signed, and submitted to appropriate USGS WRD District management. In cases where the safety of a cableway is in doubt, the structure should not be used until further testing proves it to be safe or repairs have been made. Field inspection of cableway systems is critical to the lives and safety of field personnel. USGS WRD District management and field personnel must therefore make thorough inspection and maintenance of cableways a priority of the highest order. Inspection of a cableway system should include, at a minimum, the items listed in the following sections.

ANCHORS AND FOOTINGS

1. Carefully check the general condition of concrete and steel U-bar connection to concrete. Look for crack lines in concrete or evidence of movement where the U-bar enters concrete.
2. Inspect the general condition of rock anchors for any indications of deterioration or movement of U-bar or pin. Check for fracture or other failure of adjacent rock formation.
3. Check to see that connections are free of soil and debris. Check for indications of overstress, corrosion, or damage. Clean and paint if required. Previous guidance recommended that tar should be used to seal between U-bars and concrete. However, experience has since shown that moisture frequently penetrates between the tar and metal and causes corrosion. Tar

should be removed, and metal components carefully inspected. If found to be safe, clean and paint; otherwise replace as necessary.

4. Check for movement of anchor or footings. Look for subsidence, heaving, or other signs of instability. Check dimensions between anchors and footings if instability is suspected.
5. Check for erosion or other disturbance of adjacent soil.
6. Trees used as anchors must be alive and healthy. Check bearing blocks for soundness and proper position. Root systems must not show signs of movement or damage.

MAIN CABLE SUPPORTS

1. A-frames or I-beams must be plumb. Check bolts and hardware attaching A-frames to concrete footings for rust and signs of movement.
2. All metal components must be rust free. Remove rust and paint as required. See appendix III.
3. Check wooden A-frames and walkways for rot or termite damage, especially at ends. Apply wood preservative as required.
4. Check points of contact between concrete and steel (or wood) for corrosion or rot.
5. Check sheave or saddle block for condition and proper contact with cable. Look for signs of corrosion or damage to cable at this point of contact.
6. Check ladders, walkways, platforms, and safety rails for stability and condition.
7. Check grounding of steel structures.
8. Trees used as cable supports must be alive and healthy. Check bearing blocks for soundness and proper position. Root systems must not show signs of movement or damage.

MAIN CABLE

1. Check general condition of main cable. Note rust penetration and broken wires. Particularly note condition at the point where the main cable contacts the support (sheave or saddle block) and where it connects to the anchorage. Broken wires at these locations indicate serious deterioration and require immediate replacement or inspection by a specialist.
2. Replace wire rope or structural strand when one or more of the following occur:
   a. The number of broken wires within a rope lay length, excluding filler wires, exceeds either (1) 5 percent of the total number of wires or (2) 15 percent of the total number of wires within any strand.
   b. On a regular lay rope, there are two or more broken wires in the valley between strands in one rope lay length.
   c. On a structural strand, there are more than three broken wires.
   d. There are two or more broken wires at any termination.
   e. The rope deterioration caused by corrosion exceeds that defined as moderate (see glossary).
   f. There is loss of more than 10 percent of the rope strength as determined by nondestructive testing.
   g. There is any unexplained distortion.
3. Check sag and adjust as required. If sag has changed frequently, find out why. Field personnel should not make sag adjustments on the hottest days or coldest days without making sure that sag is within acceptable limits. Sag adjustments should be made during periods near annual mean temperatures. In no case should the sag be set less than the unloaded sag from figures 3–14 in this report.
4. Check cable markings; repaint as needed.

BACKSTAY

1. Check general condition of cable. Note rust or damage to cable. Replace if indicated by using the criteria applicable to the main cable.
2. Check for undersized cable; replace if necessary.
3. Check tension. It should be taut but not under great load.
4. Check attachment on support structure and anchor.

CABLE CONNECTIONS

1. Check general condition of wire rope clips. Replace if rusted. Replace if improperly installed. Check for damage to wire rope if improperly installed. Check for slippage on cable. Check for loose clips. Tighten to proper torque.
2. Check sockets (bridge sockets or poured sockets) for corrosion, movement, or other signs of deterioration. Field repairs are not recommended. Report deficiencies; do not use structure pending replacement or inspection and approval by a specialist.
3. Check condition of turnbuckle. Apply grease to threads to prevent seizing and retard corrosion.
4. Check clips and fittings on backstay cables.
5. Check cable attachments to trees. Adjustments may be necessary to accommodate tree growth.

CABLE CAR

1. Check general condition. Grease sheaves if required.
2. Check for loose, missing, or corroded bolts. Replace as required.
3. Check brake system. Repair as required.

4. Check condition of wood on wooden cars. Apply wood preservative or replace as needed. Check and clean drainholes.
5. Check condition of aluminum components of aluminum cars for deterioration or corrosion.
6. Check and oil locking system.

MISCELLANEOUS

1. Check aircraft warning markers. Replace as required. Check all components of supporting cable and fittings, as described above.
2. Cut grass and brush adjacent to anchors and cable supports and under cable to water's edge. **Remove dirt or debris in contact with or close to anchor connection**.
3. Remove overhanging branches or trees that might fall on structure.
4. Note any encroachment of activity in area that might damage structures.
5. Check condition and integrity of security fences or other protective devices.
6. Check for warning signs. Replace if necessary.

Note any uncorrected deficiencies that may affect the safe use of the cableway and report to USGS WRD District management immediately.

In addition to making periodic safety inspections, field personnel should always look over the anchorages, turnbuckles, wire rope clips, and other system components for damage or vandalism prior to operating a cableway. The supporting and anchoring devices on the far side of the stream may be difficult or impossible to inspect before every use but should be visually checked from the cable car at the time of each discharge measurement. In wooded areas, trees may fall on the cable structure, and thorough inspection before use is required.

NONDESTRUCTIVE TESTING

Load testing of a cableway is performed as a method of testing the integrity of the entire cableway system. The load testing requires that a 2,000-lb deadload, or the design load of the cableway, whichever is the larger, is suspended from approximately center span. The usual deadload is a quantity of water. Various vessels and suspension systems have been developed for this purpose.

Load testing is performed ideally during conditions of saturated soil, when movement of footings and anchors is most likely to occur. Soil moisture conditions should be included on load test reports.

Anchor block and footing measurements should be taken prior to loading and again under fully loaded conditions to determine lateral and vertical movement. A simple set of levels run to the top of A-frame footings, corners of concrete anchors, and top of U-bars and tied to a reference mark not associated with the cableway structure is adequate. Horizontal reference can include measurements from A-frame anchor bolts to a point on the U-bar or to temporary stakes driven into the ground some distance from the structure. A simple string and batterboard setup similar to the setup used in foundation construction is an easy form of reference. Where a cableway is located near a gaging station, the elevation of cableway elements should be tied to gage datum. Periodic levels could be useful for documenting structure movement.

> **CAUTION.**—Personnel should use extreme caution during the loading, measuring, and unloading of the structure since failure of effective system components including total collapse of the structure is possible. Personnel should plan every detail by assuming that the system will fail.

Magnetometer tests can be run on the main cable to determine changes in metallic area along the length of cable. Changes in metallic area are indicative of deterioration that may not be visually detected. Unfortunately, the magnetometer can not pass over cable supports or terminations. Magnetometer tests require specialized equipment and trained operators to interpret results. Generally the USGS contracts with specialized testing firms for this work.

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APPENDIXES

APPENDIX I. NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION

DO NOT REMOVE CARBONS

Form Approved OMB No 2120-0001

U.S. Department of Transportation
Federal Aviation Administration

NOTICE OF PROPOSED CONSTRUCTION OR ALTERATION

Aeronautical Study Number

1. Nature of Proposal

A Type	B Class	C Work Schedule Dates
☐ New Construction	☐ Permanent	Beginning ______
☐ Alteration	☐ Temporary (Duration ____ months)	End ______

3A. Name and address of individual, company, corporation, etc. proposing the construction or alteration. *(Number, Street, City, State and Zip Code)*

( ) ________________
area code **Telephone Number**

B. Name, address and telephone number of proponent's representative if different than 3 above.

2. Complete Description of Structure

A Include effective radiated power and assigned frequency of all existing, proposed or modified AM, FM, or TV broadcast stations utilizing this structure

B Include size and configuration of power transmission lines and their supporting towers in the vicinity of FAA facilities and public airports

C Include information showing site orientation, dimensions, and construction materials of the proposed structure

(If more space is required, continue on a separate sheet.)

4. Location of Structure

A Coordinates *(To nearest second)*	B Nearest City or Town, and State	C Name of nearest airport, heliport, flightpark, or seaplane base
° ' " Latitude	(1) Distance to 4B Miles	(1) Distance from structure to nearest point of nearest runway
° ' " Longitude	(2) Direction to 4B	(2) Direction from structure to airport

5. Height and Elevation *(Complete to the nearest foot)*

A. Elevation of site above mean sea level	
B. Height of Structure including all appurtenances and lighting *(if any)* above ground, or water if so situated	
C. Overall height above mean sea level *(A + B)*	

D. Description of location of site with respect to highways, streets, airports, prominent terrain features, existing structures, etc. Attach a U.S. Geological Survey quadrangle map or equivalent showing the relationship of construction site to nearest airport(s) *(If more space is required, continue on a separate sheet of paper and attach to this notice.)*

Notice is required by Part 77 of the Federal Aviation Regulations (14 C F R Part 77) pursuant to Section 1101 of the Federal Aviation Act of 1958, as amended (49 U.S.C 1101). Persons who knowingly and willingly violate the Notice requirements of Part 77 are subject to a fine (criminal penalty) of not more than $500 for the first offense and not more than $2,000 for subsequent offenses, pursuant to Section 902(a) of the Federal Aviation Act of 1958, as amended (49 U.S.C 1472(a)).

I HEREBY CERTIFY that all of the above statements made by me are true, complete, and correct to the best of my knowledge. In addition, I agree to obstruction mark and/or light the structure in accordance with established marking & lighting standards if necessary.

Date	Typed Name/Title of Person Filing Notice	Signature

FOR FAA USE ONLY *FAA will either return this form or issue a separate acknowledgement.*

The Proposal:

- ☐ Does not require a notice to FAA.
- ☐ Is not identified as an obstruction under any standard of FAR, Part 77, Subpart C, and would not be a hazard to air navigation.
- ☐ Is identified as an obstruction under the standards of FAR, Part 77, Subpart C, but would not be a hazard to air navigation
- ☐ Should be obstruction ☐ marked, ☐ lighted per FAA Advisory Circular 70/7460-1, Chapter(s) ________
- ☐ Obstruction marking and lighting are not necessary.

Supplemental Notice of Construction, FAA Form 7460-2 is required any time the project is abandoned, or

- ☐ At least 48 hours before the start of construction.
- ☐ Within five days after the construction reaches its greatest height.

This determination expires on ______________ unless:

(a) extended, revised or terminated by the issuing office;
(b) the construction is subject to the licensing authority of the Federal Communications Commission and an application for a construction permit is made to the FCC on or before the above expiration date. In such case the determination expires on the date prescribed by the FCC for completion of construction, or on the date the FCC denies the application.

NOTE: *Request for extension of the effective period of this determination must be postmarked or delivered to the issuing office at least 15 days prior to the expiration date.*

If the structure is subject to the licensing authority of the FCC, a copy of this determination will be sent to that Agency.

Remarks:

Issued In	Signature	Date

FAA Form 7460-1 (8-85)

DO NOT REMOVE CARBONS

APPENDIX II. CABLEWAY DESIGN SUMMARY

District________________Office________________Region ________________
Station No.________________Name ________________
Property Owner LB Signed Easement Y N Date________________
(attach)
RB Signed Easement Y N Date________________
FAA notification________________Construction Permits ________________
Highwater Access

DESIGN CRITERIA—Attach cross section of cableway station

Channel width, Normal________________Bankful________________100 yr flood________________
Elevation of: 50 yr flood________________100 yr flood________________Historical ________________
Cableway span between supports________________Cable-car Type________________
Cableway Purpose________________
Design Load________________lbs (if <2250, justify)

DESIGN—Standard USGS design based on Streamgaging Cableways, OFR 91-84

Soil Type A B Frost Depth________ft Submergence Probable Y N
Footings: LB________________Dimensions ________________
Footings: RB________________Dimensions ________________
Cable Support LB________________Height ________________
RB________________Height________________
Anchorage LB________Angle________Size L_______ W_______ D_______ CUYDS ____________
RB________Angle________Size L_______ W_______ D_______ CUYDS ____________
Main Cable Cable Type____________Diam__________Termination________________
Backstay Wire Rope Type____________Diam__________Number________________

Unloaded Sag________________ Distance (cable loaded sag) to 100 yr elev ________________
Walkways/Platforms ________________
Other: ________________
Deviations from standard design Y N; if Y, attach design documentation
Remarks:

Designed by________________ Title________________Date________________
Checked by________________Title________________Date________________
Approved by________________Title________________Date________________

APPENDIX III. PAINTING AND PRESERVATION GUIDELINES

A major cause of deterioration of metal cableway structures is failure to maintain proper protective paint coatings. A large part of this problem is lack of thorough cleaning and rust removal from metal components prior to recoating. Metal components must be sandblasted, wire brushed, scraped, and then washed to remove all loose material, grease, and soil, allowed to dry, and recoated with a two-coat paint system. Industrial enamels having oil- or alkyd-type bases are best suited to USGS field facilities. Dampness-tolerant primers, which are particularly well suited for field application, are available. These primers are formulated to bond firmly to bare or semibare metal and should be coated with a compatible top coat after a 24-hour drying time.

Preparation time will greatly exceed actual painting time. A properly applied two-coat system should last 5 or 6 years on field structures, whereas a quick cover over with improper preparation may fail in less than a year.

Touchup or repair of damaged galvanized surfaces should be done with an organic zinc-rich paint formulated for this purpose. Badly weathered galvanized structures should be painted with one of several two-coat systems of paints developed for this purpose.

Wooden structures are best preserved by fabrication from pressure-treated lumber. Where this has not been done, field treatment with a copper-sulfate-type wood preservative, paying particular attention to the members' end-grain areas most susceptible to deterioration, is an acceptable alternative.

All coatings should be industrial quality products from reliable manufacturers. Most coatings should be applied by brush during temperatures from 40 °F to 125 °F.

Painters of all types—industrial, marine, commercial, or even weekend painters—generally have one thing in common. That is, they tend to neglect the most important part of a coating job, surface preparation. The time and expense required to take this step are generally resented, creating a psychological barrier. Physical application of the coating seems to be a much more productive and therefore satisfying activity than sandblasting, chipping, scraping, or even thoroughly washing a surface. Unfortunately, if proper surface preparation methods are omitted, the whole coating program is doomed to be a waste of both the time and expense involved.

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