project record

MAY 1979

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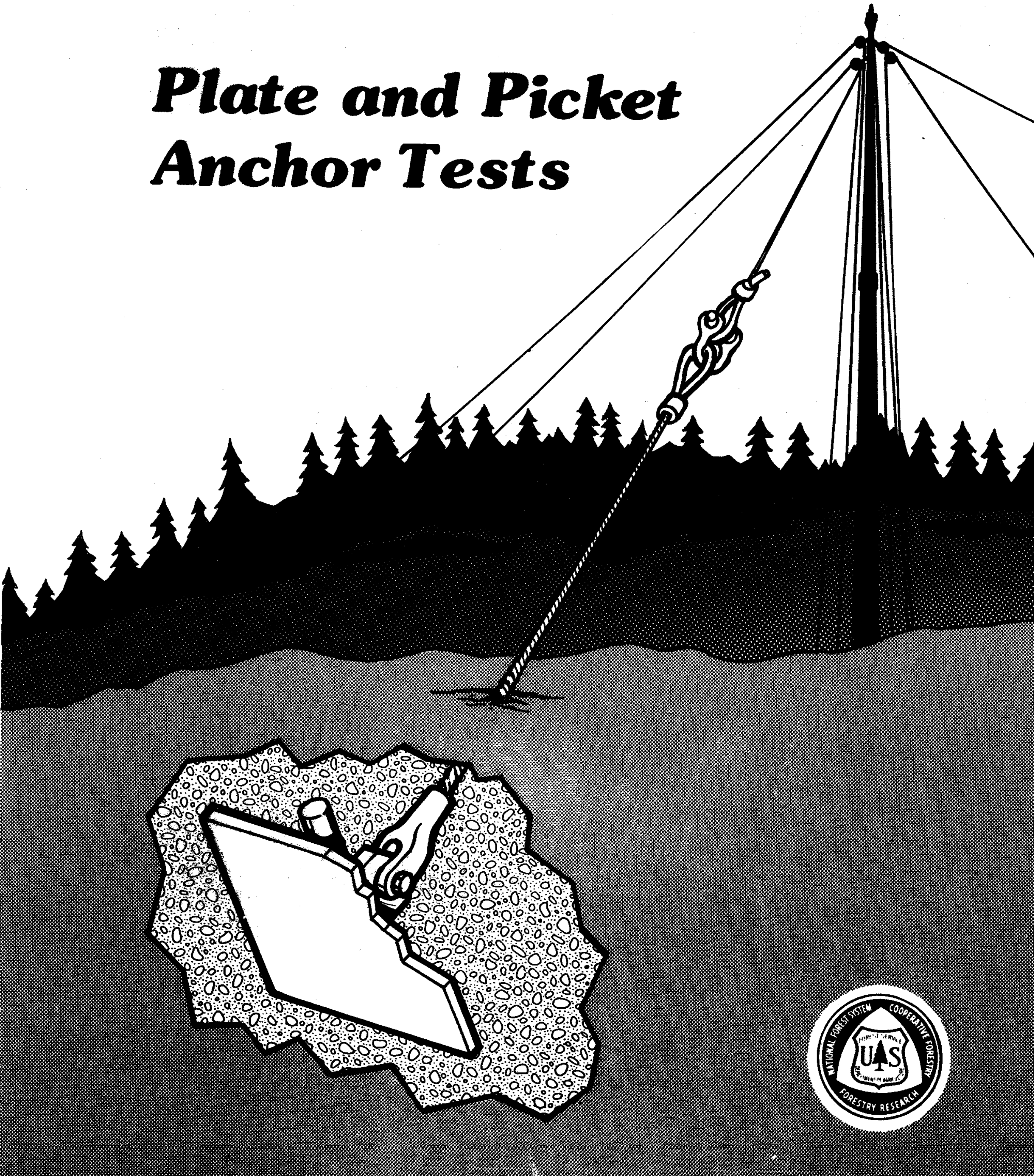
Plate and Picket Anchor Tests



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ACKNOWLEDGMENT

The following contributions to project effort are gratefully acknowledged:

- **Bruce Coombs, Logging Manager, Simpson Timber Co., Shelter, Wash.** Provided equipment, manpower, and supplies for test program.

- **Fred Weaver, Timber Management Assistant, Olympic National Forest, Shelton, Wash.** Provided Ranger District coordination and support.

- **Bill Fieber, Logging Specialist, Olympic National Forest, Olympia, Wash.** Provided help with test program and test site location.

- **Bob Nesbitt, Materials Engineer, Olympic National Forest, Olympia, Wash.** Provided materials engineering support.

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Plate and Picket Anchor Tests

by

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ED&T Project No. 2640
Substitute Anchors for Cable Transport Systems

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INTRODUCTION

Large, undecayed, old-growth stumps are used as guyline and tail-hold anchors for cable logging systems—when available. However, nowadays they are seldom found. Further, cable logging systems not dependent on stumps can be laid out with more flexibility and moved more often. In the past decade some substitute anchors have come into use. But, Occupational Safety and Health Administration (OSHA) guidelines have raised concerns as to the reliability and safety of the various substitutes.

As part of an overall project to develop and field test substitute anchors for cable logging, engineers and technicians at the San Dimas Equipment Development Center (SDEDC) gathered information on the static and dynamic anchorage requirements of cable logging systems. This report focuses on plate and picket anchor tests conducted in October 1978 on the Olympic National Forest, Wash. (Pacific Northwest Region). A plate anchor is a steel plate, driven edgewise into the soil, with a cable attached in such a way as to rotate the plate for maximum surface area exposure to enhance resistance to removal. A picket anchor consists of H-beams driven into the ground and tied together above ground level to share the load and resist removal. Both plate and picket anchors can easily be fabricated in a small machine shop.

The general objective of the test program on the Olympic was to determine the feasibility of using plate and picket anchors with cable logging systems. Specific objectives were to determine:

- **Practical methods of anchor installation**
- **Physical holding capabilities of these anchors**
- **Eccentricity required to rotate plate anchors**
- **Ratio of driving resistance to pullout force.**

MATERIALS INVESTIGATION

As a preliminary step in the test program, the Materials Engineering Support Group of the Olympic National Forest conducted a materials investigation. At three selected test locations, a pit was dug with a backhoe and soil samples were taken from the pit walls. At the sites the soil proved to be a river-deposited, sandy gravel material of medium-to-firm relative compactness. The maximum material size at sites No. 1 and 2 was 3- to 4-in. In contrast, site No. 3 consisted of 40 percent cobbles plus boulders up to 2-ft in diameter.

Standard penetration tests (SPT's) were conducted only at sites No. 1 and 2, since the material at site No. 3 was too coarse for the tests. The SPT at site No. 1 resulted in from 8 to 34 blow counts-per-foot and at site No. 2, 13 to 47 blow counts-per-foot. This indicated that the material at site No. 2 was firmer and should have a higher load-carrying capability. Direct shear tests were not conducted, because the material was too coarse for the Shelby tube sampling process.

INSTALLATION DEVICE

To install the plate and picket anchors, SDEDC chose an M-200 prototype double-acting, hydraulically driven hammer (a "vibratory punch") developed by Post Driving and Equipment (PD&E) Manufacturing, Inc., North Hollywood, Calif. This device, with a driving capability of 500 ft-lb per blow at 600 cycles/minute, was selected because of its versatility. A truck-mounted version (fig. 1) was used in the tests reported on here. It can also be attached to a crawler tractor with adequate hydraulic capabilities or be a self-contained unit; i.e., mounted on a trailer that can be readily moved to any location by a tractor or helicopter.

Figure 1. Truck-mounted hydraulic driving unit.

PLATE ANCHOR FEASIBILITY TESTS

A plate anchor consists of a main steel plate with a smaller plate, having a hole for cable anchor attachment, welded perpendicular down the centerline (figs. 2 and 3). A solid steel bar is welded to the small plate at the centroid of the driving area. A steel adaptor, which fits over the solid bar, is connected to a section of structural steel tubing, called a driving mandrel. To obtain depths greater than the driving mandrel section, another section of steel tubing can be added. After the anchor is driven edgewise into the ground to a prescribed depth, the driving mandrel is removed (figs. 4 and 5). When tension is applied to the anchor, the force acts eccentrically to the main plate, causing it to rotate ("key") until nearly perpendicular to the pulling force.

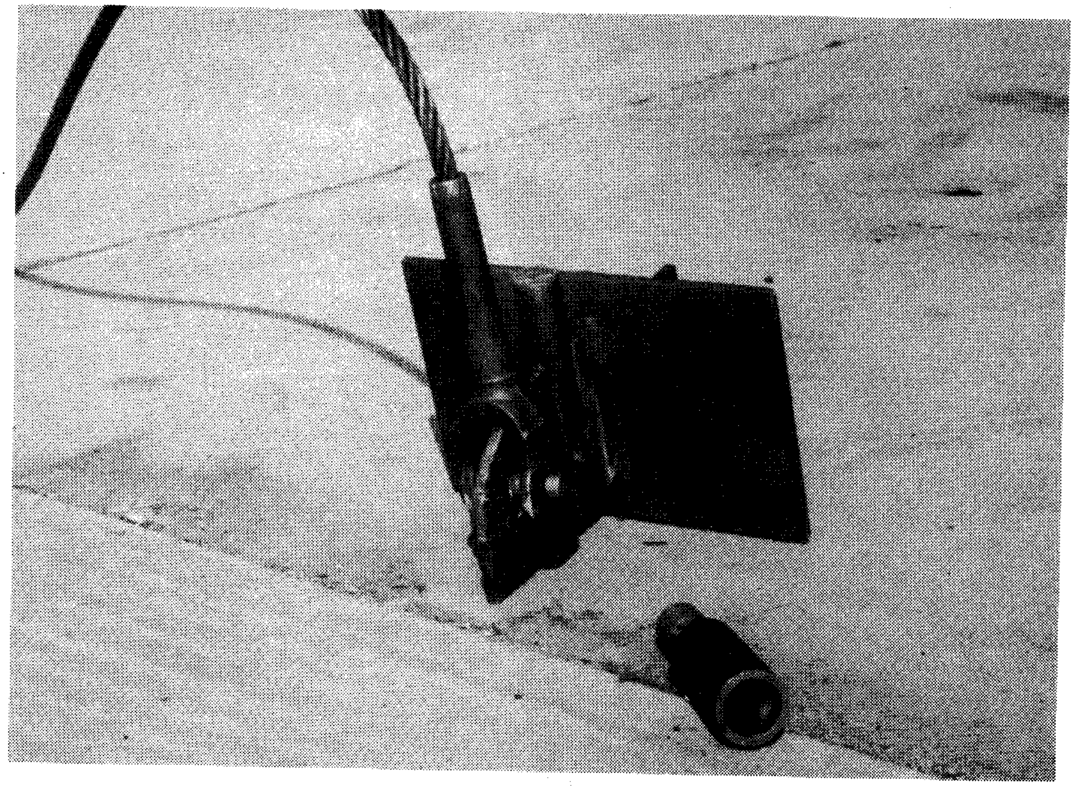

Figure 2. Typical plate anchor with driving mandrel adaptor.

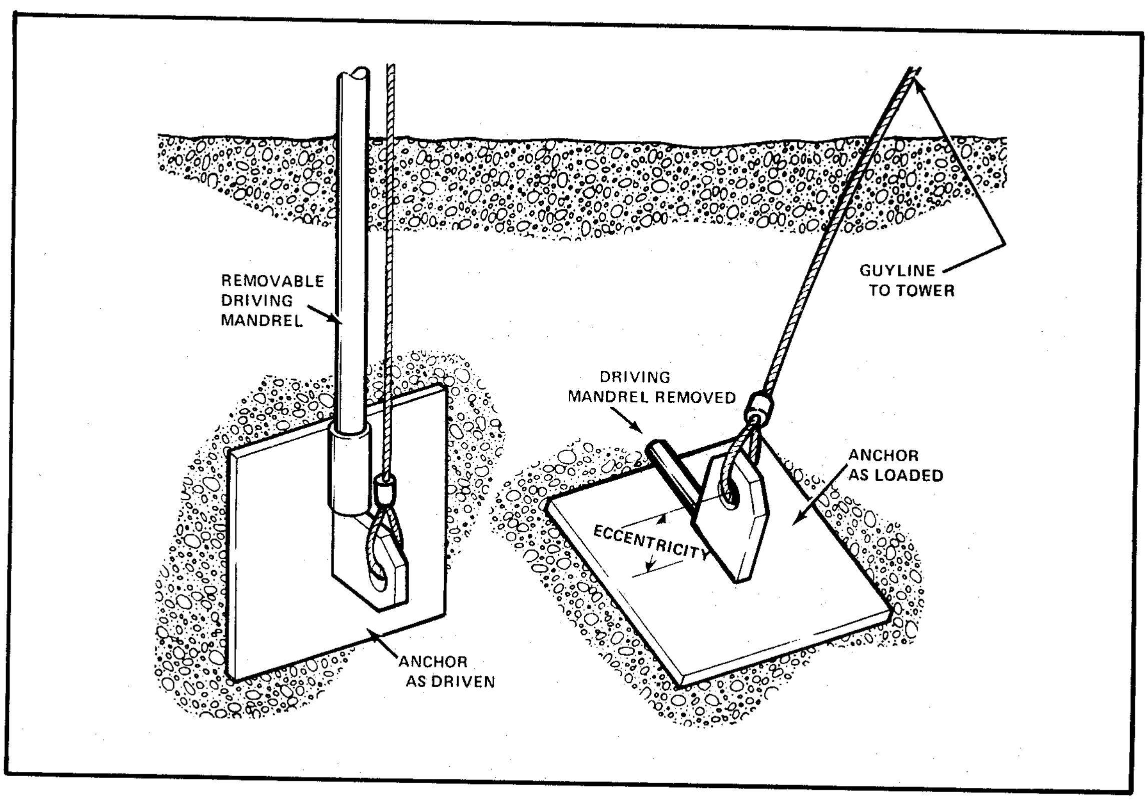

Figure 3. Plate anchor concept.

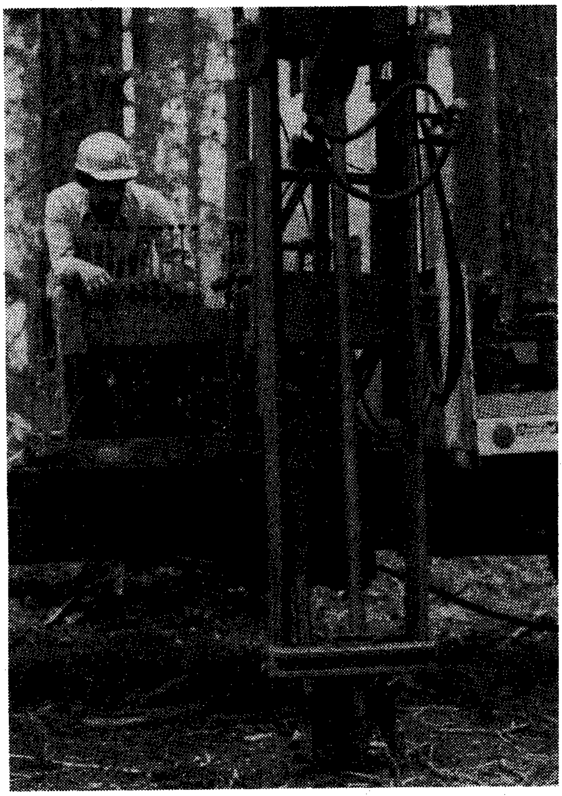

Figure 4. Plate anchor being installed.

Figure 5. Cable protruding from installed plate anchor.

The feasibility tests consisted of the fabrication and testing of 17 plate anchors (table 1). Fifteen of the anchors had a plate area of approximately 1 sq ft. Depending on the dimensions of the main plate, they were given designations of "A," "B," or "C." A's were 9 by 16 in; B's, 12 by 12 in; and C's, 15 by 9-5/8 in. The eccentricities (distances from the main plate to the hole in the smaller plate where the cable is attached) were either 3, 6, or 9 in. The final two anchors in the test series had plate areas of 2 and 3 sq ft.

The tests summarized in table 1 were conducted by installing the anchors, then keying them and continuing the loading until either the anchor was pulled from the ground or the cable or the weld failed. The anchors were loaded in either the horizontal or vertical direction at ground level. Vertical loading was achieved using a 15-ft high steel tripod (fig. 6). Loads were applied to the plate anchors by a winch line (from a Komatsu 85E crawler tractor) that passed through a three-block purchase. A 50,000-lb capacity dynamometer was inserted in the 7/8-in cable near the crawler tractor. The horizontal pulls also utilized the three-block purchase to keep the cables within their allowable working loads.

Figure 6. Tripod used for plate anchor vertical pulls.

Table 1. Plate anchor feasibility tests.

Test No.	Anchor Designation			Plate area	Cable diameter	Installation driving time	Installation depth	Direction load applied	Keying distance	Load	Failure type
	Set No.	Size 1/	Eccentricity	(sq ft)	(in)	(min)	(ft)			(kips)	
1	1	B	9	1	9/16	1.60	5.0	–	–	–	Weld, during installation
2	1	B	6	1	9/16	2.35	9.5	Vertical	–	36.6	Cable
3	1	B	3	1	9/16	1.50	4.5	Vertical	10	21.0	Soil
4	2	A	9	1	9/16	3.27	6.0	Vertical	8	20.9	Weld
5	2	B	9	1	9/16	5.15	8.0	Vertical	–	33.4	Cable
6	2	C	6	1	7/8	3.17	4.0	Horizontal	–	28.9	Soil
7	3	A	6	1	9/16	–	–	–	–	–	Weld, as installed
8	3	B	6	1	7/8	3.58	10.0	Horizontal	–	84.1	Cable
9	3	C	6	1	3/4	2.92	10.0	Vertical	4	78.2	Cable
10	4	A	3	1	9/16	2.50	10.0	Vertical	6	31.0	Cable
11	4	B	3	1	9/16	1.60	9.0	Vertical	6	20+ 2/	Cable
12	4	C	3	1	9/16	2.07	9.0	Vertical	6	20+ 2/	Cable
13 3/	5	A	6	1	7/8	8.00	4.5	Horizontal	–	42.5+ 2/	Cable
14	5	B	6	1	3/4	–	10.0	Vertical	6	67.2	Cable
15	–	B	6	1	7/8	8.30	11.0	Vertical Horizontal	6 –	53.5 81.3	– Cable
16	–	–	–	2	7/8	5.10	11.0	Horizontal	–	70.0	Weld
17	–	–	–	3	7/8	8.43	9.0	Horizontal	–	81.3	Cable

1/ See text.

2/ Dynamometer removed at these readings.

3/ This test was conducted at site No. 3; all others took place at either site No. 1 or 2.

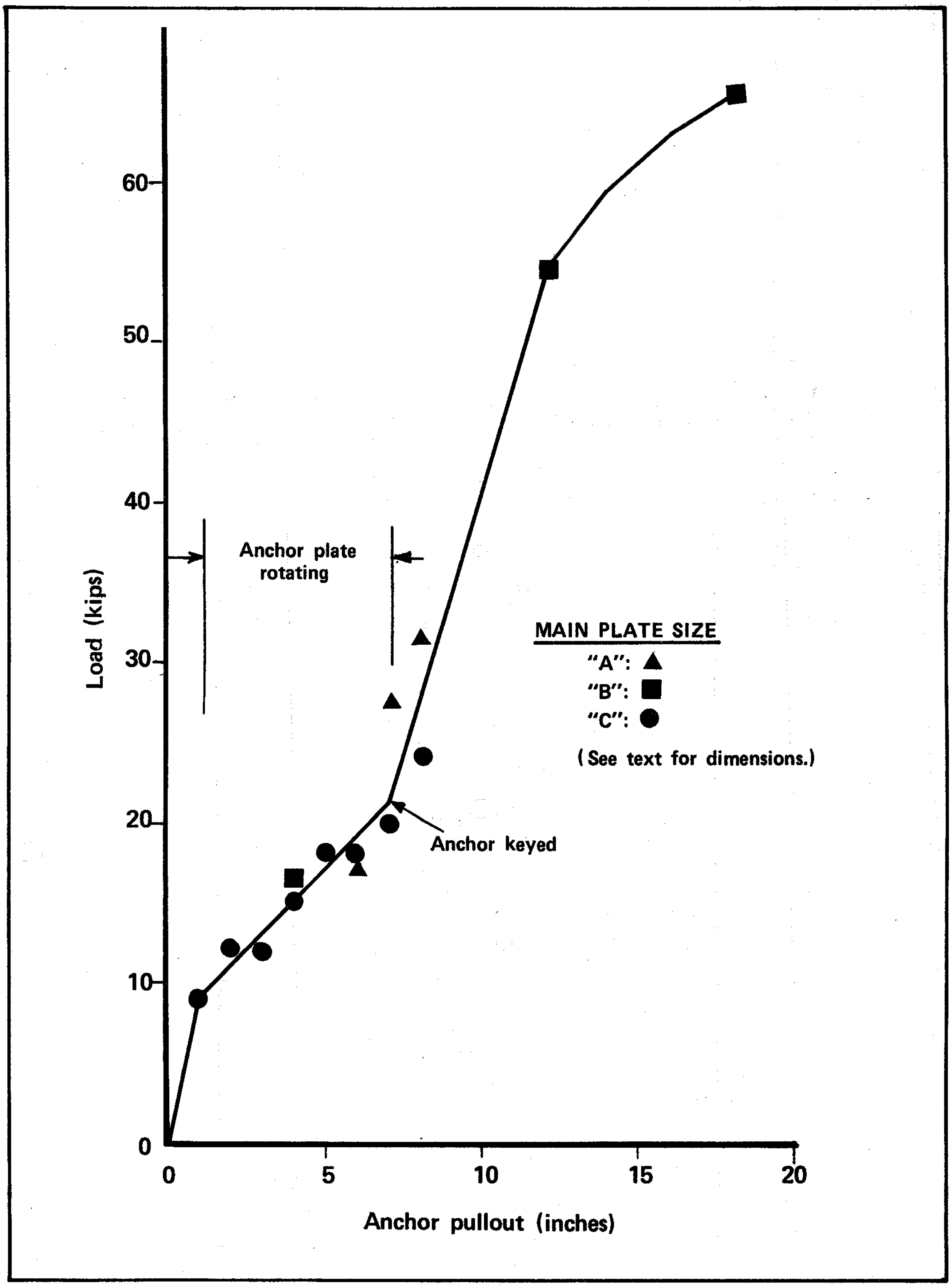

Figure 7. Load vs. pullout, 1-sq ft plate anchors.

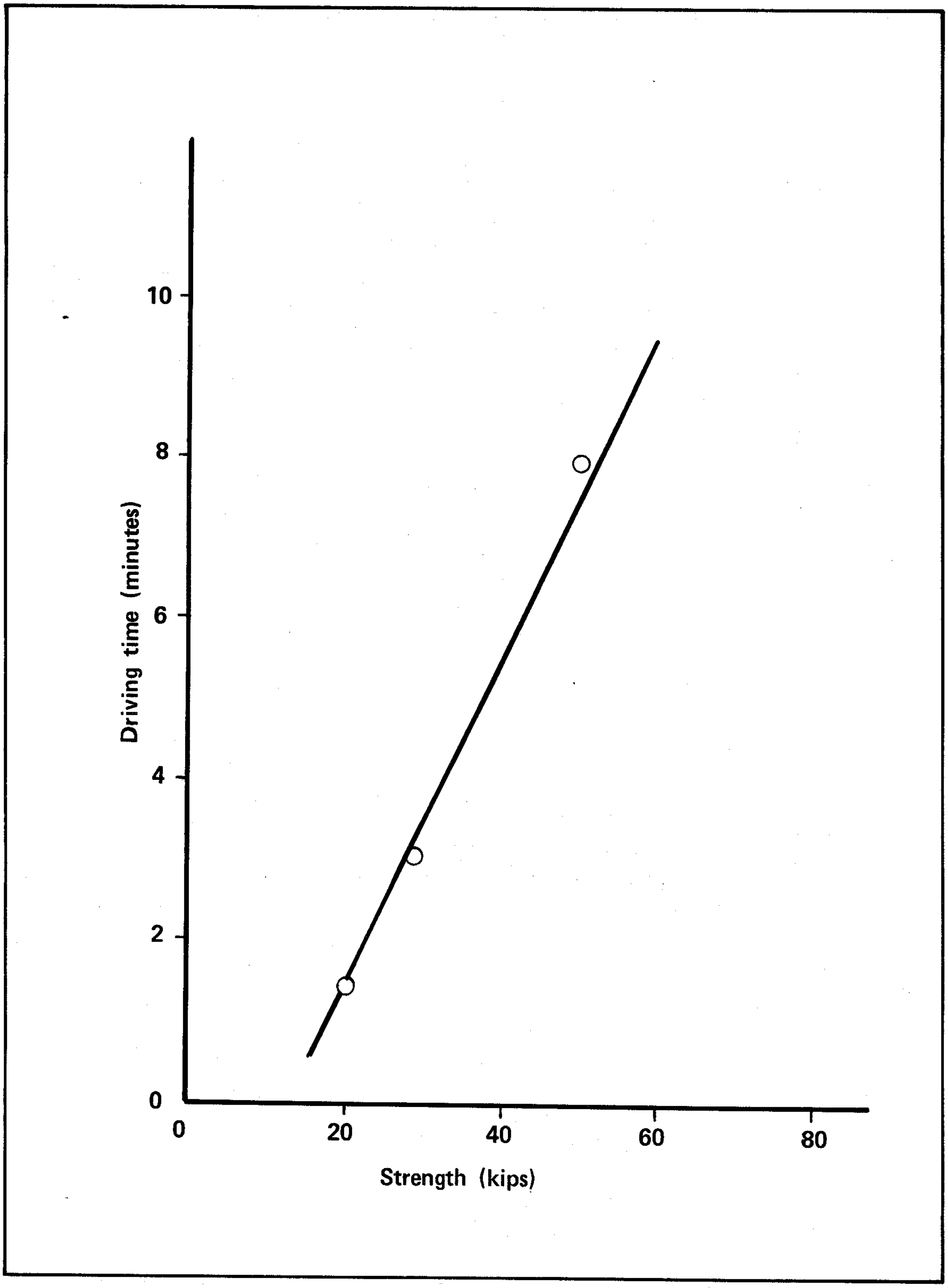

Figure 8. Driving time vs. load pullout strength.

PLATE ANCHOR TEST RESULTS

Keying Distance

The average keying distance—the vertical distance that plate anchors travel as they rotate from vertical to near horizontal—was approximately 7 in. Neither main plate size (i.e., A, B, or C) nor the length of the eccentric arm (3, 6, or 9 in) appear to have much effect on the rotating ability of these anchors in the soil type tested.

The curve in figure 7 shows the relationship between the load applied and the vertical displacement for the 1-sq ft anchors driven to a depth of 10 ft. It can be used to determine the approximate amount of vertical displacement (or pullout—"anchor retrieval") relative to loading requirements for a given type of soil.

Since during a preliminary test at SDEDC an anchor (driven to 10 ft in saturated, sandy silt) took 18 in for the anchor to key and achieve a holding capacity of 30,000 lb, plates appear to rotate quicker in dense than in soft material.

Driving Times vs. Holding Capacity

The driving time (and, therefore, the driving resistance) appears to be linearly related to the holding capabilities of plate anchors. Figure 8, based on only three data points, illustrates loads achieved at a depth of 5 ft vs. installation times.

Creep

Several 1-sq ft plate anchors were loaded to approximately 60,000 lb and held for 5, 15, and 30 minutes. The anchor cable was marked at ground level and a transit used to detect vertical cable movement. None was detected. However, the static load in the cable system did drop several thousand pounds—probably due to a combination of cable stretching, tripod settling, and tractor movement. Most of the loading decrease occurred in the first 5 minutes; little occurred after 15 minutes.

PICKET ANCHOR FEASIBILITY TESTS

Using the PD&E M-200 driving unit, three steel H-beam pickets (5- by 5-in in cross-section and 8-ft long) were driven 6 ft into the ground, 12 ft apart, at two different sites that had coarse, noncohesive gravel material (figs. 9 and 10).[1/] The average driving time was 2½ minutes to place a picket into the sandy gravel soil. Turnbuckles were placed between each picket to apply preloading forces and dynamometers were placed between each picket to record the preloading forces and also the loads transferred back (fig. 11).

1/ **A plan to drive the pickets into the ground at a fourth site (a rock pit having fractured rock material that required blasting), was abandoned after the interface adaptor between the driving head and an H-beam failed. One picket had been installed before the failure; driving it into the ground took approximately 8 minutes.**

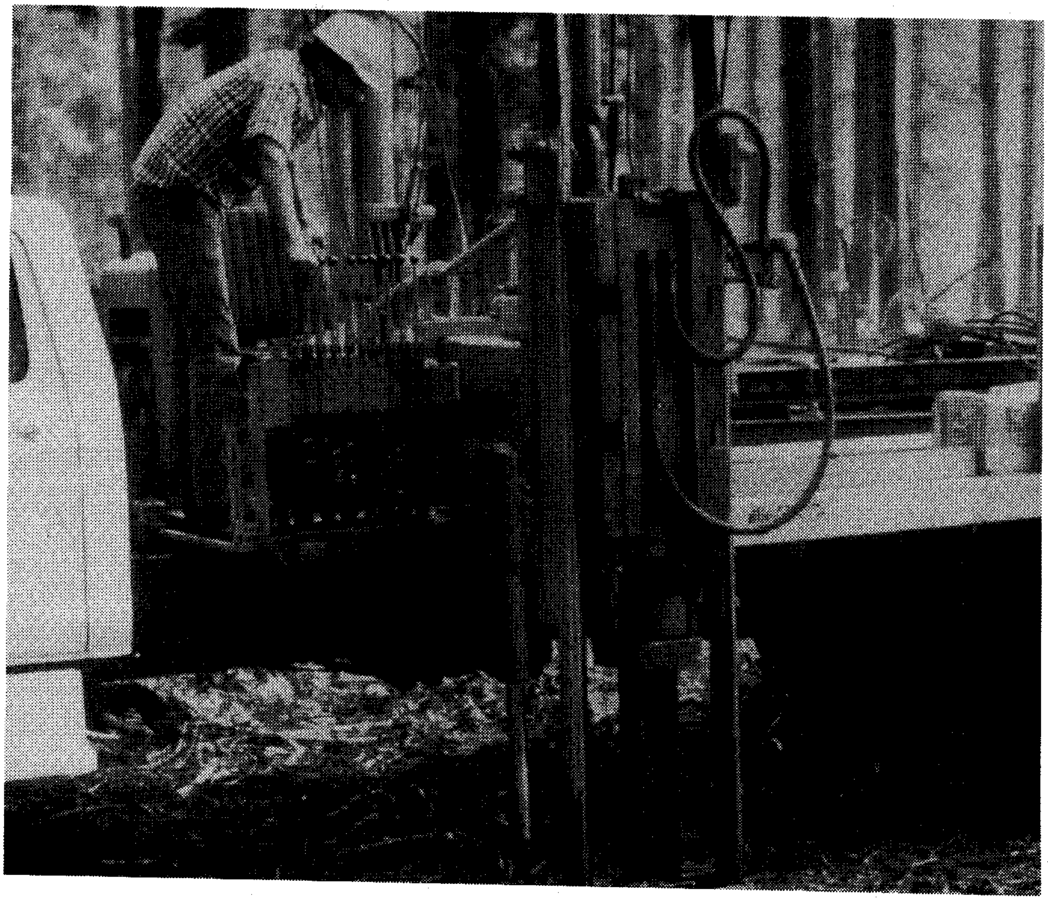

Figure 9. Pickets being installed.

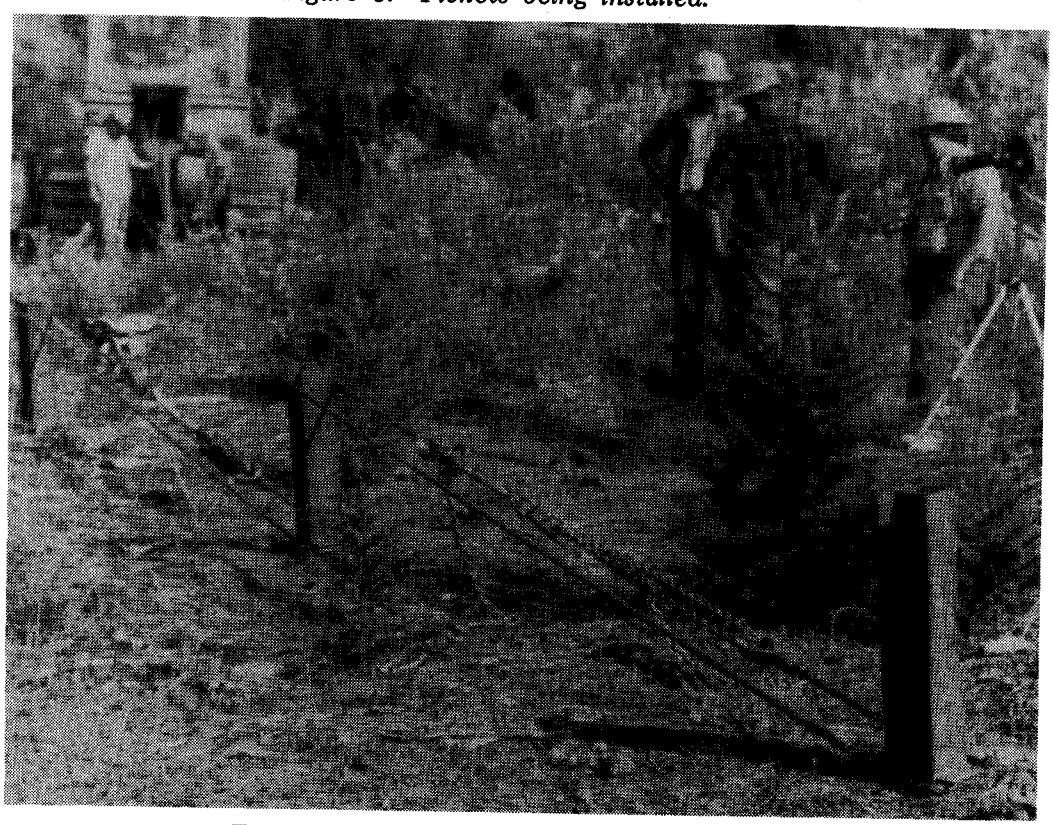

Figure 10. Installed three-picket system.

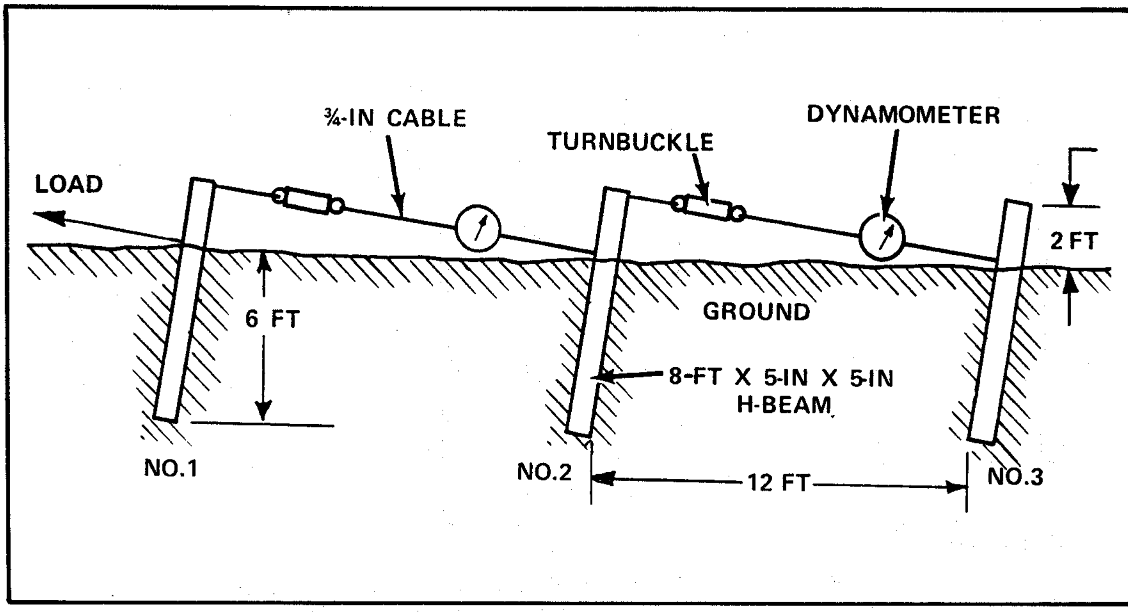

Figure 11. Three-picket system configuration.

PICKET ANCHOR TEST RESULTS

At site No. 1, the web along the center of the lead (first) picket was reinforced at the cable attachment points. Table 2 shows the load applied to this lead picket and the corresponding load transferred to the remaining two pickets. These pickets were preloaded (pretensioned) as follows:

- **3,760 lb between the lead and the second picket**
- **2,400 lb between the second and third picket.**

The first major column ("Lead picket") lists the loads applied to the system through the lead picket. The next major column ("Second picket") lists the corresponding loads in the cables between the lead and the second picket. The "Percent of lead picket load" column is the percent of the load applied to the lead picket that is transferred to the second picket. The final major column ("Third picket") follows the same pattern as the "Second picket" column. The data in table 2 clearly indicate that only approximately one-third of the load is transferred between pickets when they are tied back as in figure 11.

Table 2. Load distribution, three-picket system/site No. 1

LEAD PICKET	SECOND PICKET		THIRD PICKET			
Load (lb)	Load (lb)	% of lead picket load	Load (lb)	% of lead picket load	% of second picket load	Comments
19,640	7,500	38	2,900	15	39	
39,300	12,700	32	4,000	10	31	
49,100	15,200	31	4,400	9	29	Lead beam failed in bending

After the lead picket failed, the two remaining pickets were tied back so as to transfer greater loads to the rear supporting picket (fig. 12). Turnbuckles and dynamometers were placed between them and a dynamometer (designated No. 1, fig. 12) was placed in the applied-load line; the lines were then pretensioned to 2,000 lb. Test results are presented in table 3.

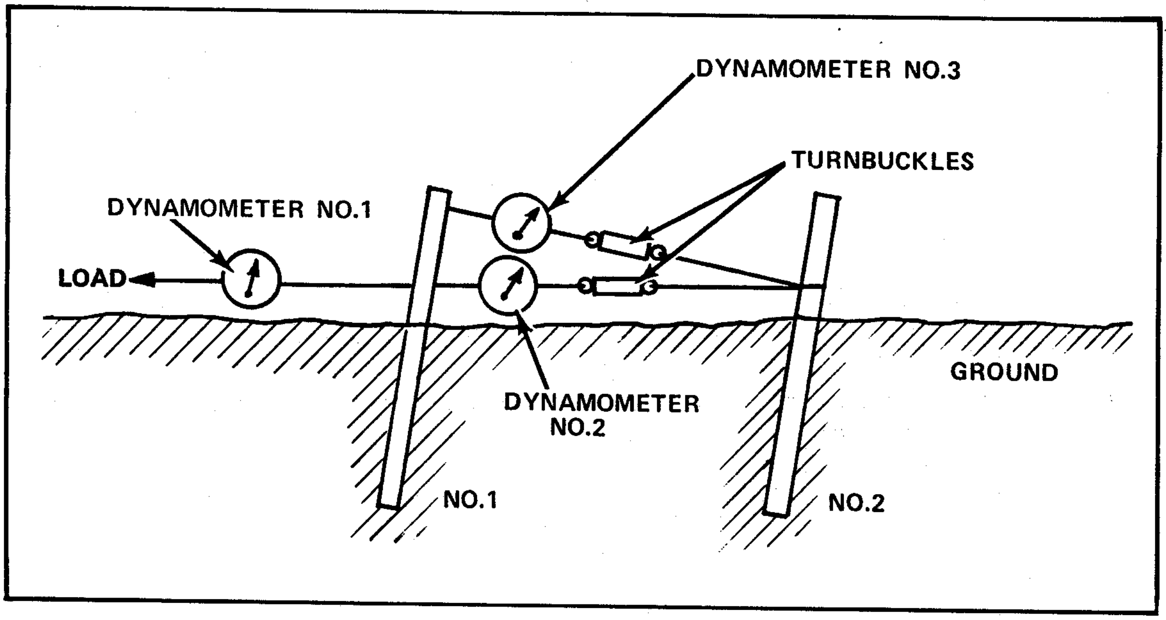

Figure 12. Two-picket system configuration at site No. 1.

Table 3. Load distribution, two-picket system/site No. 1

DYNAMOMETER NO.1	DYNAMOMETER NO.2	DYNAMOMETER NO.3		
Load (lb)	Load (lb)	Load (lb)	% of Dyna. No.1	Comments
19,830	2,100	6,400	32	
39,700	–0–	14,000	35	1st picket moved 1½ in through soil
45,000	–0–	18,000	39	Lead beam failed in bending

The data in table 3 indicate that the tieback technique used did not transfer additional loading back to the second picket. This is due, in part, to the fact that the lead picket moved further at the top than at the lower area (where dynamometer No. 2 was attached). The bottom of the lead picket did not move because of soil resistance, allowing the top of the lead picket to experience maximum deflection as all the load was transferred to its upper portion.

Table 3 data also indicate that the maximum load achieved with the two-picket system (45,600 lb) is approximately 10 percent less than the 49,100 lb achieved with the three-picket system. This corresponds to table 2 data that show the third picket absorbing approximately 10 percent of the load applied to the system.

The three-picket system installed at site No. 2 was basically the same as at site No. 1, except that the lead picket had a 12- by 60- by ½-in steel plate welded lengthwise to the leading flange instead of reinforcement at the web. This steel plate provided additional stiffness as well as greater resistance to picket movement through the soil. This modification increased lead picket load-carrying capacity. Table 4 presents the results at site No. 2 in the same manner that table 2 presented site No. 1 data. The pickets at site No. 2 were pretensioned as follows:

- **3,500 lb between the lead and second picket**
- **2,200 lb between the second and third picket**

Table 4. Load distribution, three-picket system/site No. 2

LEAD PICKET	SECOND PICKET		THIRD PICKET			
Load (lb)	Load (lb)	% of lead picket load	Load (lb)	% of lead picket load	% of second picket load	Comments
3,800	5,000	132	2,400	63	48	
– 1/	18,000	70	6,000	23	33	
52,100	21,500	42	7,200	14	33	Lead beam failed in bending

1/ Valid reading not obtained.

The three-picket system at site No. 2 was inadvertently loaded 17 degrees out-of-line, which subjected the lead picket to torsional loading and subsequently lower ultimate loads. The system would have exceeded a 60,000-lb loading had the load been applied in-line, as was the two-picket system (fig. 13)—consisting of the second and third pickets of the three-picket system—which was then tested at site No. 2 and achieved 57,600 lb (table 5). The line between the new lead and second pickets was pre-tensioned to 3,500 lb.

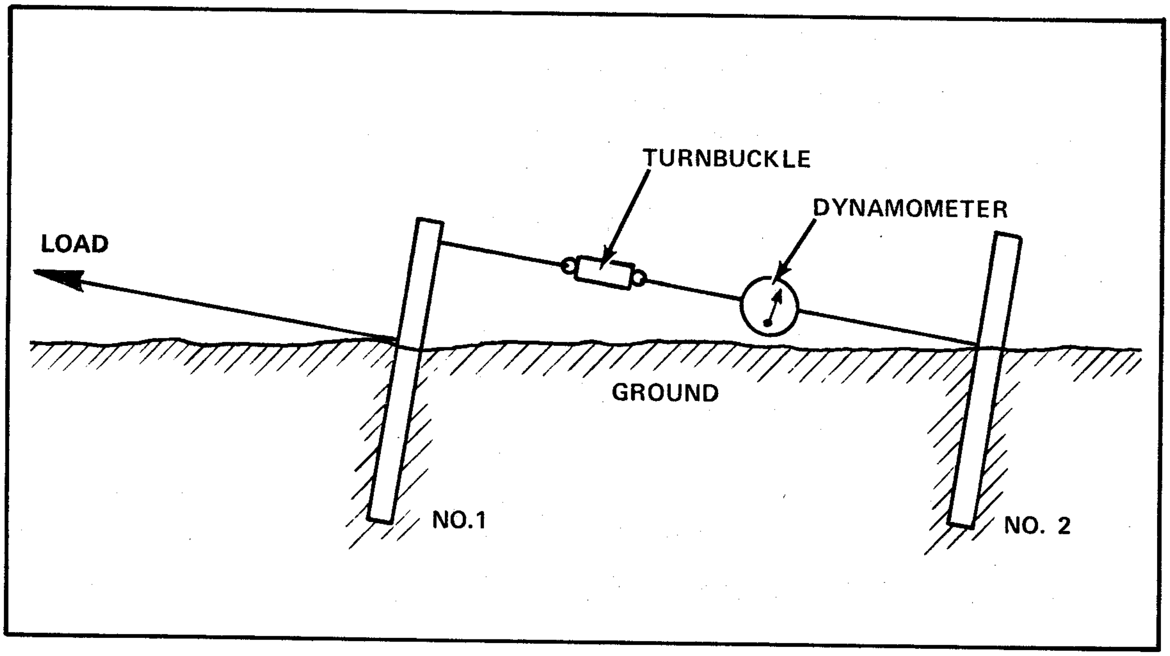

Figure 13. Two-picket system configuration at site No. 2

Table 5. Load distribution, two-picket system/site No. 2

LEAD PICKET	SECOND PICKET		
Load (lb)	Load (lb)	% of lead picket load	Comments
19,200	7,600	40	
38,400	– 1/	21	
57,600	16,500	29	Lead beam failed in bending

1/ Valid reading not obtained.

NOTE: The following detailed technical information can be obtained upon request from SDEDC: (1) a copy of the geotechnical report prepared by the Olympic National Forest and (2) an explanation of how anchor loads were computed.

CONCLUSIONS

Plate Anchors

The plate anchor concept appears to be a very promising substitute anchor for cable logging systems. The tested 1-sq ft plate anchors should achieve ultimate static loads in excess of 100,000 lb, while the 2- and 3-sq ft anchors should be able to hold static loads required for most of the current cable logging systems used in soils similar to the test sites.

Plate anchors can be quickly and easily installed in those areas where the installation equipment can gain access. Depending on soil material characteristics, a plate anchor should take less than 20 minutes to install.

As to the design of these anchors, for soils with densities that require less than 15 blow counts-per-foot, the eccentric arm can be less than one-third the length of the main plate. However, more information on appropriate eccentric arm lengths for wet or loose material is needed.

Picket Anchors

The picket anchor concept also appears to be a feasible system for cable logging applications, affording excellent anchorage capability with relatively little installation effort. After the installation equipment gains access to an area, a picket system can be completely installed in less than 60 minutes. A three-picket system, modified to correct deficiencies uncovered in the Olympic National Forest tests and installed in soils similar to that at sites No. 1 and 2, should hold loads of at least 100,000 lb.

The three-picket data from site No. 1 shows that the beams transfer only about one-third the initial load back to the next picket. At both sites No. 1 and 2, only 10 percent of the load on the lead picket reached the third picket, not a very efficient use of the third picket. Finally, the picket systems that were tested were sensitive to loads that were not applied in-line with the pickets.

RECOMMENDATIONS

Plate Anchors

Further static and dynamic tests should be conducted on plate anchors at sites with soil types expected to be encountered during cable logging, to determine their effective safe working load. Also, a chart should be generated that relates the driving rate and/or force to anchor-holding strength for various soil conditions.

Picket Anchors

A three-picket system with larger beams, a lead picket designed to take torsion loadings, and a triangular configuration used for installation should be tried. This should prove a better utilization of all three pickets and should be less susceptible to out-of-line pulls.

Further, future picket systems should incorporate load distribution through a series of blocks or some other balancing scheme. Also, pretensioning between the picket tiebacks should be increased to improve load-transfer capabilities.

EQUIPMENT DEVELOPMENT AND TEST

The Forest Service's Equipment Development and Test (ED&T) program, conducted by two Equipment Development Centers (San Dimas, Calif., and Missoula, Mont.), provides systematic application of scientific knowledge to create new or substantially improved equipment, systems, materials, processes, techniques, and procedures that meet the objectives of advanced forest management and utilization in the United States. The ED&T effort, featuring Mechanical Engineering activities, encompasses projects in forest engineering, aviation and fire management, recreation, timber, range, wildlife, occupational safety and health, forest insect and disease, and forest residues to enable forest work to be performed more efficiently, at less cost, with minimum hazard.

As needs for field development services are identified and defined, the Centers determine if already available commercial products are suitable as is or if they require modifications necessitated by the forest environment. On the other hand, sometimes needs can only be met by the Centers taking advantage of the latest technology to create new concepts through a step-by-step product development program. These developments are typically achieved by active ED&T involvement with disciplines found throughout the Forest Service. The new equipment is field tested and demonstrated and user feedback is obtained to evaluate results. The role of the Centers is not considered complete until project output is implemented in the field.