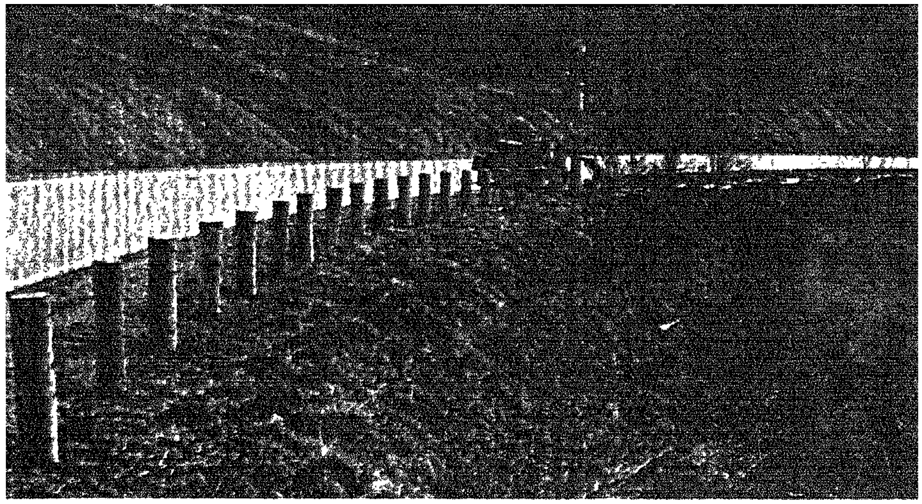

A way to reduce highway guardrail costs:

MACHINE-DRIVING of WOODEN POSTS

by Charles J. Gatchell

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Acknowledgments

THIS study is the result of the efforts and cooperation of many people. Paul Craft and George Niskala, of the Forest Products Marketing Laboratory staff, contributed their knowledge to the development of the post driver. Niskala collected background information that greatly facilitated the research efforts. George Reeves, of Cross Lanes Construction Company, Nitro, West Virginia, allowed the needs of research to interrupt his production schedule with the result that a well-trained crew, with long experience in all types of post installation, was made available to operate the driving machine. Jack Harvey of the State Road Commission of West Virginia provided sites that represented typical installation situations in southern West Virginia.

A way to reduce highway guardrail costs:

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CONTENTS

The Author

CHARLES J. GATCHELL received his Bachelor of Science degree in forestry from the University of Massachusetts in 1955. After a tour of duty with the U. S. Navy, he returned to the New York State College of Forestry at Syracuse University where, in 1961, he received his Master of Science degree in wood-products engineering. From 1961 to 1965 he was a project scientist in the product and process development project at the U.S. Forest Products Laboratory in Madison, Wisconsin. He is now project leader of the hardwood product improvement project at the Forest Products Marketing Laboratory of the Northeastern Forest Experiment Station at Princeton, West Virginia.

Why Wooden Posts?

WOOD is an excellent material for highway guardrail posts. When compared with other materials, wood has better strength characteristics,*(1, 2)* a lower initial cost, a lower cost per installed post, and—when pressure-treated with preservative—a service life of 30 years. Yet, in spite of these favorable qualities, wood is not often used for highway posts in new construction in West Virginia.

The critical problem is speed of installation.*(3)* Contractors prefer to use the type of posts that they can install most quickly. In recent years they have preferred steel posts because these can be set by machine. Wooden posts have traditionally been set by hand. In an 8-hour shift, 80 wooden posts can be set by hand whereas in the same time 240 steel posts can be driven by machine. At these rates, wooden posts cannot compete.

To find out whether the rate of setting wooden posts could be increased, staff members of the Forest Products Marketing Laboratory worked with a private guardrail contractor in devising a machine suitable for driving wooden posts. The result is a mobile post driver (figs. 1 and 2). This machine was used for installing posts on a variety of sites. Our studies showed that wooden posts can now be installed at competitive rates.

The Study

Purpose

This study was done to determine whether a finished line of guardrail posts could be installed rapidly with the new driver. For a realistic test, conditions typical of an actual guardrail post installation job were required. In addition to speed, it is necessary that guardrail posts be installed to specified tolerances. Therefore, posts were installed to meet the specifications of the State Road Commission of West Virginia for plumbness, alignment, spacing, and freedom from damage. Our main objectives in the study were:

- To compare the effectiveness of driving on a variety of sites.
- To compare the rates of installation by machine-driving and by the conventional hand-setting method.
- To evaluate the effect of post cross-sectional area on driving time.

Posts Used

The posts used were ordered with flat tops and bottoms, approximately 6 feet long, and pressure-treated with preservative. Some posts were delivered with uneven tops and bottoms. To see what effect such mismanufacture might have on driving, these posts were included in the study. Both softwoods and hardwoods were used.

The softwood posts were round, osmose-treated southern yellow pine. Post diameters were 6, 7, and 9 inches. The 7-inch size was chosen as the standard diameter and was used when comparing driving rates between sites. It was also used in a comparison of hand-setting and machine-driving on a single site. The 6- and 9-inch posts were used to determine the effect of cross-sectional area on driving time. All pine posts received two coats of white paint after installation.

The hardwood posts were sawed, creosote-treated red oak. Two sizes of posts were used: 6 by 6 inches and 6 by 8 inches.

All posts were installed to a depth of 3 feet as required by the State Road Commission of West Virginia. Driving to this uniform depth let us judge the resistance of the site; the longer it took to drive, the harder the site.

Sites Selected

Four sites, typical for southern West Virginia, were chosen with the cooperation of the State Road Commission. As these sites were on a well-traveled main highway, the Commission wanted the finished job to be pleasing to the eye of passing motorists. Therefore posts of different preservative treatments were not mixed on any given site.

Other restrictions were placed on post spacing and berm disturbance. As no guardrail was to be attached, the posts were spaced 8 feet apart The acceptable driven posts, once in place, were not disturbed.

Equipment and Manpower Used

The Forest Products Marketing Laboratory rented all necessary equipment and manpower from a commercial guardrail subcontractor.

The mobile post driver (figs. 1 and 2) consisted essentially of a post holder and hammer assembly mounted on the side of a tractor. To plumb the posts before driving, the assembly could be tilted plus or minus 20° at right angles to, or in the direction of, the line of posts. It could also be rotated 10°. The 1,368-pound hammer, automatically operated, hit a plate at the top of the holder at a rate of 30 strokes per minute. Final height adjustments were possible by manually controlling the length of stroke and rate of delivery.

The post driver was designed to be used with a 2-man crew. A driver-operator drove the machine from one post position to another, plumbed the post, and controlled hammer action. The other crew member was a laborer who loaded the posts into the post holder and helped the driver-operator center the posts at each location.

In the limited study of hand-setting, a 63-horsepower truck-mounted auger was used to drill 12-inch diameter holes. An air compressor, towed behind the truck, powered a hand-held earth tamper. In a commercial operation, five men are required to operate this equipment: a truck driver, an auger operator, a laborer to help plumb the auger and set posts, and two laborers to backfill and tamp around the set posts.

This study was conducted with a crew of three men: a foreman, a machine operator, and a laborer. The men were well-trained and experienced in the techniques of driving steel posts and hand-

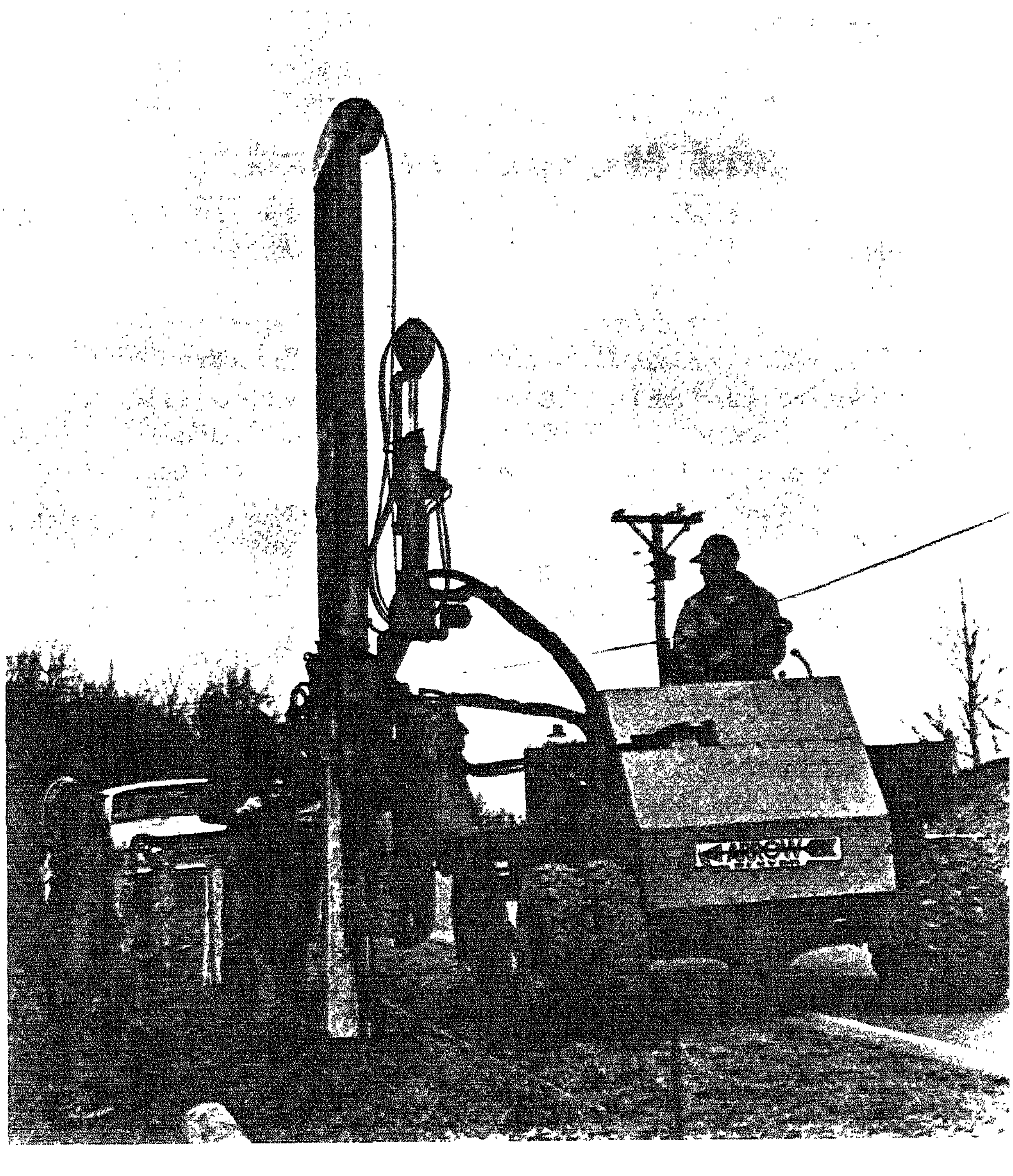

Figure 1.—A wooden post being installed with the newly developed driving machine.

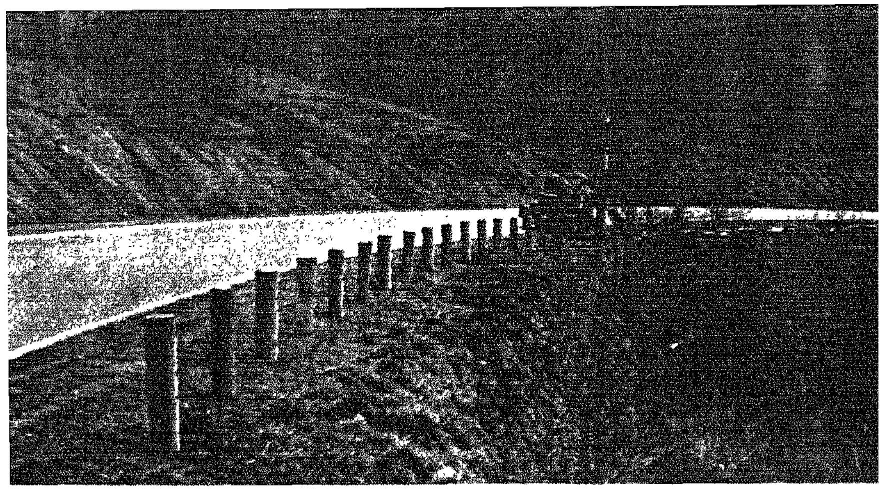

Figure 2.—A machine-driven wooden post installation on a curve in the highway.

setting wooden and concrete posts. Further, the crew was trained to use the new wooden post driving machine before the study was begun.

Factors Affecting Installation Time

In guardrail post installations, it is necessary to lay out the post line, mark the post locations, and distribute the posts along the site. The time spent is about the same regardless of the type of post or installing equipment to be used. Therefore these factors were not considered in this study.

Machine-Driving

In determining the rate of installation of guardrail posts by machine-driving, three time factors were chosen: driving time, setup time, and alignment time.

Driving time was recorded only when the machine was in automatic operation. Variations in driving time showed changes in the hardness of the site.

Setup time ran from the end of automatic driving on one post to the start of automatic driving on the next. Included here was the time to: (1) bring the post to specified height through manual control of the hammer; (2) disengage the post holder from the post; (3) move to the next post position; (4) place the next post in the post holder; and (5) center and plumb the post. Most of the setup time was spent centering and plumbing the posts before driving. In preliminary tests we found that bringing the post to specified height through manual control of the hammer was rarely necessary and took less than 0.1 minute. Also, the total time to disengage from one post, move to the next position, and place the next post in the post holder was generally only 0.2 to 0.3 minute. All of these jobs were routine, and variations in setup time showed changes in crew efficiency.

Alignment time was the total time required to straighten any posts that were out of plumb. It began at the end of driving and included the time required to move along the line of posts. Straightening was done by nudging or pulling on each post with the post driver and tamping around the base of the post.

Alignment time varied not only with the number of posts requiring straightening but also with the severity of traffic. Positioning the post driver often required maneuvering in the middle of the highway. Sometimes it was necessary to wait for cars or trucks to pass. No timing adjustments were made for traffic delays as this was considered typical of most guardrail installation jobs.

Hand-Setting

When hand-setting, it is necessary to auger a hole, set the post, and backfill and tamp around the post. In the hand-setting test, the following times were recorded: (1) setup time; (2) augering time; and (3) post setting and tamping time. Setup time was defined as the time required to move from an augered hole to the next position with the auger ready for drilling. Augering and post setting and tamping times are self-explanatory.

Total hand-setting time was slightly more than normal as we wanted to examine each part of the hand-setting method. Under normal conditions, a certain amount of augering and post setting and tamping could be done at the same time. For our purposes, it was considered more desirable to examine each part of the hand-setting method. As this study was conducted with a 3-man crew rather than the normal 5- or 6-man crew, it was necessary to complete each step before the next step was begun.

Tests and Results

Tests 1A and 1B: Effect of Substrate and Berm Width on Driving Rates

Test 1A was made on a sloping curve cut in the side of a mountain (fig. 2). The face of the cut showed no large rocks or boulders and appeared to be mostly shale or gravel. The berm was wide, allowing a convenient layout of posts before driving and an ample working space for the crew between the post line and the berm edge. Fifty-four 7-inch southern pine posts were driven on 8-foot centers and 6.5 feet from the edge of the road surface.

Test 1B was made on a level fill in a valley on the other side of the mountain. The substrate appeared to be mostly gravel—probably hauled in by truck. The berm was very narrow, preventing a convenient layout of posts before driving. Also, the crew had only 1 to 2 feet of working space between the post line and the berm edge. Forty-five 7-inch southern pine posts were installed on 8-foot centers and 4.5 feet from the edge of the road surface.

The rates of installation on the two sites were about the same. Thirty posts per hour were set in test 1A on the wide berm (table 1) and 28 posts per hour were set in test 1B on the narrow berm (table 2). However, each site had a different effect on the time factors (driving, setup and alignment times) used to calculate these rates.

Driving times in test 1A ranged from 0.4 to 1.6 minutes and averaged 0.7 minute per post. The change in site hardness was gradual. The driving times in test 1B reflected a more uniform and softer site. Driving time here ranged from 0.3 to 0.6 minute and averaged 0.4 minute per post.

The average setup time on the wide berm, at 1.1 minutes per post, was 0.1 minute shorter than on the narrow berm. The factors involved in the setup tended to balance each other. Centering and plumbing the posts were easier on the straight and level narrow berm, but loading the posts into the post holder was more difficult.

The total alignment time on the narrow berm was twice that on

Table 1.—*Seven-inch southern pine posts installed by driving: test 1A (wide berm)*

(All times in minutes)

Post number	Setup time	Driving time	Post number	Setup time	Driving time
1	0.8	0.7	30	1.1	1.0
2	.9	1.0	31	.9	1.4
3	1.1	1.2	32	.9	1.4
4	1.2	.7	33	1.2	1.4
5	.9	.8	34	1.1	1.1
6	1.1	.8	35	1.6	1.2
7	1.2	.7	36	1.4	1.4
8	1.1	.7	37	1.2	1.0
9	1.0	.6	38	1.1	1.6
10	1.1	.6	39	1.1	1.0
11	1.1	.5	40	1.2	.7
12	1.0	.5	41	1.1	.6
13	1.0	.6	42	1.1	.6
14	1.2	.5	43	1.2	.8
15	1.3	.5	44	1.1	.6
16	1.0	.4	45	1.3	.8
17	.9	.5	46	1.1	.6
18	1.0	.4	47	1.0	.4
19	.9	.5	48	1.1	.8
20	.9	.4	49	1.0	.4
21	.8	.4	50	1.1	.5
22	1.0	.4	51	.9	.7
23	1.1	.6	52	1.3	.5
24	.9	.5	53	1.0	.8
25	1.0	.4	54	1.2	1.2
26	.8	.5	Total	57.2	39.7
27	.8	.6	Average	1.1	0.7
28	1.0	.5			
29	.8	.7			

Alignment time = 11.5 minutes for 12 of 54 posts needing alignment after driving.

$$\text{Posts/hr.} = \frac{\text{Number of posts}}{\text{Total setup time} + \text{total driving time} + \text{alignment time}} \times 60 \text{ min./hr.} = \frac{54}{57.2 + 39.7 + 11.5} \times 60 = 30$$

Table 2.—*Seven-inch southern pine posts installed by driving: test 1B (narrow berm)*

(All times in minutes)

Post number	Setup time	Driving time	Post number	Setup time	Driving time
1	1.6	0.5	24	0.9	0.3
2	1.6	.3	25	1.2	.4
3	1.3	.4	26	1.0	.4
4	1.0	.5	27	.9	.4
5	1.3	.5	28	1.0	.3
6	1.5	.3	29	1.2	.3
7	1.5	.3	30	1.6	.3
8	1.6	.3	31	1.1	.3
9	1.1	.4	32	1.4	.3
10	1.1	.4	33	1.4	.3
11	1.8	.6	34	1.2	.4
12	1.0	.5	35	1.0	.5
13	1.1	.6	36	1.0	.4
14	.9	.5	37	1.3	.4
15	1.0	.4	38	1.3	.3
16	1.1	.4	39	1.2	.4
17	1.4	.3	40	1.0	.4
18	1.0	.2	41	1.1	.5
19	1.0	.3	42	1.0	.6
20	1.4	.3	43	1.1	.6
21	1.1	.3	44	1.2	.6
22	1.0	.3	45	1.1	.6
23	1.0	.4	Total	53.6	18.0
			Average	1.2	0.4

Alignment time = 24.8 minutes for 15 of 45 posts needing alignment after driving.

$$\text{Posts/hr.} = \frac{\text{Number of posts}}{\text{Total setup time} + \text{total driving time} + \text{alignment time}}$$

$$\times 60 \text{ min./hr.} = \frac{45}{53.6 + 18.0 + 24.8} \times 60 = 28$$

the wide berm. Much greater caution was needed in maneuvering the driver because traffic was moving very rapidly on this straight section of highway at the bottom of the mountain. Also, it is easier to align posts on a curve because the eye sees only a small portion of the total line. Small variations that could be seen easily when looking down a long straight line are not noticeable on a curve.

Test 2: A Comparison of Hand-Setting and Machine-Driving on a Single Site

A comparison of hand-setting and machine-driving was made next to the test 1A site. Thirty-eight 7-inch southern pine posts were installed on 8-foot centers and 9 feet from the edge of the road surface. To reduce the effect of site on the results, the hand-set posts were alternated with the driven posts. To allow a smooth production-type of installation, post driving was completed before hand-setting was begun.

The machine-driven posts were installed with an average time per post of 1.1 minutes for setup and 0.7 minute for driving. These results are similar to those of test 1A. This was expected because the sites appeared to be about the same.

At around 1 minute (table 3), there was no real difference between the setup times for hand-setting or machine-driving. However, it was of considerable importance that augering alone took twice as long (1.4 minutes versus 0.7 minute) as driving. The rate of installation for machine-driving was 29 posts per hour versus 13 posts per hour by handsetting. When all time factors were considered, it seemed safe to assume that the driving technique will be at least twice as fast as the hand-setting method with only half the number of men required.

Another important factor that favors driving in this comparison is the matter of site disturbance. Driving is a clean operation, causing no disturbance in the surface of the berm. However, when hand-setting it is necessary to smooth around each post and dispose of excess fill. The finished results of hand-setting are not so pleasing to the eye as those from machine-driving.

Test 3: A Comparison of Installation Rates for Two Sizes of Sawed Red Oak Posts

Test 3 was made on a site that was judged to be the most difficult of the series. As in tests 1A and 2, the site was located in a cut in the side of a mountain. Here, however, large boulders and rock outcroppings were visible in the face of the cut and on the

Table 3.—*Comparison of installation rates for hand-setting and machine-driving southern yellow pine posts: test 2*

(All times in minutes)

Hand-set posts					Machine-driven posts				
Post number	Setup time	Augering time	Post setting & tamping	Total	Post[1] number	Setup time	Driving time	Estimated alignment time	Total
1	2.2	1.2	2.4	5.8	1a	1.0	0.5	0.3	1.8
2	1.0	1.2	2.0	4.2	2a	1.0	.6	.3	1.9
3	.8	.9	2.7	4.4	3a	1.0	.9	.3	2.2
4	.9	.9	2.2	4.0	4a	1.4	.5	.3	2.2
5	1.0	1.0	2.8	4.8	5a	1.0	.8	.3	2.1
6	.7	1.0	2.7	4.4	6a	1.0	.7	.3	2.0
7	.7	1.6	2.2	4.5	7a	1.0	.5	.3	1.8
8	.7	1.2	2.4	4.3	8a	1.1	.7	.3	2.1
9	1.1	1.2	2.2	4.5	9a	1.4	.9	.3	2.6
10	1.0	1.6	2.5	5.1	10a	1.2	.6	.3	2.1
11	1.5	1.2	2.4	5.1	11a	1.2	.9	.3	2.4
12	1.1	1.9	2.6	5.6	12a	1.0	1.1	.3	2.4
13	1.1	1.2	1.9	4.2	13a	1.3	1.1	.3	2.7
14	1.2	2.4	2.6	6.2	14a	1.2	.5	.3	2.0
15	1.0	1.2	1.6	3.8	15a	.9	.7	.3	1.9
16	.9	1.5	1.4	3.8	16a	1.2	.6	.3	2.1
17	.9	1.7	2.0	4.6	17a	1.2	.6	.3	2.1
18	.8	1.8	2.3	4.9	18a	1.1	.5	.3	1.9
19	.7	1.4	2.8	4.9	19a	1.1	.7	.3	2.1
Average	1.0	1.4	2.3	4.7	Average	1.1	0.7	0.3	2.1
Posts per hour = 13					Posts per hour = 29				

[1]Not included are 38 posts for which only driving time was recorded. These times ranged from 0.3 to 1.1 minutes per post, with an average value of 0.6 minute per post.

Table 4.—*Rates of installation of 6-by-6-inch and 6-by-8-inch sawed red oak posts: test 3*

(All times in minutes)

6-by-6-inch posts			6-by-8-inch posts		
Post number	Setup time	Driving time	Post number	Setup time	Driving time
1	3.7	0.4	1a	2.2	2.1
2	3.4	1.0	2a	2.1	.9
3	2.8	.6	3a	2.0	1.1
4	2.5	.7	4a	2.4	3.2
5	1.7	.9	5a	1.9	1.5
6	1.4	1.3	6a	1.2	1.7
7	1.1	1.2	7a	1.3	1.9
8	1.5	1.2	8a	1.7	1.9
9	1.5	1.3	9a	2.3	2.3
10	1.6	1.3	10a	1.4	1.6
11	1.2	1.4	11a	1.5	1.7
12	1.4	1.3	12a	1.0	1.7
13	1.1	.9	13a	1.2	.6
14	1.5	1.0	14a	1.3	1.2
15	1.2	.8	15a	1.2	1.2
16	1.1	1.1	16a	1.5	1.2
17	1.1	.8	17a	1.3	.8
18	1.2	1.0	18a	1.3	.5
19	1.2	.5	19a	1.2	1.0
20	1.1	.8	20a	1.8	1.7
21	1.1	1.4	21a	1.1	1.8
22	1.2	1.1	22a	1.6	1.6
23	1.8	1.5	23a	1.6	1.3
24	1.0	.8	24a	1.2	1.1
25	1.2	1.0	25a	1.6	1.0
26	1.0	1.1	26a	1.3	1.3

Continued

side of the road shoulder. It was the judgment of the experienced crew foreman, both before and after the test, that neither augering or steel driving could be used here. Forty-one 6-by-6-inch and forty-one 6-by-8-inch creosote-treated red oak posts were set on 8-foot centers and approximately 12 feet from the edge of the road surface.

The driving times (table 4) show the unevenness and hardness of the site. Times ranged from 0.4 to 2.2 minutes for the 6-by-6-inch posts and from 0.5 to 3.8 minutes for the 6-by-8-inch posts.

Table 4.—*Continued*

6-by-6-inch posts			6-by-8-inch posts		
Post number	Setup time	Driving time	Post number	Setup time	Driving time
27	1.2	1.8	27a	1.0	1.5
28	1.0	1.2	28a	1.6	1.6
29	1.6	1.6	29a	1.1	1.6
30	1.5	1.3	30a	1.2	1.8
31	1.2	1.1	31a	2.8	2.9
32	1.4	1.2	32a	1.2	2.6
33	1.4	1.0	33a	1.2	1.6
34	1.3	1.5	34a	1.4	2.1
35	1.3	1.4	35a	1.8	2.7
36	1.1	1.6	36a	1.2	1.6
37	1.2	1.0	37a	1.2	1.3
38	2.2	1.6	38a	1.2	.9
39	1.4	1.7	39a	3.7	1.6
40	1.4	1.8	40a	1.3	3.8
41	2.5	2.2	41a	1.9	3.0
Totals	62.3	48.4	Totals	64.0	68.5
Average	1.5	1.2	Average	1.6	1.7

Alignment time = 69 minutes for 40 of 82 posts needing alignment after driving.

$$\text{Posts/hr.} = \frac{\text{Number of posts}}{\text{Total setup time} + \text{total driving time} + \text{alignment time}}$$

$\times 60$ min./hr.

6-by-6-inch posts:

$$\text{Posts/hr.} = \frac{41}{62.3 + 48.4 + 34.5} \times 60 = 17$$

6-by-8-inch posts:

$$\text{Posts/hr.} = \frac{41}{64.0 + 68.5 + 34.5} \times 60 = 15$$

Changes in these times were often abrupt, indicating that a large rock or a soft spot had been hit. With an average driving time of 1.2 minutes per 6-by-6-inch post and 1.7 minutes per 6-by-8-inch post, we found that driving time was almost directly proportional to cross-sectional area. The 6-by-8-inch posts had a one-third greater area than the 6-by-6-inch posts and took about one-third again as long to drive.

The setup times for this test were greater than those of the previous test. To insure proper post alignment with the 6-inch face parallel to the road edge, a 6-inch wide U-shaped fixture was mounted in the post holder. The position of the fixture, which was 2 inches from the top of the holder, made post loading more difficult. Had the fixture been placed several inches lower, the setup times would have been reduced. The setup times averaged 1.5 minutes per post for the 6-by-6-inch posts and 1.6 minutes per post for the 6-by-8-inch posts.

It should be recalled that setup time included all times from the disengagement of the driver from one post through centering and plumbing of the next post. Occasionally, a post would be forced considerably out of plumb by rocks in the substrate. By digging around several of these, we found that the tilt was caused by large rocks that had been only partially moved from the path of the posts. A severe tilt made it hard to disengage the machine, and the resulting delay was included in the setup time of the next post.

Forty of the 82 sawed posts required some alignment after driving. The total time of 69 minutes was arbitrarily divided between the two posts sizes in calculating the rates of installation. In spite of the difficulties found here, only four posts could not be straightened to meet the specified tolerances.

The rates of installation of 17 and 15 posts per hour for the 6-by-6-inch and 6-by-8-inch posts were considered very good for this site.

Test 4: The Influence of Cross-Sectional Area on Driving Time

The results of test 3 had shown that driving time is almost directly proportional to post cross-sectional area. However, because the site was hard and this hardness varied sharply, we could not make comparisons between posts that were side by side. As only averages could be used, we felt it necesary to check these results.

Ten 6-inch and ten 9-inch southern pine posts were alternately driven on 3-foot centers in the berm adjacent to the test 1B site. The close spacing reduced the chances of site variation.

Table 5.—*Influence of diameter on driving time of southern pine posts: test 4*

(All times in minutes)

6-inch posts		9-inch posts	
Post number	Driving time	Post number	Driving time
1	0.5	2	0.9
3	.6	4	1.2
5	.4	6	1.0
7	.4	8	.9
9	.4	10	.9
11	.5	12	.8
13	.5	14	1.0
15	.5	16	1.0
17	.6	18	1.2
19	.5	20	1.2
Average	0.5	—	1.0

This test confirmed that driving time is directly proportional to post cross-sectional area. The 9-inch posts had about twice the cross-sectional area as the 6-inch posts and took twice as long to drive (table 5). On a commercial job, these differences (between 1.0 and 0.5 minutes per post) are very real. With the setup and alignment times of test 1B, the rate of installation would be reduced from 27 posts per hour (6-inch diameter) to 22 posts per hour (9-inch diameter) or a reduction of about 20 percent. Thus contractors should use the smallest acceptable size for greatest efficiency.

Discussion

Installation Rates

What rates of installation can a guardrail subcontractor expect when machine-driving wooden posts? Each job will vary and all time factors must be considered. The results of this study provide good guidelines. Any improvements in the design of the driving machine should increase the speed of installation.

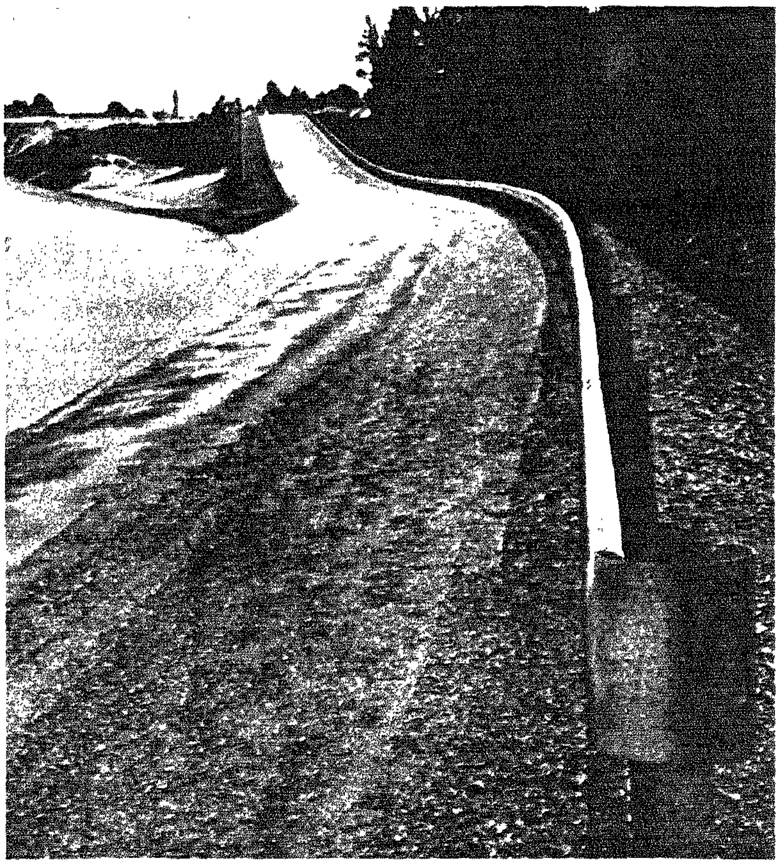

Figure 3.—A commercial installation of sloped posts with guardrail attached.

Subcontractors measure production by the number of lineal feet of guardrail installed per 8-hour shift. They consider 2,000 lineal feet to be an acceptable minimum average when posts are spaced on 12-foot-6-inch centers—the present standard. On average sites, this requirement can be easily met by machine-driving.

In tests 1A, 1B, and 2, the installation rates of 28 to 30 posts per hour would result in about 3,000 lineal feet per 8-hour shift. If, by chance, the site hardness of test 1B had been found at the test 1A site, 3,600 feet per 8-hour shift could have been installed. These are very competitive rates.

The sawed-post installation rates of 15 to 17 posts per hour would produce 1,500 to 1,700 lineal feet of guardrail per 8-hour shift. As steel posts could not be driven nor could an auger be used on the site, these rates were considered to be highly acceptable.

The Posts

In all tests, there were several mismanufactured posts that did not meet order specifications. The most common failings were slopes in the tops and/or bottoms. In general, posts with sloped tops were not visibly damaged by driving. The tops were flattened until about one-third of the top area was in contact with the plate at the top of the holder. As seen in a subsequent production installation (fig. 3) sharply sloped posts can be driven free of damage when a sloped insert is used to distribute the load on the post top.

No tapered posts were included in this study. However, driving posts with sloped bottoms (greater than 1 inch in 7 inches) led us to conclude that tapered posts would not be desirable. The sloped posts tended to drift toward the long side. This drift became more noticeable on the rockier sites. Also, as the blunt-ended posts could be rapidly driven, the cost of tapering may not be justified.

Cost Factors

What is the cost of machine-driving a wooden post compared to the cost of hand-setting wood or driving steel? The important factors in this comparison are post prices and labor costs. The costs of an auger, a steel-post driver or a wooden-post driver are about the same and can therefore be ignored.

The cost of labor per installed post depends on the number of posts installed per unit of time and the number of men required. The typical machine-driving crew for wooden posts consists of a foreman, a driver operator and one laborer, at a total cost of about $10.60 per hour. Based on an installation rate range of 15 to 30 posts per hour, the setting cost per post of driven wood is $0.70 to $0.35. Table 6 allows a cost comparison of driven and hand-set pressure-treated wood and driven galvanized steel. The total cost per wooden post installed by driving is at least $1 less

Table 6.—*Comparative installation costs of driven wood, hand-set wood, and driven galvanized steel posts in West Virginia*

(In dollars per post)

Item	Driven treated wood	Hand-set treated wood[1]	Driven galvanized steel[1]
Purchase price[2]	2.75—2.79[3]	2.75—2.79[3]	5.25—5.85
Setting	.35— .70	1.87—2.35	.35— .52
Total	3.10—3.49	4.62—5.14	5.60—6.37

[1] Source: Lindell, Gary R. MARKET OPPORTUNITIES FOR TREATED WOODEN GUARDRAIL POSTS IN WEST VIRGINIA. U. S. Forest Serv. Res. Note NE-36, 6 pp., 1965.
[2] Delivered to the installation site.
[3] Includes costs of sloping and drilling.

than by hand-setting; it is $2 to $3.30 less than the cost of driven galvanized steel.

The post driving machine should also be useful in highway district maintenance programs. These programs call for removing and replacing old or damaged posts or adding new, short sections. The driver can be driven from job to job at speeds up to 30 miles per hour. It can be used to pull as well as set posts. With this versatility, the machine should be economical in this use.

Conclusions

In applied research, it is sometimes difficult to give hard and fast rules based on the results. For any given post-installation job, differences in men, equipment, driving sites, or other factors might alter the rates of installation found in this study. However, it is possible to indicate what can be expected.

Because of desirable strength characteristics, long service life, and low cost, pressure-treated wooden guardrail posts are completely acceptable and in many ways preferable to posts made from other materials. With the introduction of machine-driving, the rate of installation of wood is now competitive with that of machine-driven steel. The results of this study allow the following conclusions to be made:

- Wooden posts can be driven on any site where steel posts can be driven. They also can be driven on some sites where steel cannot and where an auger cannot be used.

- On sites free of large rocks or other obstructions, guardrail subcontractors can expect to install around 2,500 lineal feet of guardrail line per 8-hour shift with the type of equipment used in this study. A maximum of around 3,500 lineal feet can be expected.

- On the same site, posts can be set at least twice as fast by machine-driving as by hand-setting. The subcontractor can save $1 to $2 per installed post by machine-driving.

- The installed cost of machine-driven wooden posts is $1 to $3.25 less than that of driven steel.

- For machine-driving, posts with blunt bottoms are preferable to those with slopes.

- The driving action will cause no damage to the tops of properly machined wooden posts.

- Wooden-post driving time is about directly proportional to cross-sectional area—the greater the cross-sectional area, the longer the driving time.

Literature Cited

(1) Beaton, John L., and Robert N. Field.
1960. DYNAMIC FULL SCALE TESTS OF MEDIAN BARRIERS. Calif. Dep. Pub. Works Div. Highways paper presented at the 39th Ann. Meeting of the Highway Res. Board, Washington, D. C. 36 pp., illus.

(2) Cichowski, W. G., P. C. Skeels, and W. R. Hawkins.
1961. GUARDRAIL INSTALLATIONS — APPRAISAL BY PROVING GROUND CAR IMPACT AND LABORATORY TESTS. General Motors Proving Ground, Milford, Michigan, paper presented at the 40th Ann. Meeting Highway Res. Board, Washington, D. C. 42 pp., illus.

(3) Lindell, Gary R.
1965. MARKET OPPORTUNITIES FOR TREATED WOODEN GUARDRAIL POSTS IN WEST VIRGINIA. U. S. Forest Serv. Res. Note NE-36. NE. Forest Exp. Sta. 6 pp., illus. Upper Darby, Pa.

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