PORTABLE SURFACES FOR CROSSING UNSTABLE ROADBEDS

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Abstract

Low-volume roadbeds surfaced with aggregate and native soil are a vital part of many U.S. Department of Agriculture Forest Service road networks. A common concern of low-volume road designers is the development of ruts through short, unstable sections. Ruts reduce vehicle access, affect local streams and hydrology, increase maintenance, and accelerate the loss of surfacing material as a result of erosion. The Forest Service has investigated portable surfaces as an alternative to continuous maintenance, use of crushed aggregate, or reconstruction. This report discusses field evaluation to quantify the reduction of rut depth for two types of wood portable surfaces. Wood pallets and wood mats were installed on native soil timber harvest roads in northcentral Florida. On average, the surfaces reduced rut depth by 127 mm (5 in.).

Keywords: Road, portable, surface, harvesting, rut

Introduction

Most low-volume roads maintained by the Forest Service consist of roadbeds surfaced with aggregate or native soil and designed according to established engineering design principles. Often, the roads are designed to provide short-term access for routine maintenance. A concern of designers and managers is the short sections of unstable surface or subsurface material, which typically are due to high moisture content. This unstable material leads to the development of ruts (Fig. 1). Continued traffic deepens the ruts until they are bladed or crushed aggregate surfacing material is added to the unstable section.

Limiting the development of ruts is important for several reasons. As ruts develop, surface or intercepted subsurface water is diverted from the designed road drainage, which may alter local hydrology, especially in very flat topographical areas. Water can run in the ruts, loosening and transporting soil particles, which erodes the roadbed within the ruts. Subsequent erosion may destroy sections of the road. Also, water with suspended soil particles may eventually drain into local streams, potentially increasing the stream turbidity. Deep ruts can damage or incapacitate vehicles.

The Forest Service recognized the need for portable surfaces to inhibit the development of ruts. The surfaces were visualized as a means of crossing short sections cf unstable soil as an alternative to continuous maintenance, the use of crushed aggregate, or reconstruction. The San Dimas Technology and Development Center performed a market search and published a report describing 12 portable surfaces (Mason 1990). Six of these surfaces were chosen for field evaluation based on the following criteria: portability, recyclability, purchase price, and availability. These surfaces were evaluated on the Osceola Ranger District in northcentral Florida under normal low-volume forest road use. All were qualitatively judged to be successful at visibly reducing rut depth and increasing the duration of vehicle access.

Figure 1—Rut development on low volume road in Florida.

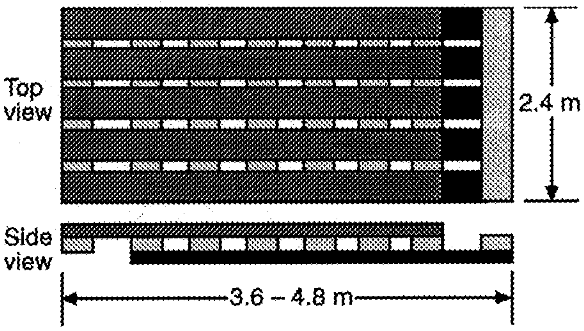

Figure 2—Schematic of prefabricated wood pallet (1 ft = 0.3048 m).

Field evaluations were continued to quantify the reduction in rut depth (Hislop 1996). In the work reported here, we discuss two wood portable surfaces that were evaluated on existing native soil roadbeds in northcentral Florida. The evaluations were performed in cooperation with the Rayonier Corporation and the Osceola National Forest. The majority of the vehicles driven over the sections during the field evaluation period were five-axle loaded and unloaded log trucks with a gross vehicle weight of 11,200 N (80,000 lb).

Description of and Experience With Portable Surfaces

Some important considerations common to portable surfaces are as follow:

- surface weight, when considering installation and removal equipment
- blading of existing ruts, for reducing bending stress
- use of geotextile, for confining soil beneath the portable surface and for separating the soil and portable surface (separation facilitates removal of the surface by reducing tension-related stress)
- coverage of entire section, to prevent ruts at surface ends
- dividing and marking of section prior to installation, to avoid unnecessary moving of portable surface

Wood Pallets

Private companies are producing a much sturdier variation of wood pallets typically used for shipping. One type of new pallet is made of 76.3- by 203.2-mm (3- by 8-in.) timber planks, nailed together in three plies. The pallets range from 2.4 by 3.6 m to 2.4 by 4.8 m (8 by 12 ft to 8 by 16 ft). They are reversible, and broken planks can be replaced easily, prolonging the life of the pallet. Each end has an overlap area for connection between pallets to make roads and platforms (Fig. 2).

One disadvantage is pallet width. Pallets are connected along the 2.4-m (8-ft) edge, which is too narrow for log truck roads. The pallet can be cut into 1.2- by 4.3-m (4- by 14-ft) half-pallets. Each half-pallet is placed in a wheel path, providing the necessary road width. Half-pallets weigh less (154 N (1,100 lb)) than full pallets and are less cumbersome during installation. Another disadvantage of wood pallets is that forklifts are the easiest means for installation and removal but they are not typical equipment on forest harvesting road construction sites. A front-end loader or backhoe and lifting chains are common construction equipment, but the planks are too close together to use chains. An option is a thin choker cable that can be run between the planks and hooked to the lifting chains.

Wood Mats

Wood mats are similar to dragline mats typically used by tracked vehicles. The mats are constructed of wood posts with nominal dimensions of 101.6 by 101.6 mm (4 by 4 in.) and 152.4 by 152.4 mm (6 by 6 in.), at least 3 m (10 ft) long. Holes are drilled through each post 0.6 m (2 ft) from each end. The posts are connected together by threading 4.8-mm (3/16-in.) galvanized steel cable through each set of holes over the full length of the mat. Loops are made at the end of each cable using cable clamps. The loops extend beyond tbe last post at each end of the mat and are used to pick up the mat during installation and removal (Fig. 3).

The construction of the mat is the most time-consuming aspect of the operation. Three people need up to 3 hours to cut, drill, and cable together a 6.1-m- (20-ft-) long, 3-m- (10-ft-) wide mat. One set of drilling location marks should be made on the ground for all

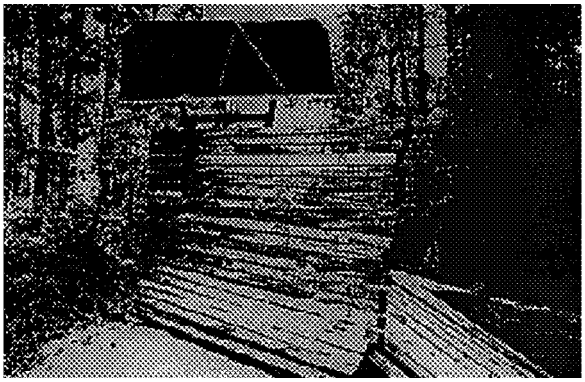

Figure 3—Wood mat installation.

the posts to prevent errors in marking each post. Time can be saved if several drills are available. A welding torch or some other means of controlling cable-end fraying increases threading speed. Care must be taken in using the cable clamps; incorrect use can lead to slippage. It is important to make sure that all cable loops are placed under the mats after installation. Otherwise, they catch on the underside of vehicles. The 101.6-mm- (4-in.-) thick mats are considered the most critical in terms of bending strength and have been proven to work well. These mats are lower in cost and lighter in weight than the 152.4- (6-in.) mats.

Geotextile

There is much literature on the use of geotextiles, and many types of geotextiles are available. The main type used for field evaluations is a nonwoven, needle-punched filter fabric. This geotextile is inexpensive and was readily available where the field evaluations were performed. In general, the geotextile should meet the following requirements: (1) be capable of retaining soil underneath while allowing water to pass through, (2) have a rough surface to limit movement of the portable surfaces, and (3) be removable after use.

Installation of a geotextile is recommended to limit penetration of portable surfaces into the soil. Moreover, the time required to remove a portable surface is often reduced by adding a geotextile. Although the geotextile may be in good condition after use, additional weight from soil and water may make the fabric too heavy to be removed, Some concerns have been raised about leaving the geotextile in place after use. Ideally, to form a visually acceptable solution and limit continued access, the geotextile should be removed. If the geotextile is cut in short lengths, it may be removable and reusable although the length at which a geotextile is no longer effective is unknown.

Table 1—Stabilization alternatives.

Surface type	Weight (N (lb))	Cost[a] ($/m^2)
Wood half-pallet	176.4 (1,260)	46.92
Wood mat		
101.6 mm (4 in.) post	288.4 (2,060)	25.93
152.4 mm (6 in.) post	393.4 (2,810)	34.57
Limestone aggregate	3,920 (28,000)	12.35

[a] 1 ft^2 = 9.29 × 10^{-2} m^2.

Comparison of Portable Surfaces

Table 1 summarizes information on different types of portable surfaces as well as crushed limestone aggregate, which is typically used to stabilize roadbeds in northcentral Florida. The cost data include labor to construct the surface and installation and removal costs. Geotextile is included in the cost of each portable surface. Costs are based on the surface necessary to cross an unstable roadbed section 9.1 m (30 ft) in length on a straight section of a single-lane road. Such a surface would require two 2.4-by 4.8-m (8- by 16-ft) pallets cut in half, with one 1.2-m (4-ft) half-pallet placed in each wheel path; two 3- by 4.6-m (10- by 15-ft) wood mats; or crushed limestone aggregate covering 3 by 9.1 m (10 by 30 ft), 203.2 mm (8 in.) deep. Information on service life is too limited to determine lifecycle costs. Howewr, unlike portable surfaces, crushed limeestone aggregate cannot be removed and reused. Also, several applications of the aggregate may be necessary, depending on soil conditions and amount of traffic.

Site Description and Data Collection Methods

The previous study by the San Dimas Technology and Development Center concluded that portable surfaces visibly reduce rut depth. The objective of our field evaluation was to measure this reduction in rut depth. The evaluation consisted of determining soil characteristics and collecting rut depth data for control and portable surface sections. The general site preparation consisted of the following:

- locating short, straight road sections where continuous maintenance was being performed,
- blading existing ruts in the chosen control and portable surface sections,
- placing the geotextile and portable surfaces on the roadbed,
- giving access to traffic, and
- installing stringline stakes and initiating daily data collection until the end of traffic use or field evaluation.

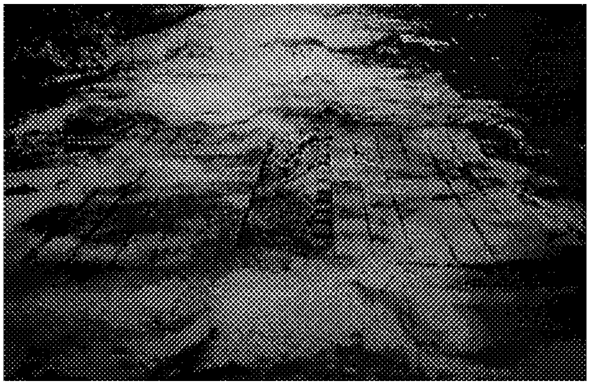

Figure 4—Portable surface section.

Figure 5—Control section.

Site Description

The road section stabilized by the portable surfaces was near a culvert installation where road drainage tended to collect. Figure 4 shows the 2.4-m- (8-ft)- long wood mats made of 101.6-mm (4-in.) posts as ramps on either side of the 4.3-m- (14-ft-) long mats made of 152.4- (6-in.) posts. The wood pallets butted up to the mats. Geotextile was placed under the portable surface. The control section was located on the same road approximately 54.9-m (180-ft) from the portable surfaces (Fig. 5). The control had similar moisture content and shading characteristics as that of the portable surface. The log truck traffic volume was approximately 30 round trips/day.

Soil Characterization and Rut Depth

The soil under the control and portable surfaces was characterized to determine similarities within each site. Provided the sections were similar, differences in rut depth would be attributable to the portable surfaces. Figure 6 shows the portable surface layout at the test site. The circles show stake locations where cross-section profiles were measured for rut depth. Soil characterization data point locations are not shown because (1) they varied each day as a result of disturbance from the previous day's tests and (2) we assumed that each entire section was similar. Also, the data were gathered each day at one location for the control and at three locations for the portable surfaces. Rut depth data were collected along the same cross-section each day.

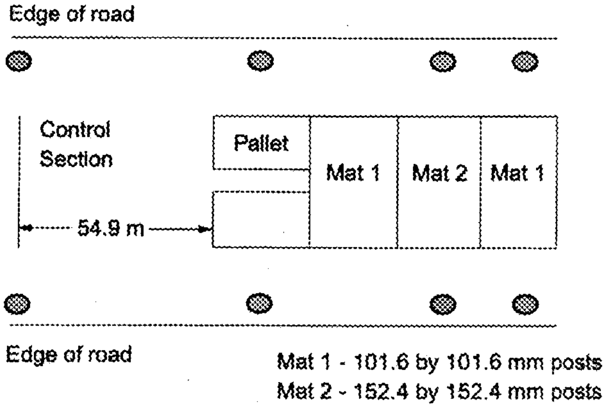

Figure 6—Schematic of site layout and cross-section locations.

Soil samples were taken at a depth of approximately 50.8 mm (2 in.) to determine moisture content as the main indicator of soil instability. The samples were placed in resealable plastic bags. Moisture content was determined using a moisture content machine, which runs on the same principles as does the oven drying technique. Cone penetrometer data were gathered to characterize soil strength. Figure 7 shows the Irregular Cone Index penetrometer. The 25.4-mm (1-in.) marks along the staff are the points of gage reading. The penetrometer was manually driven into the soil to a depth of 152.4 mm (6 in.) or until the maximum load was reached on the gage. The cone penetrometer readings were initially taken once at each data point location each day. Later, readings were verified by taking two to three readings for each data point location.

Rut depth was determined from road cross-section profiles using a stringline method. Stakes were permanently placed along the road edges. The stakes were marked at 0.3 m (1 ft) above the soil surface for placement of the stringline (Fig. 8). Road cross-sections were drawn by measuring transversely along the stringline to the highest and lowest ground elevations outlining the ruts. Elevations were measured from the stringline. The points representing the highest and lowest elevations were determined visually.

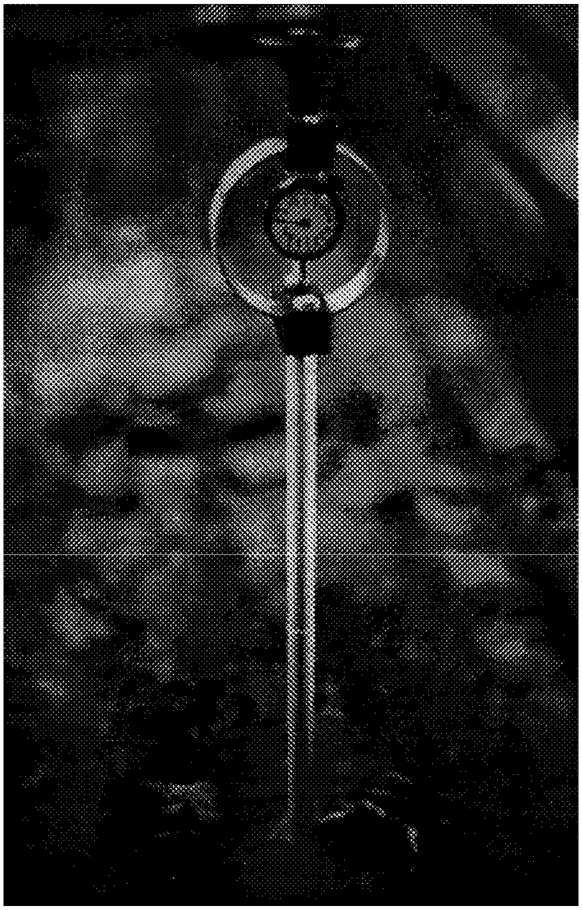

Figure 7—Cone penetrometer.

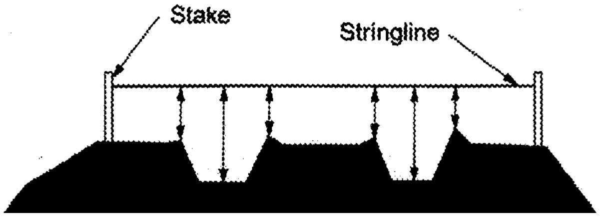

Figure 8—Stringline method used to measure rut depth.

Analysis of Results

Soil strength and moisture content of the control and portable surfaces were analyzed to verify that the control was representative and a viable baseline for the site. Cone penetrometer readings were converted to soil strength (California bearing ratio) using conversion factors supplied with the equipment. The other variables—traffic, climate, construction, and maintenance—were the same for the control and surface sections. The soil was determined to be a silty sand.

Practical constraints limited data collection. Because the portable surfaces could not be moved during use, all soil characterization data, except for the data for the final day, were gathered from the side of the surfaces. For the control section, all soil characterization data, except the data for the first day, were gathered from the wheel paths. Therefore, only the first day's data from outside the wheel paths and the final day's data from inside the wheel paths were compared for soil strength. Because of traffic constrains, no data were taken prior to roadbed use by traffic. Traffic was stopped in order to blade the sections and place the portable surfaces and was then allowed to continue while initial measurements were taken. Thus, we thought it reasonable to assume that both the control and portable surface sections had no initial ruts and that the first day's data represented the entire section.

Soil Characteristics

The California bearing ratio (CBR) is an index of soil strength in regard to shear failure under load. Because the change in CBR is not linear, a doubling of the CBR value does not equate to a doubling of soil strength (Barksdale 1991). The relationship of CBR to soil strength is a logarithmic curve. Thus, for smaller CBR values, changes in soil strength are large for incremental changes in CBR; strength rapidly decreases at higher CBR values. The following comparisons of the measured CBR are based on a soil strength chart supplied with the cone penetrometer equipment.

Figure 9 shows the CBR values for the first day. These data are assumed to be representative of soil conditions prior to placement of the portable surfaes and use by traffic. The portable surface data are averages, Moisture content was 2 percent greater in the portable surface section.

From a depth of 0 to 50.8 mm (2 in.), the CBR values of the portable surface section were slightly greater than that of the control but less then 3.2. At these CBR values, a shear failure through the 50.8-mm (2-in.) depth would be expected within two passes of a log truck. The CBR of the surface section was less than that of the control by up to 0.5 at depths of 76.2 to 101.6 mm (3 to 4 in.). Because the values are so close, little difference in shear failure would be expected to a depth of 101.6 mm (4 in.). At 127 mm (5 in.), the CBR value was 1.3 greater in the control section, which would result in a difference in rut depth for a small number of vehicle passes.

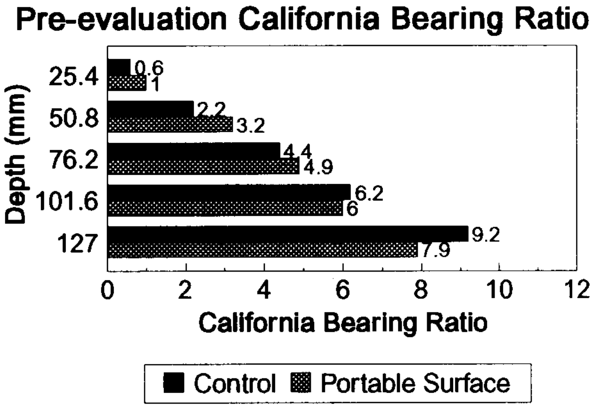

Figure 9—Comparison of California bearing ratio (CBR) to rut depth prior to traffic.

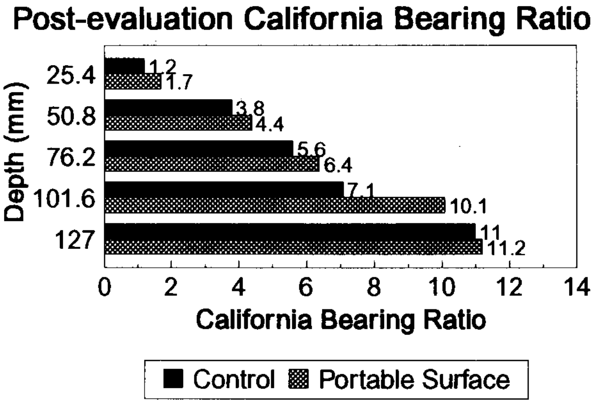

Figure 10—Comparison of CBR to rut depth at end of evaluation.

Figure 10 shows the CBR values for the final day. There was no difference in moisture content between the sections. Cone penetrometer data were averaged trom four values, two taken within each wheel path. The CBR of the portable surface section was greater by up to 0.8 at a depth of 76.2 mm (3 in.) and 127 mm (5 in.). Because the CBR values are so close, little difference in rut depth would be expected. At a depth of 101.6 mm (4 in.), the CBR of the portable surface section was greater by 3, which would result in a difference in rut depth for a small number of vehicle passes.

Based on these data, the control section is representative of the portable surface section. Given the total number of log truck passes and the higher moisture content in the surface section during the test period, the rut depth in the control section is expected to be a conservative estimate of the rut depth expected in the surface section. The following rut depth analysis determines the reduction in rut depth caused by using portable surfaces.

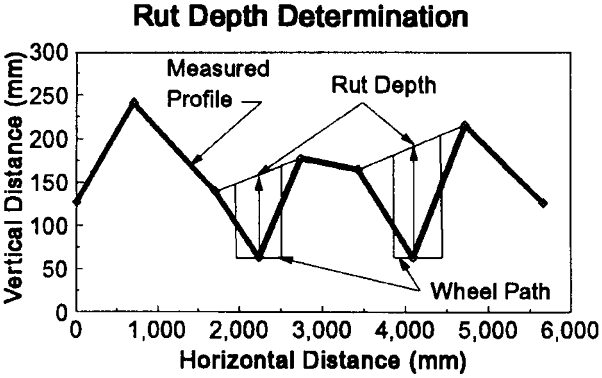

Figure 11—Determination of rut depth.

Rut Depth

Rut depth was interpreted as the difference between the low point within a wheel path and the average of the high points on either side of a wheel path (Fig. 11). Control and portable surface sections were compared for rut depth differences within the same wheel path.

Interpretation of rut depth for the portable surface sections proved difficult. The wood mat surfaces were uneven as a result of tracked dirt and natural warp of the wood. With the wood pallets, the difficulty in interpretation was due to plank breakage. It was difficult to determine if the changes in depth were due to broken planks or compaction of the pallet into the road surface. Measurements taken along the edges of the portable surfaces at the completion of the field evaluation indicated that the portable surfaces were embedded in the roadbed surface approximately 38.1 mm (1-1/2 in.). Using this embedment value as the baseline, the rut depths were determined for each day. Figures 12 to 13 show the differences in rut depth for each wheel path. In the north wheel path, the difference varied from 134.6 to 154.9 mm (5.3 to 6.1 in.); in the south wheel path, from 66 to 101.6 mm (2.6 to 4 in.).

Conclusions

This report describes a portion of a field evaluation of portable surfaces used to cross short sections of unstable roadbed in northcentral Florida. The evaluation quantified the effectiveness of the portable surfaces in reducing rut depth from log truck traffic. Moisture content and cone penetrometer data were gathered to determine soil characteristics of portable surface and control sections. Cross-section profiles were measured to compare rut depths in portable surface and control sections.

Comparison of data taken on the first and final days verified that the control section conservatively represented the surface section. Moisture content averaged slightly higher in the portable surface

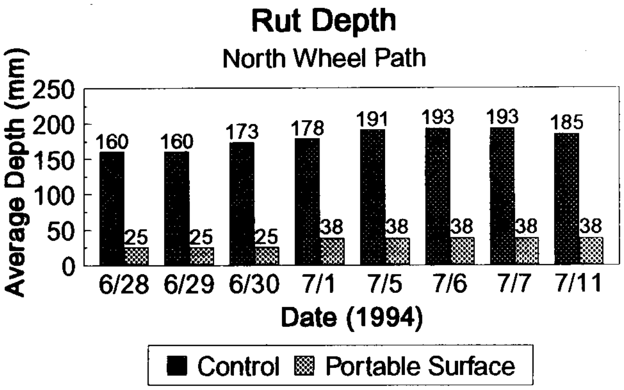

Figure 12—Rut depth in north wheel path over time.

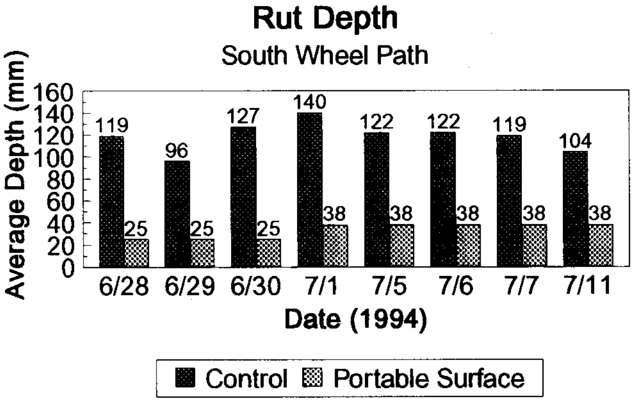

Figure 13—Rut depth in south wheel path over time.

sections. In general, differences in CBR values were minimal, and for the total number of vehicle passes, rut depths would be similar.

The cross-section profiles indicated that the portable surfaces reduced rut depth by an average of 127.0 mm (5.0 in.). The main cause of ruts appears to be localized bearing capacity failure. The top 25.4- to 50.8-mm (l- to 2-in.) of roadbed soil become saturated and loosened by traffic and move laterally from under the loads. The portable surfaces distribute the load over a larger area and the geotextile retains the soil. This inhibits the lateral movement of the soil, which reduces rut depth.

Portable surfaces are a temporary, reusable alternative for crossing unstable low-volume roadbeds surfaced with aggregate or native soil, under specific conditions. For the field evaluation reported here, those conditions were short sections prone to continual rut development in silty sand soil roadbeds that provide access for log trucks. Portable surfaces are inexpensive, readily available products for road designers to consider as an alternative to reconstruction, frequent road maintenance, or use of nonreusable crushed aggregate. The most effective portable surface depends on the equipment and funding available, and the initial and allowable final site conditions.

For manual installation, wood mats can be assembled and disassembled on site. For limited funding, wood mats made of 101.6- by 101.6-mm (4- by 4-in.) posts would be least costly. Wood mats should be used for initial sites that are not flat, such as rolling dips. For final site constraints of few or no ruts, wood mats or wood pallets leave no noticeable ruts. Wood mats are recommended as the best overall portable surface for crossing short sections of unstable roadbed soil.

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