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History of Reinforced Walls in the USDA Forest Service

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Introduction

The USDA Forest Service manages activities on 123 national forests and 19 national grasslands covering 191 million acres. Accessing and managing these lands requires an extensive transportation system. Retaining walls and reinforced soil concepts have been used extensively to build and maintain a functional transportation system. The rugged terrain, remote areas, and secondary nature of the roads require innovative and adaptable designs.

Forest Service personnel have been innovative in applying the theories of soil reinforcement since the early 1970's. The first geotextile reinforced wall in the United States was built on the Siskiyou National Forest in southwestern Oregon in 1974, the second on the Olympic National Forest in western Washington in 1975. Since 1975, the Forest Service has built a variety of structures using different types of reinforced soil materials. Geotextiles, tires, lightweight wood backfill materials, chainlink fencing, fiberglass roving, manure, straw bales, and geocomposite drains have all been used in retaining structures.

This paper presents the development of soil reinforcement uses by the Forest Service. Topics include: basic principles and guidelines developed during the 1970's, which were marked by trial uses of new materials and methods for the use of soil reinforcement; creative engineering and innovation in the 1980's, which can be captured by updating the *Retaining Wall Design Guide* (Driscoll, 1979); and a look to future developments, such as soil nailing, in the 1990's.

The 1970's — Development of Basic Principles and Guidelines

Many geotechnical engineers and engineering geologists were hired by the Forest Service in the early 1970's. Their skills proved essential for locating and building a stable transportation system in rugged terrain. Until the early to mid-1970's, standard design gravity retaining structures were the norm. Steel and aluminum bin walls, concrete and wood crib walls, and wire gabion walls were the predominant retaining structures built during this period. The geotechnical personnel, with their understanding of soil mechanics and slope stability, began to develop custom designs for local conditions.

The geotechnical personnel readily adopted the concepts of soil reinforcement when introduced in the early 1970's. The introduction of geotextiles as soil reinforcement in the mid-1970's presented many opportunities. Table 1 lists some key developments in geotextiles and soil reinforcement in the Forest Service. By 1979, the basic principles and guidelines of soil reinforcement were established for use with low-volume roads. These principles and guidelines were captured, along with good basic design information, in the *Retaining Wall Design Guide* (Driscoll, 1979).

Table 1. —Historical use of geotextile and soil reinforcement.

1973	Used for filter layers (drainage) for roads
1974	First geotextile reinforced wall constructed on the Siskiyou National Forest near Cave Junction, OR.
1975	Second geotextile reinforced wall constructed on the Olympic National Forest near Shelton, WA.
1976	Geotextile test road constructed on the Olympic National Forest near Quinault, WA.
1976	Report: "Use of Fabrics in Construction and Maintenance of Low-Volume Roads"
1977	Report of 1976 republished by Federal Highway Administration (FHWA).
1979	*Retaining Wall Design Guide* published.

The first geotextile reinforced wall in the United States was built on the Siskiyou National Forest in 1974. This wall, shown in Figure 1, was built using nonwoven, needle-punched, polypropylene geotextiles. The wall was built to verify laboratory model tests performed by Professor J. Richard Bell at Oregon State University. The wall face was formed by bags filled with sand and was covered with gunite (shot concrete) for protection from sunlight and vandalism. Plastic pipes were inserted in the wall for drainage.

Figure 2 shows the second geotextile reinforced wall, built in 1975 near Shelton, Washington. This wall, 176 feet long by 19 feet high, was fully instrumented for internal and external movement. Nonwoven, needle-punched polyester and polypropylene geotextiles were used to compare their strength and elongation characteristics. There was much concern at the time about the potential for long-term creep in geotextiles under constant tensile load. Less than 1 inch of horizontal or vertical movement was measured in the wall during the first 6 months after construction. Monitoring over the next 3 years indicated no further movement within the wall (Mohney and Steward, 1977).

Temporary steel L-braces and wood boards were used to support the face during construction. This method continues to be used today for the construction of geotextile retaining walls. The surface of this wall was sprayed with the emulsified asphalt for protection from sunlight (Figure 3). Very little

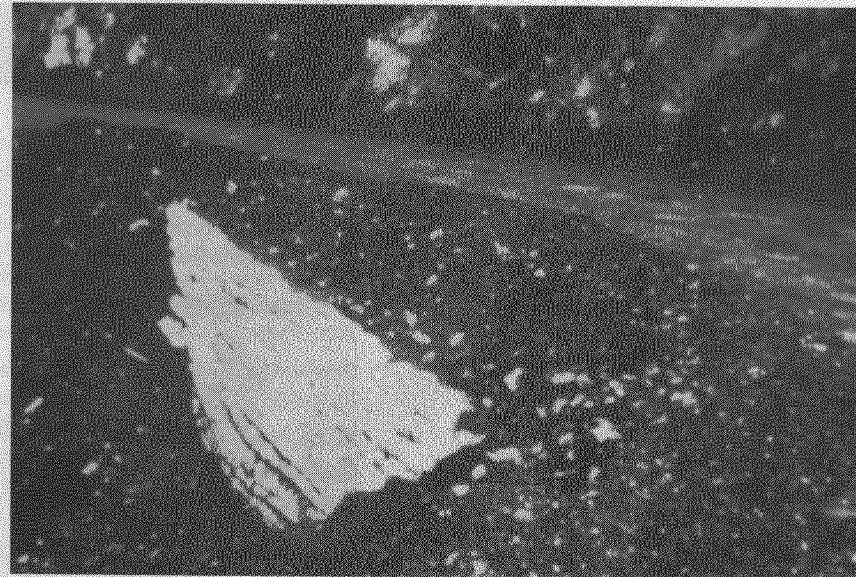


Figure 1.—First geotextile reinforced wall before gunite facing.

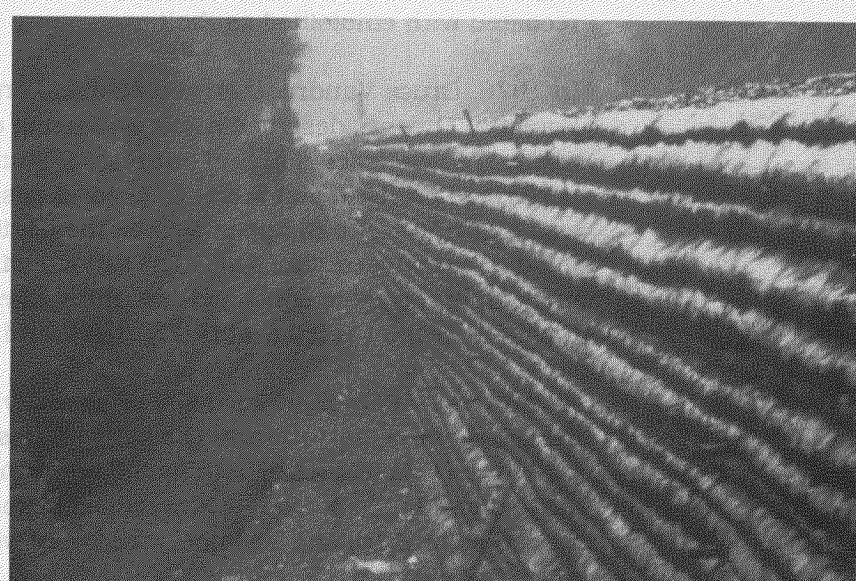


Figure 2.—Second geotextile reinforced wall.

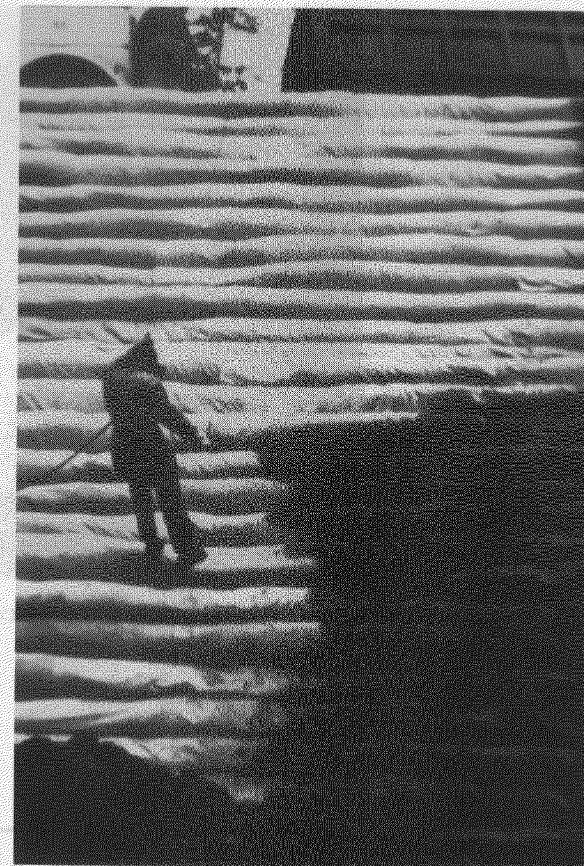


Figure 3.—Wall being coated with emulsified asphalt.

degradation of the geotextile face had occurred by 1985 when the wall was recoated with emulsified asphalt.

In 1976, Bruce Vandre, then geotechnical engineer on the Siskiyou National Forest in Oregon, designed a soil wall using chainlink fencing for reinforcement. Tensile tests, soil pull out tests (Figure 4), and corrosion tests were performed on the metal fabric to develop design information. The chainlink wall (Figures 5 and 6) appears to be the basis for the commercial development of the welded wire wall. The welded wire wall has proven to be economical and easy to construct, resulting in extensive use of this wall type throughout the United States (Figures 7 and 8).

Several innovative reinforced soil or partially reinforced soil wall types were designed and constructed in the early 1970's. Figure 9 shows a culvert pipe wall, nearly 60 feet high, with facing restrained by strap anchors. This wall, located on Mary's Peak near Corvallis, Oregon, was instrumented for performance (Figure 10) and has performed very well.

The variety of wall types developed and being used in the early to mid-1970's presented a need for retaining wall design guidelines. The *Retaining Wall Design Guide*, developed by a contractor, documented design methods and

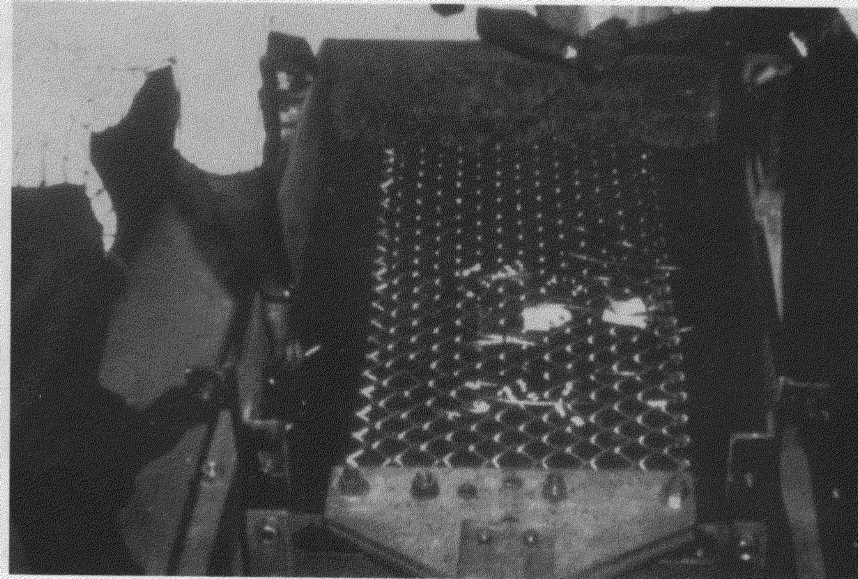


Figure 4.—Soil pullout test.

Figure 5.—Chainlink wall under construction.

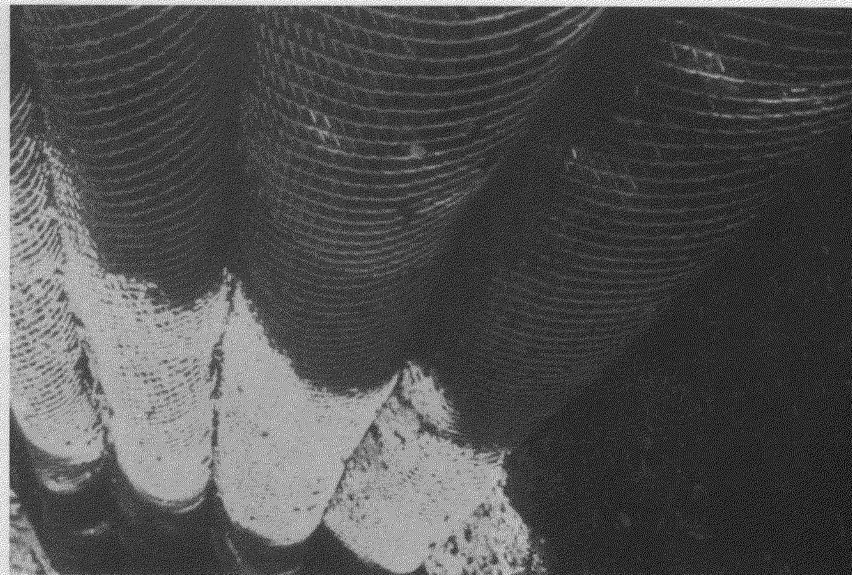


Figure 6.—Completed chainlink wall.

Figure 7.—Unstable slope between two roads, Plumas National Forest.

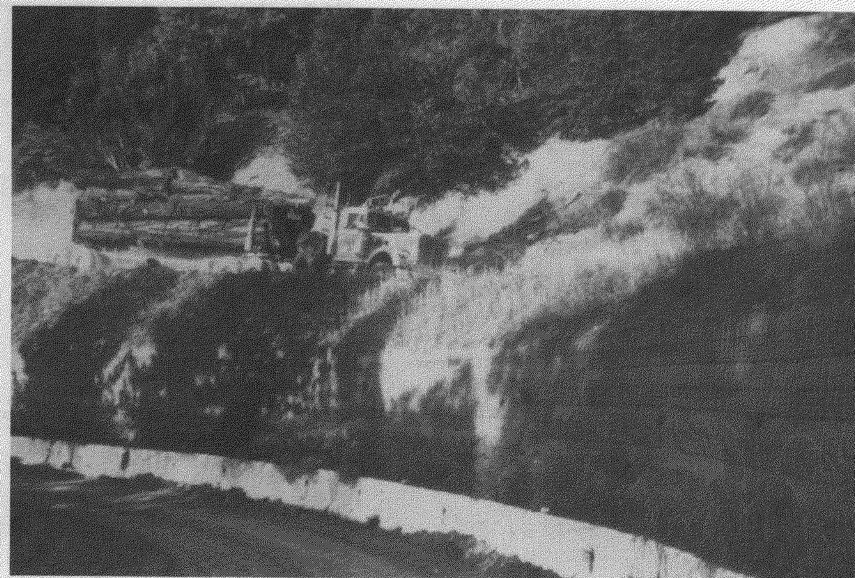


Figure 8.—Slope after repair with welded wire wall.

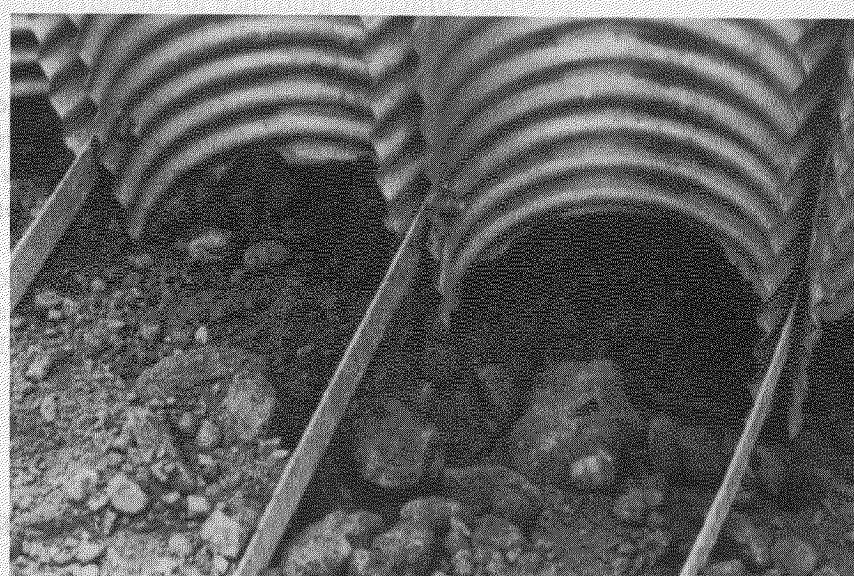


Figure 9.—Culvert pipe wall facing and metal straps.

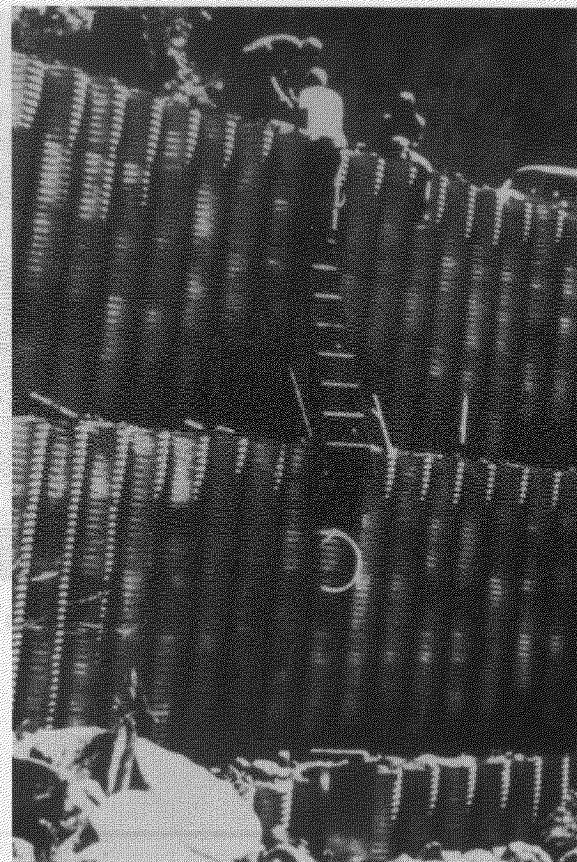


Figure 10.—Placing instruments at height of 40 feet.

provided practical guidance for design and construction of retaining walls for low-volume roads (Driscoll, 1979).

The *Retaining Wall Design Guide* provided design guidance for most wall types in use at the time. Table 2 lists the wall types contained in the design guide by design method and probable behavior of the wall. The walls are further classified in the guide as standard or nonstandard (Table 3).

Retaining walls are designed for internal and external stability. Table 4 presents recommended factors of safety for external stability analysis. Important features for internal design of soil reinforced geotextile walls are shown in Figure 11.

Design equations related to Figure 11 are:

Vertical Spacing: x

$$x = \frac{S_r}{(FS)(T_h)}$$

Embedded Length: Le

$$Le = \frac{S_r}{(FS_r)(2d_a \tan\phi_r)}$$

or 3.0 ft min

Overlap: Lo

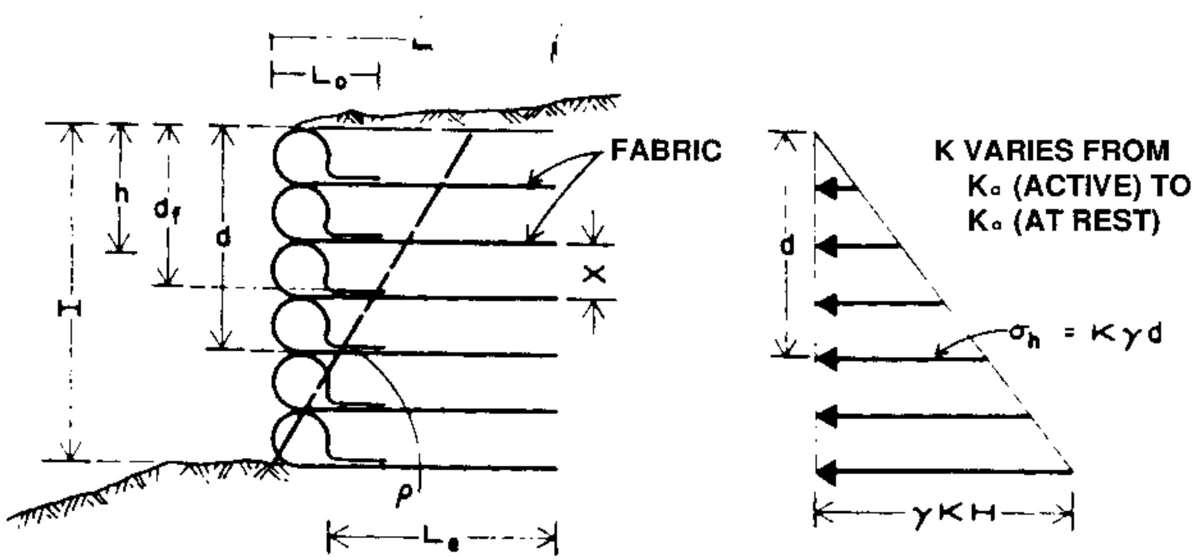
$$Lo = \frac{h\,K\,x\,(FS_o)}{2d_f \tan\phi_f}$$

or 3.0 ft min

Where:

S_f	=	Strength of the geotextile
FS	=	Desired factor of safety
T_h	=	Horizontal stress at midpoint of layer
FS_f	=	Factor of safety for the geotextile, generally in the range of 1.50 to 1.75
∂	=	Unit weight of backfill
$ø_f$	=	Soil-geotextile friction angle, generally taken as 2/3 ø
FS_o	=	Factor of safety of the overlap

The basic approach to the design of geotextile reinforced walls presented here has been used for most soil reinforced walls designed by Forest Service personnel since the mid-1970's. One factor that has changed is the geotextile strength used for the design.



(a) (b)

Figure 11.—Geotextile wall — earth pressure distribution (Driscoll, 1979 and Steward, et. al.).

Table 2.—Wall classification (Driscoll, 1979).

Gravity	*Anchored*
1. Bin Walls	1. Vertical Culvert Pipe
a. Rectangular	2. Horizontal Sheet Pipe
b. Circular	3. H-Pile, Timber Lagged
c. Cross Tied	4. Vertical Sheet Pile
2. Concrete Crib	5. Stack Sack
3. Timber Crib	6. All Gravity Structures
4. Gabions	
5. Concrete Gravity	
6. Concrete Cantilever	
Reinforced Backfill	*Cantilever Piles*
1. Reinforced Earth	1. Vertical Sheet Piles
2. Fabric	2. H-Pile, Timber Lagged
3. Stack Shack	

Table 3.—Standard and nonstandard wall designs (Driscoll, 1979).

Standard Walls	*Nonstandard Walls*
1. Bin Walls	1. H-Piles, Lagged
a. Rectangular	2. Vertical Culvert Pipe
b. Circular	3. Geotextile
c. Cross Tied	4. Horizontal Sheet Pile
2. Reinforced Earth	5. Vertical Sheet Pile
3. Timber Crib	6. Anchored (Tied Back)
4. Concrete Crib	7. Stack Sack
5. Gabions	
6. Concrete Gravity	
7. Concrete Cantilever	

Table 4.—Recommended factors of safety.

	Bearing Capacity	*Over-Turning*	*Sliding at Base*	*Slope Stability*
Normal Highway Loadings	2.0 – 3.0*	1.5 – 2.0*	1.5 – 2.0*	1.2 – 1.5
Occasional Heavy Transient Loading	1.5 – 2.0	1.2	1.2	1.2

** Upper range of factor of safety refers to silt and clay backfill or foundation soil.*

Initially, the working strength was based on limiting the loading to minimize creep. The working load was limited to 35 to 50 percent of the wide width (8-inch minimum sample width) tensile strength of the geotextile. Later, some walls were designed for the minimum of the strength at 10 percent elongation or 30 to 50 percent of the wide width tensile strength. Recent work by the FHWA (Christopher, et. al., 1990) indicates other strength properties may be more appropriate.

The 1980's — Innovative Engineering Applications

The 1980's were a period of innovation and creativity in the design of soil reinforced walls using the concepts developed in the 1970's. Walls were constructed using local and lightweight materials for backfill and a variety of facing and internal reinforcement materials. Innovative reinforced soil walls developed or used include:

- Chainlink fabric walls (Figure 6)
- Welded wire walls (Figure 8)
- Concrete-block-faced reinforced walls (Figures 12 and 13)
- Geotextile reinforced soil walls (Figure 14)
- Tire-faced reinforced soil walls (Figures 15 and 16)
- Wood-faced reinforced soil walls (Figures 17 and 18)
- Manure/Hay reinforced soil walls (Figures 19 and 20)
- Fiberglass roving reinforced soil walls (Figures 21–23)
- Walls and buttresses using local backfill materials (Figures 15–25) (Burke, 1988; Keller, 1989 and 1990; and McNemar, 1989)
- Lightweight backfill reinforced walls (Figure 26)

Table 5, developed by Gordon Keller, Geotechnical Engineer on the Plumas National Forest, summarizes soil properties and performance of several walls using local materials (Keller, 1990). Positive internal drainage to prevent hydrostatic pressures is a key feature in the design and construction of each of these walls. Geocomposite drainage materials have been used extensively in retaining walls in the last 5 to 7 years.

Wood materials — such as sawdust, wood chips, and "hog fuel" (small pieces of wood produced by processing wood scraps through a machine called a "hog") — have been used for retaining wall backfill (Figure 26). The wood backfill, which weighs 40 to 60 pounds per cubic foot (wet weight), is about 50 percent of the weight of soil and rock backfill materials, minimizing loading in potentially unstable areas. Shredded tires, with a unit weight of about 35 pounds per cubic foot, would also be a suitable lightweight backfill material.

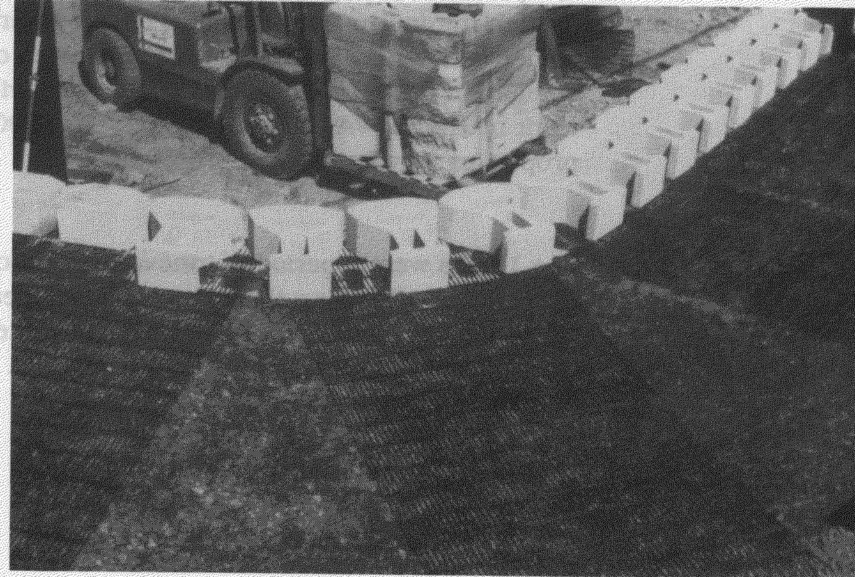


Figure 12.—Concrete-block-faced reinforced wall under construction (top view).

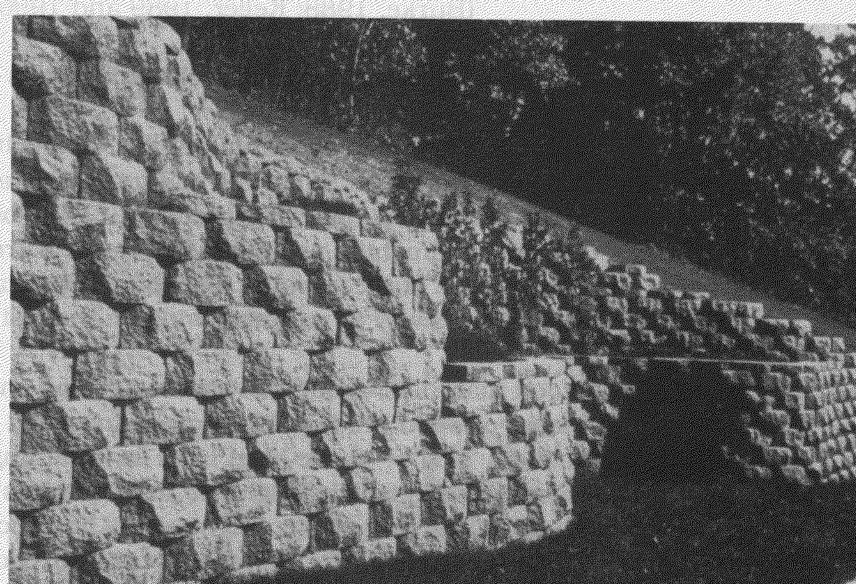


Figure 13.—Completed concrete-block-faced reinforced wall, Siuslaw National Forest, 1990.

Figure 14.—Road repaired using geotextile-faced reinforced soil wall/slope.

Figure 15.—Placement of soil backfill in tire facing for tire-faced wall, Plumas National Forest, 1992.

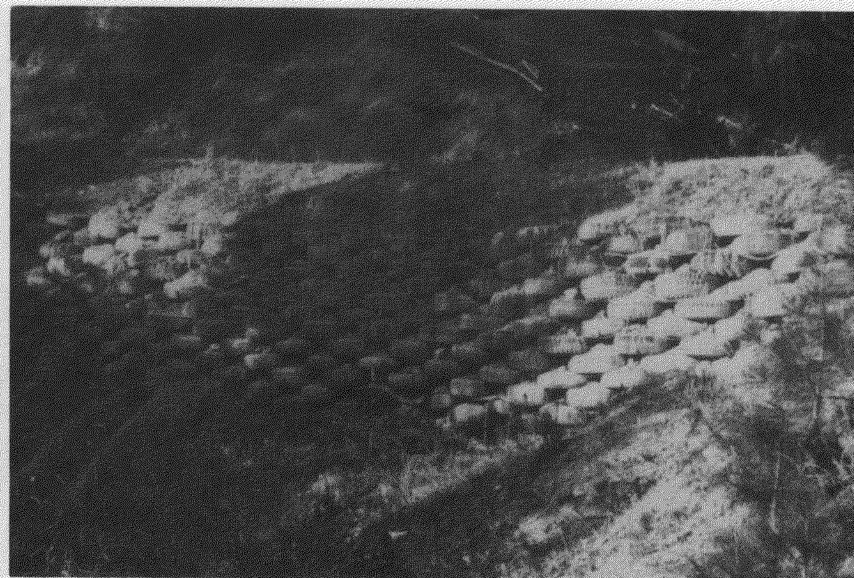


Figure 16.—Completed tire-faced wall.

Figure 17.—Wood-faced wall under construction.

Figure 18.—Completed wood-faced wall.

Figure 19.—Workers placing internal reinforcement material (note: geocomposite drain behind backfill).

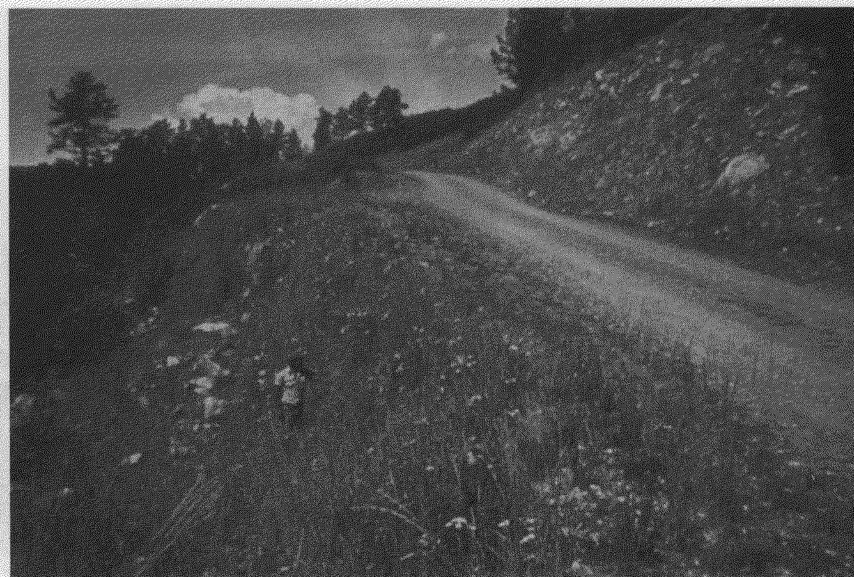


Figure 20.—Completed manure-faced wall after one growing season.

Figure 21.—Placement of fiberglass roving material on face of wall, San Juan National Forest.

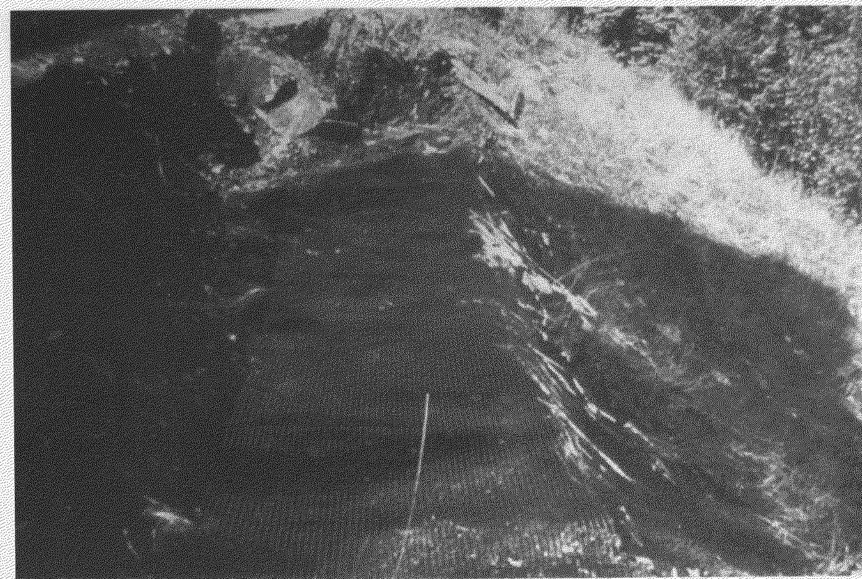


Figure 22.—Internal reinforcement placed over fiberglass roving material.

Figure 23.—Completed fiberglass roving material wall.

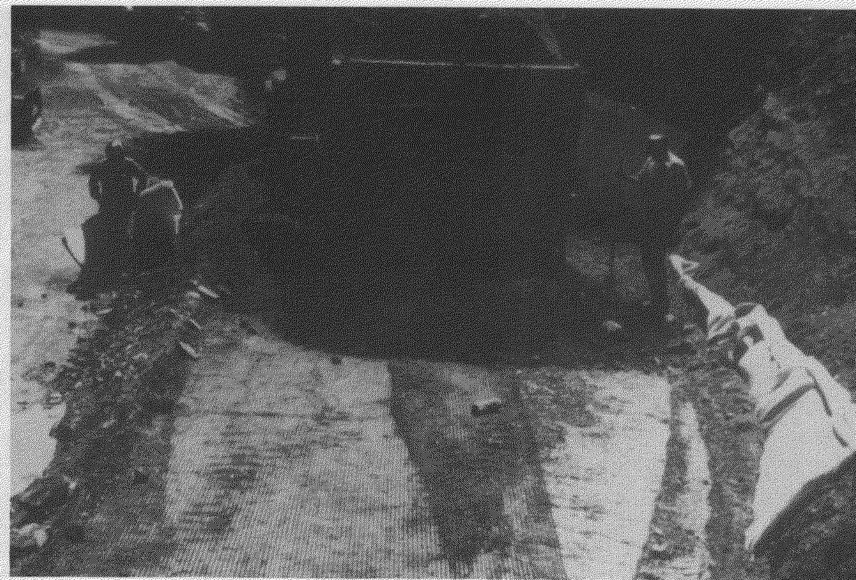


Figure 24.—Placement of local soil backfill for a reinforced soil buttress on the Plumas National Forest.

Figure 25.—Completed reinforced soil buttress.

Figure 26.—Construction of geotextile reinforced wall using lightweight wood materials for backfill.

Table 5.—Typical "local" soil used in structures.

Site	*Wall Type*	*USC*[1]	*% Minus 200*	*PI*[2]	*Phi' (Deg)*	*c' (psf)*	*Comments*
Goat Hill	Welded Wire	SM	21	5	34	200	Some face settlement
		SC	20	8	31	300	
L. North Fork	Reinforced Fill (1:1)	SM	38	2	34	100	Slight slope ravel
		ML	55	3	33	150	
B. Longville	Welded Wire	CL	50+	–	26	200	Poor foundation
Grave	Geotextile	SM	26	NP	35	850	Irregular face
Butt Valley	Tire-Faced	SC	38	8	26	400	10% face settlement
Klamath	Timber-Faced	SM	27	NP	30	0	Minimal settlement
Willamette	Wood Chips & Geotextile	GP	0	NP	32	0	5% total settlement

[1]Unified Soil Classification
[2]Plasticity Index

Note: Phi' (internal angle of friction) and c' (cohesion) are from Consolidated-Undrained tests at 95 percent of T-99 Density (1 psf = 0.0479 kN/m²)

Table 6, also developed by Gordon Keller (Keller, 1990), shows a comparison of various internally reinforced walls. Costs of these walls, updated to 1992, appear reasonable, especially considering the remote locations. Driven H-pile walls, commonly used in steep terrain, typically cost in the range of $30 to $60 per square foot of front face.

Table 6.—Summary of alternative earth retaining structures (Keller, 1990).

Type of Structure	*Height (Ft)*	*Cost* (Per Ft²)*	*Advantages/Disadvantages*
Reinforced Fills	15 – 50	$5 – $14	Less expensive than walls where they fit; slope typically 1:1; 1/2:1 slope with extra measures
Tire-Faced Walls	10	$14 – $20	Significant face settlement; visually questionable
Timber-Faced Walls	1 – 8	$16 – $22	Optimum wall considering cost, durability, and aesthetics; easy to construct
Geotextile-Faced Walls	1 – 20	$15 – $29	Temporary structures; irregular and nondurable face unless covered or treated
Lightweight Walls	28	$16 – $25	Special geotextile walls suited for landslide terrain; moderate settlement with sawdust
Chainlink Fencing Walls	22	$23 – $29	Require a custom design; accommodate face settlement
Welded Wire Walls	6 – 30	$23 – $34	Most commonly built Forest Service wall; good construction support from manufacture; standard designs available
Block-Faced Walls	5 – 30	$14 – $25	Masonry block facing; very aesthetic and durable; standard designs available; used for landscaping

**1992 costs, typically including drainage, excavation, and backfill. Total wall cost can increase significantly depending on wall size, site difficulty, and other road repair work.*

Note: 1 ft = 0.3048 m

The 1990's — What Lies Ahead?

An effort is just beginning, in cooperation with the FHWA Coordinated Technology Implementation Program (CTIP) to rewrite and update the 1979 *Retaining Wall Design Guide* (Driscoll, 1979). Planned modifications include: (1) updating reinforced soil wall design criteria and facing systems; (2) updating risk analysis methodology; (3) adding standard designs for low height walls, especially for geotextile reinforced walls; and (4) adding reinforced soil slopes.

The variety of facing materials and systems available now and in the future will increase the aesthetic acceptability of geotextile reinforced soil walls. Long-term durability testing of geotextiles under the leadership of the FHWA will increase the reliability and predictability of long-term designs. These developments, aided by improved and simplified design methods and favorable costs, will lead to increased use of reinforced soil walls by the Forest Service and others.

An example of new technology for the 1990's is the use of launched soil nails for stabilizing slopes in lieu of retaining walls. The soil nail launcher literally shoots 1- and 1 1/2-inch diameter steel nails up to 20 feet long into the ground using one shot of compressed air. The soil nail launcher is being demonstrated in the western United States during July and August 1992.

Summary

Forest Service employees have developed, adopted, and provided basic concepts and criteria for design and construction of soil reinforced walls and slopes during the 1980's and 1990's. Innovation has included a variety of facing, backfill, and internal reinforcement methods and materials. The use of local and lightweight materials for backfill has demonstrated the adaptability of these methods to build low-cost durable walls.

Soil reinforced walls and slopes are adaptable to many sites and conditions. Use of these types of walls is expected to increase in the future.

Table 7 lists Forest Service personnel responsible for many of the case histories cited in this paper. These contacts are provided for readers wanting to "try these walls at home."

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Table 7.—Forest Service authors.

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Clifford Denning	Geotechnical Engineer Mt. Hood National Forest 2955 NW Division St. Gresham, OR 97030	(503) 666-0681
Richard VanDyke	Geotechnical Engineer Westside Engineering Zone II Siskiyou National Forest 93976 Ocean Way Gold Beach, OR 97444	(503) 247-7026
Michael Burke	Geotechnical Engineer San Juan National Forest 701 Camino Del Rio Room 301 Durango, CO 81301	(303) 385-1271
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Update on the Soil Nail Launcher Demonstration Project

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Introduction

The Waldport Ranger District on the Siuslaw National Forest was the site of the first installation of a launched soil nail in North America. The galvanized nails, which are 1 1/2 inches in diameter and 18 feet long, were installed instantly as part of the Soil Nail Launcher Demonstration project. The demonstrations are progressing well, and an applications guide and video will be produced this winter. The project is sponsored jointly by the Forest Service and Soil Nailing Limited, with financial assistance from the Federal Highway Administration (FHWA) Coordinated Technology Implementation Program (CTIP).

The Soil Nail Launcher

The soil nail launcher is an air-operated device that shoots 1- and 1 1/2-inch diameter metal reinforcement nails or drain pipes into the ground. The nails are launched or shot into the ground to a depth of up to 20 feet using high pressure compressed air.

Conventional soil nails are installed in the ground by drilling with a 6- to 8-inch-diameter auger, inserting the nail, and grouting it in the hole. Typical drilling equipment requires a 15-foot-wide bench below the soil nail location for operation.

The soil nail launcher mounts on a hydraulic hoe or other equipment to move into position. Depending on the length and reach of the boom, the hoe can be located 10 to 40 feet above or below the nail location. This capability makes the soil nail launcher ideal for pinning or nailing unstable roadway backslopes and embankment slopes with slip depths to 10 feet.

Purpose of the Demonstration

Launched soil nails have been used in the United Kingdom and Europe for the last 2 years for reinforcing road and railroad embankments and strengthening retaining walls, but they have not been used in the United States prior to this project. Two conditions are necessary to make this technology available to transportation agencies in the United States at a reasonable cost:

(1) Enough potential work must be identified for contractors to invest in the equipment and supplies.

(2) Contractors must invest in the equipment and supplies to provide launched soil nail services.

This demonstration project is an opportunity for potential users and contractors to view and explore the potential of this "High Tech/High Touch" technology. The goal of this project is to:

(1) Demonstrate soil nail launching technology.

(2) Evaluate the potential for use of launched soil nails.

(3) Encourage contractors to provide soil nail launching services.

(4) Develop an applications guide and video for launched soil nails.

Design guidelines for conventional soil nails — developed by the FHWA, State transportation departments, and private consultants — appear to be applicable to launched soil nails. Therefore, it is not the intent of this demonstration project to develop design guidelines for launched soil nails.

Economics of Launched Soil Nails

Launched soil nails are currently estimated to cost about $130 per installed soil nail. On a 3- by 3-foot spacing, this is about $14 per square foot of reinforced slope. This compares very well with retaining walls costing $15 to $60 per square foot of front face on low-volume roads. One national forest estimates saving $6,000 per site for shoulder repairs on paved roads using soil nails in lieu of retaining walls or excavation and replacement. The potential cost savings do not reflect the reduced environmental impact of reinforcing soils inplace in lieu of removal and replacement.

Demonstration Project Schedule

During the last 2 weeks, we have successfully demonstrated the soil nail launcher on the Siuslaw and Siskiyou National Forests in Oregon and on the Klamath and Stanislaus National Forests in California. In the next 2 weeks, additional demonstrations are planned on the San Juan National Forest in Colorado, the Mt. Hood National Forest in Oregon, and on State Department of Transportation projects in Colorado and Washington.

Mauricio Ribera, Project Facilitator, is travelling with and coordinating the demonstration project and will be leading the effort to develop the applications guide and video. He will be assisted by Bernard Myles with Soil Nailing Limited, Jeff Hino with the Oregon State University Forestry Media Center, and the Regional and project forest coordinators, as well as information from the project questionnaires.

Watch future issues of Engineering Field Notes for the results of the demonstration project and for ideas for using launched soil nails. Look closely, for the best ideas for using this emerging technology may be yours.

Summary

Field demonstrations of the soil nail launcher technology are progressing very well. Launched soil nails appear to have good promise for reinforcing road shoulders, road backslopes, and retaining walls. The applications guide, project video, and future Engineering Field Notes articles will help us understand, evaluate, and implement launched soil nail technology by the Forest Service.

You Can Help

The attached questionnaire was prepared to help evaluate launched soil nail technology and to provide information for the applications guide. Readers can assist with the project by completing and returning it to the project facilitator, Mauricio Ribera, Assistant Forest Engineer on the Siuslaw National Forest, by November 1, 1992.

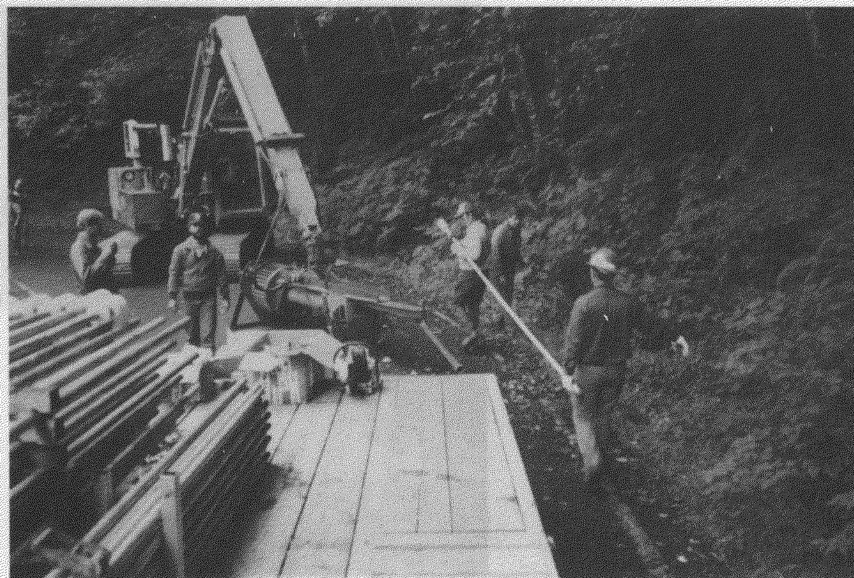

Figure 1.—Carrying the nail to the launcher.

Figure 2.—Positioning the launcher for shooting the nail in road shoulder.

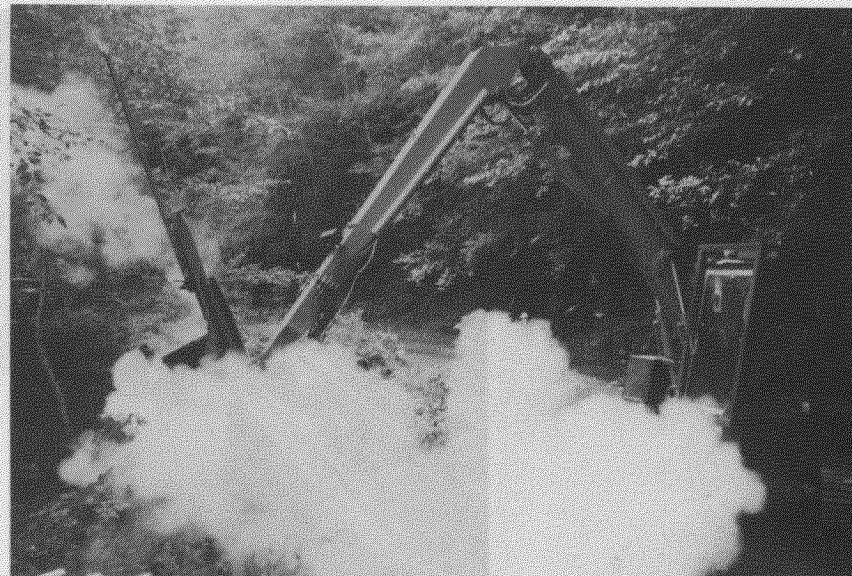

Figure 3.—Launching the nail.

Figure 4.—Installed nail—.5 feet above ground and 17.5 feet into ground.

SOIL NAIL LAUNCHER DEMONSTRATION PROJECT

Demonstration date: _______

RETURN QUESTIONNAIRE TO:

Mauricio Ribera,
Assistant Forest Engineer
Siuslaw NF
4077 Research Way
Corvallis, OR 97333
FAX (503) 750-7234
(503) 750-7140

To receive future information:
(Spring 1993)
Applications Guide: YES ____ NO ____
Applications Video: YES ____ NO ____
Name: ______________________
Unit/CO.: ______________________
Address: ______________________
____
____
Phone: (_____) _____-_____
FAX: (_____) _____-_____

1. Application of This Technology:

	Low	Med	High
a. Road Shoulder Reinforcement:	0..................	5..................	10
b. Road Backslope Reinforcement:	0..................	5..................	10
c. Slope Reinforcement:	0..................	5..................	10
d. Existing Wall Reinforcement:	0..................	5..................	10
e. Horizontal Drain Insertion:	0..................	5..................	10
f. New Walls:	0..................	5..................	10
g. Anchor Insertion:	0..................	5..................	10
Other:			
h. ______________________	0..................	5..................	10
i. ______________________	0..................	5..................	10
j. ______________________	0..................	5..................	10

Comments:

2. Volume of Work:

How much work do you see for launched soil nails for your organization?*

	# Projects	# Nails/Proj**		# Projects	#Nails/Proj
1.a	________	________	1.b	________	________
1.c	________	________	1.d	________	________
1.e	________	________	1.f	________	________
1.g	________	________	1.h	________	________
1.i	________	________	1.j	________	________

* Organization covers (Road miles? Area included?, etc.).
** Assume 3 x 3 foot pattern and $130/nail without facing.

Comments:

3. Equipment Preference:

What type soil nail launcher carrier would be most useful?

a. Tracked excavator (as demonstrated) ________
b. Portable (skid-mounted) ________
c. Truck-mounted excavator ________
d. Other (specify) ________

Comments:

4. Features: Importance —

	Very Low		None		Very High
a. Reinforce in situ	-10	-5	0	5	10
b. Keep road open	-10	-5	0	5	10
c. Rapid	-10	-5	0	5	10
d. Cost	-10	-5	0	5	10
e. High Technology	-10	-5	0	5	10
f. Controllability	-10	-5	0	5	10
g. Mobility	-10	-5	0	5	10
h. Rapid deployment	-10	-5	0	5	10
i. Specialized equipment	-10	-5	0	5	10
j. Use in sensitive areas	-10	-5	0	5	10
k. Minimum ground disturbance	-10	-5	0	5	10
l. Stay within right-of-way	-10	-5	0	5	10
m. Use in restricted areas	-10	-5	0	5	10
n.	-10	-5	0	5	10
o.	-10	-5	0	5	10
p.	-10	-5	0	5	10

Comments:

5. Comments on Soil Nail Launcher Technology:

   a. Limitations?

   b. Advantages?

   c. Design information: What is needed? How well will current methods apply?

6. Facing Needs and Suggestions:

   a. What uses require a facing system? What type facing is needed?

   b. What ideas do you have for facing systems? Attachments of the nails to the facing system? Attachment of the nails to a wall face? Sketches?

   c. Other comments and ideas:

Summary

Field demonstrations of the soil nail launcher technology is progressing very well. Launched soil nails appear to have good promise for reinforcing road shoulders, road backslopes, and retaining walls. The Applications Guide, project video, and future *Engineering Field Notes* articles will help us understand, evaluate, and implement launched soil nail technology by the Forest Service.

MTDC Seedling Counter Field Tests

Dave Gasvoda,
Electronic Engineer
Missoula Technology and Development Center
Missoula, Montana

Diane Herzberg,
Mechanical Engineer
Missoula Technology and Development Center
Missoula, Montana

Introduction

The seedling counter (Figure 1) was developed by the USDA Forest Service Missoula Technology and Development Center (MTDC) in cooperation with Dr. Glenn Kranzler, Oklahoma State University, to count conifer seedlings in nurseries. It automates the inventory process, which traditionally has been accomplished by hand-counting samples within beds. The counter provides nursery managers with a tool for obtaining quick, reliable inventories.

The counter relies on custom-designed optoelectronics to detect and count seedlings. A portable computer controls the counting and records the data (Figure 2). The counter counts a single row of seedlings in a bed with rows spaced 6 inches apart. The gross inventory for the lot can be estimated from the count obtained for one drill row. The more rows that are counted, the more accurate the estimate. Precision seeding will improve counting accuracy, but it is not required. Acceptable accuracy can usually be obtained using the seedling counter on seedlings sown in a band with nonprecision seeders. Due to the configuration of the counter machinery, seedlings must be at least 2 millimeters in diameter and 2 inches in height to be counted (Figure 3). Seedlings up to 2 feet tall can be counted.

Originally three seedling counters were constructed. One was delivered to the W.W. Ashe Nursery at Brooklyn, Mississippi, in the fall of 1988. Another was delivered to the Lucky Peak Nursery in Boise, Idaho, in the spring of 1990. The third has been used for trials and demonstrations by MTDC personnel. Six additional seedling counters have been constructed by MTDC in fiscal year 1992 for Federal forest tree nurseries.

This report describes field tests conducted by MTDC during 1990 and 1991.

Counting Procedures

The seedling counter uses a plane of infrared light to count seedlings. As the seedling counter passes the length of the bed, it counts the seedlings in a single drill row. The inventory of the seedlings in the lot can be estimated from one or more drill row counts.

Figure 1.—MTDC seedling counter.

Figure 2.—Portable computer and optoelectronics count seedlings.

Figure 3.—Seedlings must be 2 in. high and 2 mm in diameter to be counted.

Before counting seedlings, the seedling counter must be calibrated. During the calibration process, the length, width, and vertical position of the infrared beam is adjusted to provide the most accurate count of the seedlings in a 20- to 30-foot length of drill row. A slight (less than 3 percent) undercount is usually preferred. The seedling counter must be calibrated for each species and size of species to be counted.

The seedling counter has two skids. The skid marked "small" has a 1-millimeter-wide beam with five light segments. The skid marked "large" has a 2-millimeter-wide beam with six light segments. Each segment is 0.2 inch tall.

The large skid counts the 2-0 stock, transplants, and some large 1-0 stock. The small skid counts mostly 1-0 stock and smaller 2-0 stock. Seedling separators on the front of the skid help the operator distinguish drill rows in bushy stock. The separators will accommodate seedling rows sown on 6-inch centers in bandwidths to a maximum of 2 inches.

Field Tests

In September 1990, MTDC's Dave Gasvoda and Diane Herzberg demonstrated the seedling counter at Bend, Humboldt, and Placerville Nurseries to show how it can automate the inventory process. The seedling counter inventories and the corresponding hand (gross) inventories for each bed or lot counted are compared in Tables 1 and 2. Table 1 groups this information by species. Table 2 groups this information by nursery.

Bend Pine Nursery, Bend, Oregon

At Bend Pine Nursery the counter was used to inventory 1-0 and 2-0 ponderosa pine and 2-0 lodgepole pine. The discrepancy between the nursery inventories and estimated inventories obtained with the seedling counter was about 15 percent for the 1-0 and 2-0 ponderosa pine. The discrepancy was less than 9 percent for the 2-0 lodgepole pine inventories.

Sand castling, where the irrigation sprinklers washed soil into mounds around the seedlings, made it difficult to count the 1-0 ponderosa pine. Sand castling makes it difficult to find a height for the light beam above the sand castle, but not above the shorter trees. Sand castling could be reduced or eliminated by using different irrigation techniques or using Geo-Tech[R]. With this change, over 90 percent accuracy could have probably been obtained. In the 2-0 ponderosa pine, there was a significant number of short seedlings (3 inches and smaller). If these were not included during the calibration (because they would no doubt be culled), the seedling counter would have likely produced an inventory number more comparable to the hand-counted inventories. The 2-0 ponderosa pine was counted with over 90 percent accuracy when the small seedlings that are routinely culled were not included in the hand-count. The 2-0 lodgepole was counted with over 90 percent accuracy.

Humboldt Nursery, McKinleyville, California

At Humboldt Nursery the counter was used to inventory 1-0 and 2-0 Douglas-fir. The large skid worked well for counting 2-0 Douglas-fir, and the small skid worked well on the 1-0 Douglas-fir; however, some difficulties were encountered. For the 1-0 Douglas-fir, two machine inventories were considerably lower than the hand inventories, probably because of the large variation of the stem diameters. The calibration was done in locations comprised of mostly large caliper seedlings, but these lots also had a substantial number of small caliper seedlings. It would be fairly difficult to calibrate for the size variation, but the size difference could be minimized by counting the trees earlier in the season while the trees are more uniform. For the 1-0 Douglas-fir, over 85 percent accuracy was obtained. The 2-0 Douglas-fir were very tall and bushy, over 24 inches in places, which made it difficult for the skid to go down a row without running over the branches and pushing the seedlings down. A path breaker was developed to eliminate this problem. Also, the seedling would raise the front end of the skid, and it was very difficult to tell when the skid was centered in the row.

Table 1.—MTDC seedling counter 1990 results by species.

Species	Date 1990	Place	ID	Nursery Inventory (M)	Counter Inventory (M)	Percent Diff.	SkidSize: Segments
1-0 PP	9/11	Bend Pine	1662	141,900	118,834	-16.0	S:2-5
	9/17	Placerville	1829-02	11,100	12,254	10.0	S:2-4
	9/17	Placerville	2834-02	26,900	26,654	-0.9	S:2-4
	9/17	Placerville	2188-02	2,300	1,971	-14.0	S:2-4
	9/17	Placerville	3081-02	16,300	17,183	5.0	S:2-4
1-0 DF	9/13	Humboldt	I-27-4	7,700	7,602	1.2	S:1-4
	9/13	Humboldt	J-24-5	40,340	28,186	-30.0	S:1-4
	9/13	Humbodlt	C-14-5	55,001	44,890	-18.0	S:1-4
2-0 PP	9/11	Bend Pine	0766	142,250	120,368	-15.0	L:1-3
2-0 DF	9/13	Humboldt	K-10-3	39,400	41,487	5.0	L:1-4
	9/13	Humboldt	K-10-3	39,400	36,762	-7.0	L:1-4
	9/17	Placerville	606-91	10,300	6,315	-39.0	L:1-4
	9/17	Placerville	608-91	18,600	16,330	-12.0	L:1-5
	9/17	Placerville	605-91	18,500	20,511	10.9	L:1-5
2-0 LPP	9/11	Bend Pine	2023	44,900	48,989	9.0	L:1-3
2-0 JP	9/17	Placerville	2895*91	6,800	6,764	-0.5	L:1-4

Table 2.—MTDC seedling counter 1990 results by nursery.

Species	Date 1990	Place	ID	Nursery Inventory (M)	Counter Inventory (M)	Percent Diff.	SkidSize: Segments
1-0 PP	9/11	Bend Pine	1682	141,900	118,834	-16.0	S:2-5
2-0 PP	9/11	Bend Pine	0766	142,250	120,368	-15.0	L:1-3
2-0 LPP	9/11	Bend Pine	2023	44,900	48,989	9.0	L:1-3
1-0 DF	9/13	Humboldt	I-27-4	7,700	7,602	1.2	S:1-4
	9/13	Humboldt	J-24-5	40,340	28,186	-30.0	S:1-4
	9/13	Humboldt	C-14-5	55,001	44,890	-18.0	S:1-4
2-0 DF	9/13	Humboldt	K-10-3	39,400	41,487	5.0	L:1-4
	9/13	Humboldt	K-10-3	39,400	36,762	-7.0	L:1-4
1-0 PP	9/17	Placerville	1829-02	11,100	12,254	10.0	S:2-4
	9/17	Placerville	2834-02	26,900	26,654	-0.9	S:2-4
	9/17	Placerville	2188-02	2,300	1,971	-14.0	S:2-4
	9/17	Placerville	3081-02	16,300	17,183	5.0	S:2-4
2-0 DF	9/17	Placerville	606-91	10,300	6,315	-39.0	L:1-5
	9/17	Placerville	608-91	18,600	16,330	-12.0	L:1-5
	9/17	Placerville	605-91	18,500	20,511	11.0	L:1-5
2-0 JP	9/17	Placerville	2895*91	6,800	6,764	-0 5	L:1-4

Placerville Nursery, Camino, California

At Placerville the counter was used to inventory 1-0 ponderosa pine, 2-0 Douglas-fir, and 2-0 Jeffrey pine. The small skid worked well for counting the 1-0 ponderosa pine. The large skid worked well for the 2-0 Douglas-fir and very well for the 2-0 Jeffrey pine. The extreme slopes and sidehills at this nursery were not difficult for the seedling counter.

There were some large differences between the nursery inventories and the counter inventories. The 1-0 ponderosa pine and 2-0 Douglas-fir beds had not been weeded before the machine counting. The accuracy of the seedling counter was erratic, discrepancies between the inventories ranging from 1 to 39 percent.

Often, when the skid encountered a weed, the weed would roll the trees over, which caused them to lean forward. With the trees leaning forward, the infrared beam would produce false counts and detect unrealistically large calipers. Only two of eight rows in the bed were counted; thus, any error in the count due to a weed was magnified four times. On small lots, this error can be a significant percentage of the total inventory. This is supported by the results. The small 1-0 ponderosa pine and the small 2-0 Douglas-fir had fairly high discrepancies. As the lot sizes increased, the errors decreased. It would be advantageous to count more rows of the bed in the smaller lots.

The 2-0 Jeffrey pine lot resulted in the most accurate inventory at any of the nurseries (99 percent accuracy). Bed conditions were ideal, the trees were approximately 7 inches tall, and there was little variation in height or caliper. These conditions permitted a calibration to be obtained and higher accuracy resulted.

J. Herbert Stone Nursery, Central Point, Oregon

In July 1991, MTDC's Diane Herzberg and Neal Maier demonstrated the seedling counter at the J. Herbert Stone and Wind River Nurseries. MTDC added seedling separators to the front of the machine to help the operator distinguish between drill rows in bushy stock. Tables 3 and 4 compare seedling counter inventories with hand (gross) inventories for each bed or lot.

Before MTDC's visit, nursery personnel at J. Herbert Stone made a 100-percent hand-count of the seedlings in one drill row of each bed or lot to be counted with the seedling counter. The counts obtained with the seedling counter were compared with the hand-counts. In addition, the nursery personnel had determined the gross inventory of each bed or lot using their traditional hand-sampling method. The estimated inventories obtained with the seedling counter were compared to the gross inventories obtained by the hand-sampling method.

The seedling counter did well in most of the species and sizes of seedlings counted (Figure 4). The drill row counts obtained with the seedling counter compared within +2.5 percent of the corresponding hand-count for all species except ponderosa pine.

The seedling counter was used to count 1-0 and 2-0 ponderosa pine, 2-0 lodgepole pine, 1-1 and 2-0 Douglas-fir, and 2-0 Jeffrey pine.

Table 3.—MTDC seedling counter 1991 results by species.

Species	Date 1991	Place	ID	Nursery Inventory (M)	Counter Inventory (M)	Percent Diff.	SkidSize: Segments
1-0 NF	30-Jul-92	Wind River	606-07	44.9	59.2	31.9	S:4-5
1-0 PP	26-Jul-91	J.H. Stone	065-1 (LD)	4.4	4.0	-9.1	S:3-5
1-0 PP	26-Jul-91	J.H. Stone	065-1 (HD)	20.7	19.8	-4.3	S:3-5
1-0 PP	26-Jul-91	J.H. Stone	065-1 (LD)	4.4	4.2	-4.5	S:3-5
1-0 PP	30-Jul-92	Wind River	616-02	23.8	21.0	-11.8	S:4-5
1-1 DF	25-Jul-91	J.H. Stone	881	102.9	104.1	1.2	L:4-6
1-1 DF	25-Jul-91	J.H. Stone	876	56.4	51.9	-8.0	L:4-6
2-0 DF	24-Jul-91	J.H. Stone	441	28.1	29.8	6.0	L:1-5
2-0 DF	24-Jul-91	J.H. Stone	441	28.1	24.2	-13.9	L:1-5
2-0 DF	30-Jul-92	Wind River	605-04	10.5	11.0	4.8	L:3-4
2-0 DF	30-Jul-92	Wind River	606-01	11.0	11.6	5.5	L:4-5
2-0 DF	31-Jul-92	Wind River	603-026	44.6	46.5	4.3	L:1-5
2-0 DF	31-Jul-92	Wind River	603-026	44.6	47.3	6.1	L:1-5
2-0 DF*	25-Jul-91	J.H. Stone	469	36.4	28.9	-20.7	L:1-5
2-0 JP	24-Jul-91	J.H. Stone	531	26.4	27.0	2.1	L:1-3
2-0 JP	24-Jul-91	J.H. Stone	531	26.4	26.8	1.5	L:1-3
2-0 LPP	24-Jul-91	J.H. Stone	672	12.2	11.9	-2.5	L:1-5
2-0 LPP	24-Jul-91	J.H. Stone	672	12.2	11.9	-2.5	L:1-5
2-0 LPP	31-Jul-92	Wind River	603-03	17.4	16.7	-4.0	L:1-6
2-0 PP	26-Jul-91	J.H. Stone	565-0	26.7	26.6	-0.4	L:3-6
2-0 PP	30-Jul-92	Wind River	617-02	6.7	5.6	-16.0	L:1-6
2-0 SF	30-Jul-92	Wind River	15-2	8.8	6.8	-22.8	L:1-6
2-0 WP	29-Jul-91	Wind River	618-03	27.8	30.3	9.0	S:3-5
2-0 DF	30-Jul-92	Wind River	616-04T	7.1	6.9	-3.5	L:4-6
2-0 ES	31-Jul-92	Wind River	603-04T	3.9	3.6	-7.0	L:3-6

** Tall Cultural Group*   *LD - Low Density*   *HD - High Density*

Table 4.—MTDC seedling counter 1991 results by nursery.

Species	Date 1991	Place	ID	Nursery Inventory (M)	Counter Inventory (M)	Percent Diff.	SkidSize: Segments
2-0 DF	24-Jul-91	J.H. Stone	441	28.1	24.2	-13.9	L:1-5
24 DF	24-Jul-91	J.H. Stone	441	28.1	29.8	6.0	L:1-5
2-0 JP	24-Jul-91	J.H. Stone	531	26.4	26.8	1.5	L:1-3
2-0 JP	24-Jul-91	J.H. Stone	531	26.4	27.0	2.1	L:1-3
2-0 LPP	24-Jul-91	J.H. Stone	672	12.2	11.9	-2.5	L:1-5
2-0 LPP	24-Jul-91	J.H. Stone	672	12.2	11.9	-2.5	L:1-5
1-1 DF	25-Jul-91	J.H. Stone	881	102.9	104.1	1.2	L:4-6
1-1 DF	25-Jul-91	J.H. Stone	876	56.4	51.9	-8.0	L:4-6
2-0 DF*	25-Jul-91	J.H. Stone	469	36.4	28.9	-20.7	L:1-5
1-0 PP	26-Jul-91	J.H. Stone	065-1 (LD)	4.4	4.0	-9.1	S:3-5
1-0 PP	26-Jul-91	J.H. Stone	065-1 (LD)	4.4	4.2	-4.5	S:3-5
1-0 PP	26-Jul-91	J.H. Stone	065-1 (HD)	20.7	19.8	-4.3	S:3-5
2-0 PP	26-Jul-91	J.H. Stone	565-0	26.7	26.6	-0.4	L:3-6
2-0 WP	29-Jul-91	Wind River	618-03	27.8	30.3	9.0	S:3-5
1-0 NF	30-Jul-92	Wind River	606-07	44.9	59.2	31.9	S:4-5
1-0 PP	30-Jul-92	Wind River	616-02	23.8	21.0	-11.8	S:4-5
2-0 DF	30-Jul-92	Wind River	605-04	10.5	11.0	4.8	L:3-4
2-0 DF	30-Jul-92	Wind River	606-01	11.0	11.6	5.5	L:4-5
2-0 PP	30-Jul-92	Wind River	617-02	6.7	5.6	-16.0	L:1-6
2-0 SF	30-Jul-92	Wind River	15-2	8.8	6.8	-22.8	L:1-6
2-0 DF	30-Jul-92	Wind River	616-04T	7.1	6.9	-3.5	L:4-6
2-0 DF	31-Jul-92	Wind River	603-026	44.6	46.5	4.3	L:1-5
2-0 DF	31-Jul-92	Wind River	603-026	44.6	47.3	6.1	L:1-5
2-0 LPP	31-Jul-92	Wind River	603-03	17.4	16.7	-4.0	L:1-6
2-0 ES	31-Jul-92	Wind River	603-04T	3.9	3.6	-7.0	L:3-6

**Tall Cultural Group* *LD – Low Density* *HD – High Density*

Figure 4.—Successful counting of most species and sizes of seedlings.

The 1-0 ponderosa pine provided the most challenge for the seedling counter. These seedlings were 3/4 to 2 inches tall and the bed had a soft layer of mulch on top. There were two portions to this lot — one portion had a density of approximately 20 trees/square foot; the other portion had a density of approximately 10 trees/square foot. The seedling counter undercounted the lower density portion by 5.8 percent. This error could be reduced by counting the seedlings a month later in the season when they are likely to be at least 2 millimeters in diameter and 2 inches high.

Estimated inventories for 1-0 ponderosa pine, 2-0 lodgepole pine, 2-0 Jeffrey pine, and 2-0 ponderosa pine were within 5 percent of the nursery's gross inventories. The count of the lot of 2-0 lodgepole pine was repeated to test the repeatability of the seedling counter. The estimated inventory in both cases was 2.5 percent under the nursery's gross inventory. The test showed that the seedling counter can be repeatable and accurate.

The estimated inventory of one lot of the 1-1 Douglas-fir transplants differed by 8 percent from the nursery inventory. This can be reduced by selecting a different row to count in each bed. This was done in the second 1-1

Douglas-fir lot, in which one row in each of the six beds was counted. The six rows were a mixture of inside and outside rows of the bed. The difference in inventories for this lot was an acceptable 1.2 percent.

The greatest differences occurred in the tall, cultural 2-0 Douglas-fir. This was an impromptu test. A drill row had not been pre-counted, and 1991 inventory data were not available. Comparison of the estimated inventory with the 1990 gross inventory resulted in a 20.7 percent difference. The calibration produced counts of 106 and 103 on a sample of 104 seedlings. Two rows of the 430-foot bed were counted. The row counts were 3,926 and 3,327. These counts indicate respective tree densities of 9.1 and 7.7 trees per lineal foot of drill row. Random 1-foot hand-samplings of the drill rows produced nine trees per lineal foot of drill row. The drill rows were not recounted because insufficient tractor clearance might have damaged the trees.

In the lower density portion of the 1-0 ponderosa pine, a 9.1 percent discrepancy resulted between inventories. The drill row count was within 2.5 percent of the 100 percent hand-sampling. Counting more rows and counting these trees later in the season would probably reduce the difference. Even a small inaccuracy in counting only one row can be quite significant in a small lot. At the time of counting, the trees were taxing the physical limitations of the skid because they were from 3/4-inch to 2 inches in height. Waiting 2 to 4 weeks before counting these trees would improve counting accuracy.

Two counts of the 2-0 Douglas-fir produced estimated inventories 6 percent over and 13.9 percent under the nursery's gross inventory. On the first count, the operator crossed over from row number 3 to row number 4. On the second count, only row number 3 was counted. The count of row number 3 produced a count that was within 2.5 percent of the hand-sample. The high and low estimated inventories indicate a wide variation of seedling density between rows. The difference in the inventory numbers could be reduced by counting more rows. For example, the estimated inventory based on the composite of the two runs was 27,000, which is within 4 percent of the nursery's gross inventory of 28,100.

The 2-0 ponderosa pine provided an example of how varying row densities can affect the estimated inventory. The drill row count was within 2.5 percent of the hand-count. The estimated inventory based on one or two row samplings differed by over 20 percent. By counting every row of the lot, the seedling counter inventory differed from the nursery inventory by -0.4 percent.

The seedling counter must be calibrated just before counting a particular size and type of species. During the calibration process, the length and width of the infrared beam is adjusted to obtain the most accurate count of the seedlings in a 20- to 30-foot portion of a drill row, or a sampling of approximately 100 to 250 seedlings. Once the seedling counter is calibrated, many lots can be counted as long as the growth characteristics of the seedlings and bed conditions are similar to those of the calibration sampling.

Wind River Nursery, Carson, Washington

At Wind River Nursery, the seedling counter was used to count 1-0 ponderosa pine and noble fir; 2-0 ponderosa, white, and lodgepole pines; 2-0 Douglas- and Shasta firs; and 2-1 Douglas-fir and Engelmann spruce.

During MTDC's visit to the nursery, bed conditions were not ideal. Many of the 2-0 beds had recently been pruned vertically or brush cultivated, resulting in clumps of soil on the bed surface. In addition to the unsuitable bed surface conditions, the beds were extremely weedy. The counter cannot distinguish a green, healthy seedling from a brown seedling, weed, or marking stake.

The best results were obtained in the 2-0 ponderosa pine, 2-1 Douglas-fir, and the 2-0 Douglas-fir. Estimated inventories for the 2-0 lodgepole pine and the 1-1 Douglas-fir were within 4 percent of the gross inventories. Estimated inventories of three lots of 2-0 Douglas-fir were within 4.3 to 6.1 percent of the gross inventories. One lot of 2-0 Douglas-fir was counted twice. The two estimated inventories differed from the gross inventory by 6.1 percent and 4.3 percent. This indicates the seedling counter was counting consistently.

The seedling counter also did well in the 2-1 Engelmann spruce. The estimated inventory, which was within 7 percent of the gross inventory, was based on the average of four counts of the same drill row. All the weeds were pulled from the drill row before counting. This bed tested the capability of the seedling counter on sloping terrain. The bed had an initial 5 percent downgrade, an intermediate flat spot, and a final 2 percent upgrade.

Direction of travel while counting on sloping terrain appeared to affect the count. A southbound direction of travel produced counts that were consistently higher than the counts obtained in a northbound direction. On level terrain, the main stems of the trees are fairly perpendicular to the bed surface. The skid was designed so the light beam would remain perpendicular to the bed surface as it is pulled down the bed. On sloping terrain the tree stems grow at a slight angle with respect to the bed surface. To keep the light beam aligned with the tree stems during counting, the operator would tilt the skid backward or forward slightly with a foot or hand. Tilting the skid and counting more rows in both directions of travel should produce reasonably accurate counts on sloping terrain.

The seedling counter was difficult to calibrate on a bed with more than a 2-percent grade. This was probably due to the "lean" of the trees with respect to the bed surface. Calibration had to be performed on a level portion of the bed.

The estimated inventory of the 2-0 white pine was within 9 percent of the gross inventory. The seedling counter was calibrated within 3 percent and four rows were counted. A small error in the hand-count might have contributed to the slightly high discrepancy between the inventories.

Bed conditions were not ideal in the 2-0 Shasta fir or the 2-0 ponderosa pine. Both lots had many fairly mature weeds. The seedling counter was purposely calibrated low (17 percent) in the 2-0 Shasta fir to exclude the weeds from the count. As a result, the estimated inventory differed from the gross inventory by -22.8 percent. This difference might also be influenced by the variation in drill row density. The adjusted counts of the two drill rows counted were 743 and 952. The inaccuracy obtained in the two rows could be magnified four times in the estimated inventory. In the 2-0 ponderosa pine, the seedling counter was calibrated within 3 percent. The estimated inventory and the gross inventory differed by 16.4 percent. The row density appeared fairly consistent across the four rows counted. The discrepancy between the estimated and gross inventories was lower than that for the 2-0 Shasta fir. Some of the difference might be from inaccurate hand-counts.

The 1-0 ponderosa pine and the 1-0 noble fir were too small for the seedling counter to count. The seedling counter was marginally successful in the 1-0 ponderosa pine. It was calibrated within 4 percent using two beam segments. Even so, the inventory was underestimated by 11.8 percent. The seedling counter was not at all successful in the 2-0 noble fir. The best calibration factor obtained was 44 percent using two beam segments. This resulted in a 32 percent difference between the estimated and gross inventories. Only two rows of the bed were counted. Counting more rows of the bed would probably not help reduce the error as much as counting the trees later in the inventory season.

Conclusions

Field testing has shown that the MTDC seedling counter can automate the seedling inventory process and should perform well in most pine and fir stock.

Nurseries will have to coordinate their inventory with their cultural practices. Beds should be weeded and dry for best results, and the bed surface should be free from disturbance by vertical pruning or brushing.

Some experimentation may be necessary to find the best technique to eliminate the influences of sloping beds.

Comparing the accuracies obtained by MTDC in 1990 and those in 1991 is evidence that user experience is a factor in obtaining consistently acceptable accuracies with the seedling counter.

In general, the best approach to obtain confident results with the seedling counter is timing the inventory to count the seedlings when they are within the size limits of the machine. This is more important with the very large, very small, or very bushy stock. It is advisable to start the inventory in the taller bushy stock. The rest of the 2-0 stock and the larger 1-0 stock should be counted next. The small 1-0 stock should be counted last. Nurseries should duplicate the seedling counter inventories with the traditional inventory process until confidence in the machine and its operator is established.

MTDC will continue to test and make appropriate modifications to ensure the efficiency of the counter.

Drawings, an operator's manual, a complete report on counter field tests, and a video may be requested from:

USDA Forest Service
Missoula Technology and Development Center
Building 1, Fort Missoula
Missoula, MT 59801

For information on the seedling counter, contact Dave Gasvoda, Project Leader, (406) 329-3986.

Have Some Fun While Learning (and Teaching)

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Southern Region

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Construction Engineer
Southern Region

Introduction

We established several objectives for the Southern Region's Basic Construction Engineering Workshop, held May 4 – 8, 1992, but overall we wanted to use innovative teaching to make learning as painless as possible — even fun. By curtailing boring lecture and getting the participants involved, we hoped to create enthusiasm for the subject material, in other words, HAVE SOME FUN WHILE LEARNING! A by-product of this teaching process is the sharing of firsthand experiences. The objectives were:

(1) Teach technical material for basic contract administration/inspection; construction engineering, sampling, and testing; and some basic design.

(2) Help prepare the participants for the construction certification exams.

(3) Provide an understanding of the two primary contract methods of constructing roads in the Forest Service.

(4) Review the administration procedures involved in the contracts.

(5) Review the construction engineering responsibilities in attaining compliance with commonly used construction specifications.

Innovative Techniques

Here are a few samples of what we did:

(1) Got several forest folks involved with presentations and used case studies and practical examples.

(2) Brought in some industry folks to speak firsthand about manufacturing of construction materials, quality control, and certification.

(3) Took a field trip to a culvert manufacturing plant (Figure 1), timber fabricating and treatment facility, and concrete batch plant.

(4) Used an exercise in desk nameplate construction to illustrate differences between method and end product specifications (Figure 2). For this exercise, the participants divided into three groups and worked in

Figure 1.—Field trip—coating culvert with asphalt.

Figure 2.—Desk nameplate exercise.

pairs. Each group was given one of three specifications with which to comply. They compared and discussed the final product and time (cost) and asked the question, "Was the improved quality of the finished product worth the additional cost?"

(5) Presented a skit, "Why Inspectors Get Gray." This was an exercise to familiarize students with Federal Acquisition Regulations (FAR's) references.

(6) Held a mock construction certification panel, complete with prearranged questions and a "real live" panel and inspector. The students were on the edges of their seats for this one.

(7) Held a construction engineering scavenger hunt (Figures 3 and 4). This competition for prizes really got the students into the subject matter, including contract administration, specifications, sampling and testing guide, and basic math.

(8) Used field and lab exercises for teaching basic design.

(9) Used four quizzes as teaching tools, not strictly as tests.

(10) Participants learned the importance of documentation and (by the hands-on method) how to organize the public works contract and timber sale contract administration folders into six sections.

This preparation required a lot of hard work. It took more than 40-hour weeks, but it paid off.

Some quotes from the critiques:

The workshop has been fun and a learning experience.
A lot more lively than last year.
One of the best sessions I've been to.
Thanks for a fun week full of learning opportunities.
Good idea of scavenger hunt.
The mock panel was very, very useful in letting me know what to expect.

The Skit

To illustrate the techniques used, we are providing part of the skit, "Why Inspectors Get Gray," an exercise to familiarize students with FAR references. The skit consisted of three acts, and, at the end of each act, the students were asked to furnish the FAR reference and paraphrase. What follows are excerpts from the skit, along with teaching points, FAR references, and paraphrases.

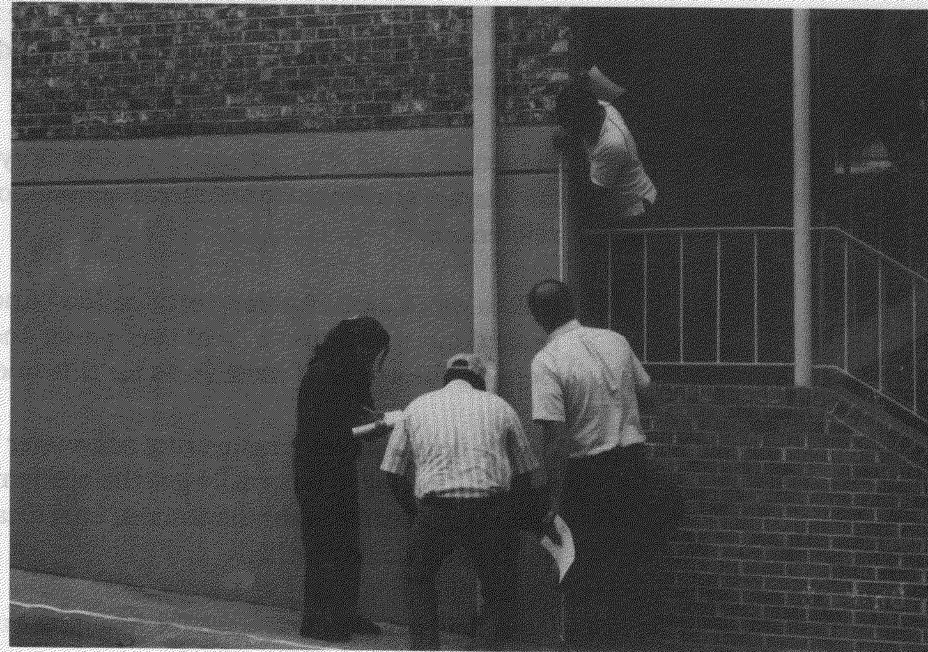

Figure 3.—Scavenger hunt—measuring for problem 1.

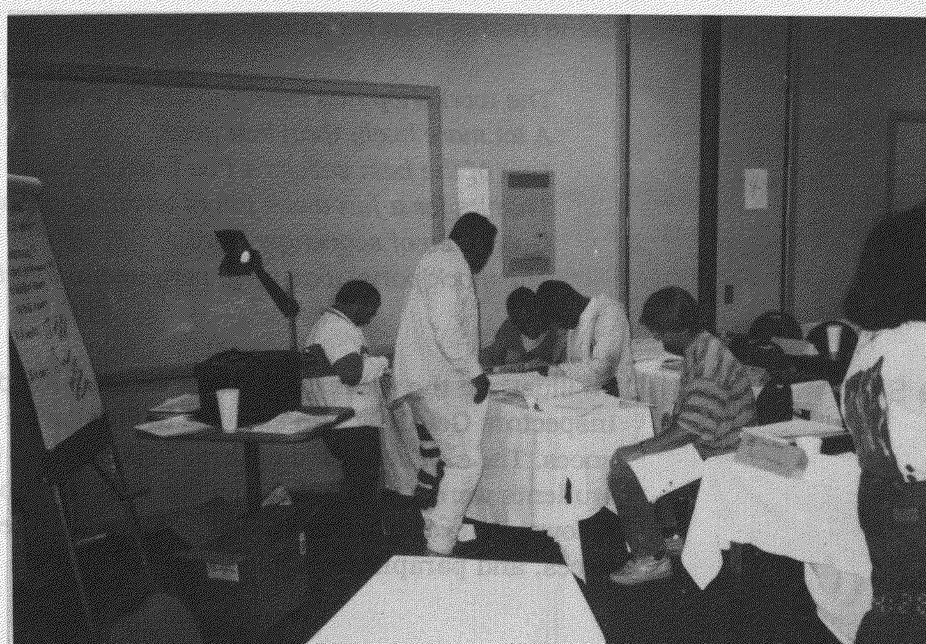

Figure 4.—Scavenger hunt—classroom.

Inspector's Statement	*Contractor's Response*	*FAR Reference*
Do you have the specs?	I don't wear glasses.	52.236-21 Specs and Drawings for Construction
Contractor must keep specs on project site.		
You are responsible for the stakes.	Do you want yours rare or well done?	52.236-17 Layout of Work
Contractor must preserve all stakes.		
Why are you furnishing Japanese culvert?	The price is right.	52.225-5 Buy American Act
Contractor must furnish American made unless designer specifies otherwise.		
I need the certification for these culverts.	Just wait a minute. I have a drawer full.	452.236-76 Samples and Certificates
Certificates shall be submitted as required by contract.		
I'm going to shut you down because of imminent danger.	I divorced Emmy a long time ago.	52.236-13 Accident Prevention
Contractor must maintain a safe work area. CO may stop all or part of work.		

Scavenger Hunt

To illustrate the techniques used, we are providing the Scavenger Hunt in this article. The point scoring scheme, with team results, is also given.

SCAVENGER HUNT

FOLLOW THE INSTRUCTIONS. THE TEAM THAT FINISHES ON TIME WITH THE MOST POINTS WINS TEE SHIRTS.

TEAM ____________ START ______ END ______ TOTAL PTS. ______

(1) From the entrance of the Peachtree Building, proceed northwest 125 feet to a right triangle formed on the tan foundation wall (bounded by the sidewalk, brick, and stairwell). Assume this is structural concrete and must be cured. How many gallons of curing compound must the contractor order (Figure 3)? 25 POINTS Reference? 5 POINTS

Answer: *Reference:*

If one bag of dry stucco covers 9 square yards after mixing, how many bags must the contractor order to cover the triangle? 10 POINTS

Answer:

What is the grade on the sidewalk at the right triangle, in percent (nearest tenth) and degrees (nearest minute)? 10 POINTS EACH

Answer:

(2) Using Spec. 552, does the north column below the parking deck meet specifications? Why? 20 POINTS Reference? 5 POINTS

Answer: *Reference:*

Estimate the volume (nearest cubic yard) of concrete in the column. 20 POINTS

Answer:

(3) Go up to the next floor. Are the steps at the east end of the building acceptable? Why? 5 POINTS Reference? 5 POINTS

Answer: *Reference:*

What is the measurement (tenths of a foot) to the southeast from the defective step to the center weephole in the curb? 5 POINTS In tenths of a meter? 5 POINTS Bring back the document with the highest number of points shown. 1–6 POINTS

Answer:

(4) East of the pool, locate an "X" in the pavement. Does the roadbed width (curb to curb) meet Tolerance A for 24-foot-wide pavement? 5 POINTS Reference? 5 POINTS

Answer: *Reference:*

From the top of the fire hydrant, measure 32.25 feet to the east, then measure 36.3 feet from a nail in the utility pole and intersect the first line. What instrument is buried there? 10 POINTS Rebury it. 5 POINTS

Answer:

For what is it used? 10 POINTS

Answer:

Find the NO PARKING sign between the pool and tennis court. What is the distance (feet and inches) from the base of the sign to the center of the street? 5 POINTS

Answer:

(5) Who approves the contractor's quality control plan (Figure 4)? 5 POINTS Reference? 5 POINTS

Answer: *Reference:*

(6) What is the pay item number that would be used for lump sum scattering of construction slash? 5 POINTS

Answer:

(7) Where in the timber sale contract do you find a list of applicable C(T) provisions? 5 POINTS

Answer:

(8) Are construction warning signs required for both Timber Sale and Public Works contracts? 5 POINTS What reference applies to both contracts? 5 POINTS

Answer: *Reference:*

What is the meaning of MUTCD? 5 POINTS

Answer:

(9) First team to finish gets 10 extra points.

MAXIMUM POINTS: 216

TIME ALLOWED: 1 HOUR, 20 MINUTES

SAFETY FIRST! WATCH FOR TRAFFIC WHEN OUTSIDE!

Team Results

Problem	*Points*	*Team* 1	2	3	4	5	6
(1)	25	–	25	–	–	10	25
	5	–	5	–	–	5	–
	10	–	–	–	–	10	–
	10	–	–	10	10	10	10
	10	–	–	–	10	–	–
(2)	20	10	–	–	10	–	–
	5	5	–	5	–	–	–
	20	–	–	–	20	20	–
(3)	5	5	5	5	5	–	3
	5	–	5	–	–	–	–
	5	5	5	5	5	–	–
	5	5	5	–	–	–	–
	1–6	5	6	3	–	–	4
(4)	5	5	5	5	5	5	5
	5	5	5	–	5	5	5
	10	10	10	10	10	–	10
	5	5	5	5	5	5	5
	10	–	10	10	–	10	10
	5	–	5	–	–	5	–
(5)	5	–	3	5	5	5	–
	5	–	–	5	5	5	–
(6)	5	–	5	5	5	5	–
(7)	5	5	5	5	5	5	5
(8)	5	5	5	5	5	5	5
	5	–	–	5	5	5	–
	5	5	5	5	5	5	5
(9)	10	–	10	–	–	–	–
	216	75	129	93	120	120	92

Conclusion

Learning does not have to be laborious and boring — neither does teaching. Making it interesting takes more preparation by the instructors, but we had fun; so did the participants, who had a quality learning experience. Because our workshop was so successful, we have shared this information in case someone would like to try all or part of it. We would be glad to discuss and assist you. Contact Gary or Les (DG addresses below).

Challenge

Using a base of 111.1 feet and a height of 8.75 feet, try your hand at computing the number of gallons in problem 1 of the Scavenger Hunt. Send your answer to Gary Murphy or Les Pence.

The DG addresses are: G.Murphy:R08B and L.Pence:R08B. A prize will be awarded for the first correct answer.

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