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Engineering Field Notes

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FOREST SERVICE—USDA
Engineering Staff—Washington Office
Attn: D.J. Carroll, Editor
M.J. Baggett, Editorial Assistant
P.O. Box 2417—Washington, D.C. 20013

Telephone: Area Code 703—235-8198

Technology Transfer in the Rocky Mountain Region

*Royal Ryser
Assistant Director of Engineering
Region 2*

REGIONAL TECHNOLOGY TRANSFER PLAN

Region 2 hosted an Engineering Program Review by the Washington Office in 1984, and one of the action items was to develop a Regional Technology Transfer (TT) Plan. We were transferring technology, but we had no structured plan and the effort was somewhat erratic.

We used the following criteria to develop a TT Plan:

- (1) It had to be inexpensive.
- (2) It could not be labor-intensive.
- (3) It had to be effective.

The plans we were aware of seemed more costly and labor-intensive than we could afford, although we envied their quality and utility. As we applied the criteria to various alternatives, it became apparent that, for Region 2, the integration of technology transfer as a part of our normal work was sufficient, efficient, and effective. We just needed to formalize it and ensure that all of the components were carried out.

The developed TT Plan consists of three components:

- (1) Engineering Computer Application Coordinator's Conference.
- (2) Regional Engineer's "Notes" to Forest Engineers and Group Leaders.
- (3) Functional Assistance Trip Reports.

Computer Conference System

The first component is a computer conference system, including a contact person (coordinator) at each design location in the Region. Coordinators communicate with each other individually and as a group.

The primary topics are engineering computer applications. The Regional Office coordinator assembles and distributes a monthly newsletter.

Notes From the
Director of
Engineering

The second component is the "Notes" that the Director of Engineering periodically prepares and sends to Forest Engineers and Group Leaders about once a month. The "articles" range from personnel actions to technical applications, and they are written by the Director, Assistant Directors, and Regional Office Group Leaders. If Forest personnel send in materials of general interest, they are included also.

Structured System for
Functional
Assistance Trips

The third component of the TT Plan is a structured system of actions related to functional assistance trips. Each Regional Office-Engineering traveler carries the "corporate word" to the Forests, trains his or her counterpart within the involved specialty, exchanges information with other line and staff personnel, and writes a report to the Director upon return to the Regional Office. The Director reviews the reports and forwards them to the Forest Supervisors with a cover letter pointing out particular items for emphasis.

In addition to implementing these three TT Plan components, we routinely distribute other Regions' technology transfer publications to the Forests and to Regional Office Group Leaders.

SUMMARY

Our TT Plan is less complex, costly, and sophisticated than some others, but it is quite adequate and, by nature, an integral part of our everyday work.

EFN

RTIP Update

INTRODUCTION

The purpose of the "RTIP Update" feature is to foster a greater awareness of the Road Technology Improvement Program (RTIP) objectives, status, and payoff.

It's your chance to get the word out about the RTIP and other efforts you've been involved with. By sharing your RTIP-related experiences with others, you can help the Forest Service manage its roads program more efficiently.

There are no length or format requirements for submissions to "RTIP Update," but we do need you to get involved.

RTIP 1, TECHNOLOGY TRANSFER

Issue 3--Communications, Action Item 1-3-1. The RTIP Bulletin Board has been in use continuously (24 hours a day, 7 days a week) since November 1985. From January 30, 1985, through September 18, 1986, the Bulletin Board handled about 1,360 calls, with a total of 229 individual users. Nearly 500 files and programs have been uploaded and downloaded from the Bulletin Board. The Bulletin Board also is receiving limited use by both the Federal Highway Administration and the Bureau of Land Management.

As part of the Bulletin Board's software dissemination function, 700 floppy diskettes containing public domain programs were distributed within the Forest Service. In July 1986, KERMIT file transfer protocol was added to the bulletin board in order to allow transfer of binary files over TELENET.

An evaluation of the usefulness of the Bulletin Board as a telecommunications system for fostering technology transfer within Engineering will be conducted in early fiscal year 1987.

RTIP 2, TOTAL COST
of ROADS

Issue 1--No Standard Process for Measuring and Displaying Road Costs. A work group has developed 19 factors that display various road program costs. These factors are all computed from data included in the Forest Road Program Report submitted by Regions to the Washington Office.

Regional Engineers were sent the formulas for these factors, along with a National Summary, by Region, based on fiscal year 1985 actual expenditures. The Regions were requested to review and comment on the factors and to propose 3 to 6 factors that they felt were most significant.

Regional comments were summarized and discussed at the RTIP 2 meeting in October 1986. Based on the review and discussions at the meeting, the work group will determine the factors to be used as well as revisions to the instructions for the Forest Road Program report.

The initial publication of the data, using the selected factors, will compare fiscal year 1985 to fiscal year 1986, based on the final Forest Road Program reports. A similar report will be issued at the close of each fiscal year in the future.

RTIP 3, ROAD
OPERATION &
MANAGEMENT

Issue 1--Road User Information, Action Item 3-1-2; and Issue 4--Lack of Understanding and Commitment by Vehicle Users Concerning Good Road and Off-road Use Practices, Action Item 3-4-4. Two questionnaires were prepared and sent to the Regions, requesting information on state-of-the-art techniques, nontraditional tools, and other opportunities for supplying road information to users and managing off-road vehicle use. While this effort produced some good insights, the results were somewhat limited; therefore, a technical report will not be developed, but perhaps an Engineering Field Notes article will be prepared. The results have been turned over to the Washington Office Engineering Road Operations and Maintenance Group for final disposition.

RTIP 4, AGGREGATE
BASE & SURFACING

Issue 5--Design Idea, Action Item 4-5-1. An article entitled "Aggregate Design Considerations" was published in the September-October 1986 issue of Engineering Field Notes. The "15 Ideas" have been incorporated in the latest draft revision to the Transportation Preconstruction Handbook, FSH 7709.56. The draft handbook was submitted to InS-Directives for review in October 1986.

RTIP 5, CLEARING &
GRUBBING

Issue 5--Determining the Long-Term Effects of Disposal Methods, Action Item 5-5-1. Data were collected from all Regions in Spring 1986. The information regarding burial of slash in fills was sent to the Regions by Ted Zealley's Washington Office Engineering 7100 letter dated July 31, 1986.

Action Item 5-5-2. The Washington Office was responsible for defining a process for monitoring the performance of fills where construction slash was intentionally incorporated in fills as part of the design process. The following team met in April 1986 to set up the process:

Ted Zealley, Washington Office Staff Engineer

Mike Cook, Forest Engineer, Nezperce National Forest, Region 1

Jim Baker, Forest Engineer, Salmon National Forest, Region 4

Ed Burroughs, Research Engineer, Intermountain Station

The monitoring process was sent to the Regions by the Acting Director of Engineering's 7100 letter dated May 13, 1986. Actual monitoring and use of the identified process are optional.

EFN

An Overview of the Federal Land Highways Coordinated Research & Development Program

*Chris Schwarzhoff
Civil Engineer
Washington Office Engineering*

The Federal Land Highways Coordinated Research and Development Program (CRDP) was implemented to carry out applied highway research needs of Federal land agencies and of the Federal Highway Administration (FHWA) Direct Federal Program. The passage of the Surface Transportation Assistance Act of 1982 (PL 97-424) established a coordinated Federal Lands Highway Program. One of the program components established an operational type research effort involving Federal land management agencies and the FHWA Direct Federal Programs Office. This program is entirely separate from the much larger National Research and Development activities of the FHWA; however, there is extensive coordination between the two. The CRDP annual budget is \$1 million.

A council was established to develop program policy, to review and approve project studies, and to ensure effective management and use of funds. The following are current council members:

Tom Edick, Office of Direct Federal FHWA

Harold Strickland, Forest Service

(Vacant), Park Service

Jim Ball, Bureau of Indian Affairs

Other agencies, such as the Bureau of Land Management, the Department of Defense, the Corps of Engineers, and the Federal Aviation Administration, also participate in, but are not voting members of, the council. The council has the following responsibilities:

- (1) Inventory existing, ongoing work of member agencies.

- (2) Review problem statements (see figure 1 for format) or other research proposals as candidates for the CRDP.
- (3) Approve and make revisions to the CRDP. Assign priorities for the approved program of work.
- (4) Suggest methods for accomplishing research work:
 - (a) Staff research by FHWA, a cooperating agency, or others.
 - (b) Contracted research by FHWA, cooperating agency, or others.
- (5) Coordinate CRDP, technology transfer, and technology development activities with member agencies, TT centers, and others.
- (6) Ensure timely accomplishment of council activities and revise CRDP policy as necessary.
- (7) Promote the timely implementation of successful research, technology transfer and technology development (TD) items, and, where appropriate, provide funding for project implementation and evaluation of TD and TT activities.

Title: (preferably 10 words or less)

Problem Statement:

Objective:

Degree of Urgency:

Submitter: Agency/Division
Name
FTS Telephone Number
Date

Figure 1.--Format for CRDP problem statements.

Figure 2 shows the overall process for carrying out the CRDP. The program currently has about a dozen ongoing projects; those of great interest to the Forest Service include the Central Tire Inflation (CTI) study, harsh slope revegetation, low-cost bridges, and soil nailing to stabilize unstable slopes.

We will ask the Regions for project proposals in early 1987; meanwhile, anyone may submit a proposal. If you have a topic you believe should be researched, you may submit it directly by Data General to C.Schwarzhoff:W01B or by entering a message in the Council for the CRDP (CTIP) conference on the RTIP Bulletin Board.

Identify and develop problem statements or proposals for CRDP

Perform applicable oversight/monitoring

Assemble problem statements and proposals

Perform program and budget coordination

Call for advisory council meeting

Review, select, and approve research and development projects

Establish fiscal year research and development approved program

Determine method and responsibilities for accomplishing work

Make CRDP policy changes or additions

Administer FHWA work

Monitor others' work

Seek consultation

Promote implementation of successful research and technology development

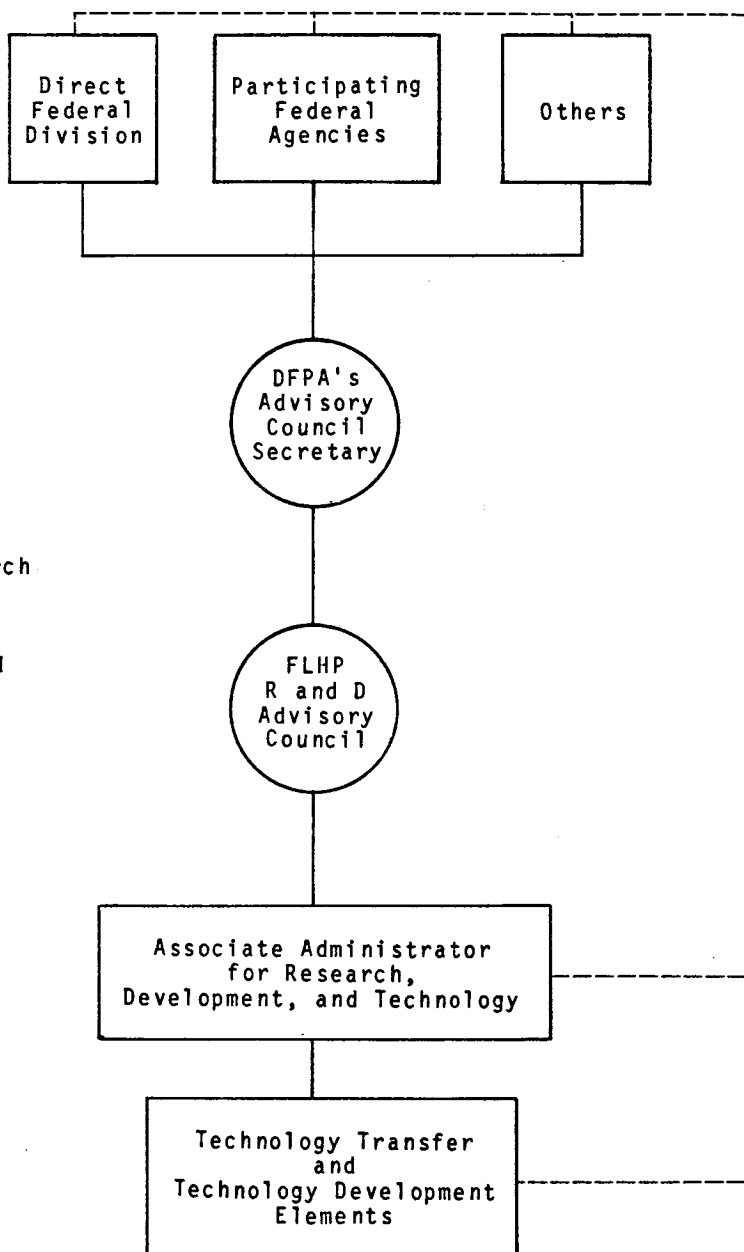


Figure 2.--Coordinated Federal Lands Highways Research.

Comparative Evaluation of Micro Road Design Software

Ted Zealley
Chief Transportation Preconstruction Engineer
Washington Office Engineering Staff

During the week of August 11, Washington Engineering sponsored an evaluation of PC-type road design software currently in use or readily available to the Forest Service. Following is a list of evaluation team members.

Frank Damaskos, Region 1 Regional Office

Frank Williams, Region 1, Kootenai National Forest

Margaret Bro, Region 2 Regional Office

Jerry Leonard, Region 2 Regional Office

Gordon Anderson, Region 6 Regional Office

Ron McCall, Region 8 Regional Office

Marty Hanson, Region 9 Regional Office

Bill Burtt, Bureau of Land Management, Denver Service Center

The following software and hardware was included in the evaluation.

<u>Software</u>	<u>Hardware</u>
FLRDS	HP9020
HANS_ON	HP150
LVRDS and LUMBERJACK (Alternattech)	IBM-AT, AT&T 6300, Tandy, and Compaq
ICAHD (Proper Engineering)	IBM-AT

The last two programs are commercial products.

The purpose of the evaluation was not to determine the best program, but to identify the capabilities of the various systems to enable future users to select software and hardware combinations that best fit their particular needs.

FLRDS is the most "mature" of the systems. However, it can be operated only on the HP9020.

HANS_ON and LUMBERJACK are roughly comparable. Their current features indicate that HANS_ON may be preferable, but it is limited to the HP150 hardware. LUMBERJACK will operate on IBM and IBM-compatible hardware. (LUMBERJACK was written by Bob Graham, a former Forest Service employee.)

LVRDS is an adaptation of earlier software. It is adequate for many situations, but not as capable as the three previously noted programs.

Interactive Computer Assisted Highway Design (ICAHD) is a software system more suitable for higher standard road designs than normally needed in the Forest Service. It is a capable system, but generally not suitable for our use.

Table 1 shows the results of the evaluation. More detailed information from the evaluation has been sent to each Regional Office.

Table 1.--Micro road design software features.

Features	LVRDS	HANS_ON	LUMBERJACK	FLRDS
<u>Preliminary Data</u>				
Deflection Angles	N	N	N	Y
External Angles (Right)	N	N	N	Y
Deflection Angles	N	N	N	Y
Quadrant Bearings	Y	Y	N	Y
Azimuth Bearings	Y	Y	Y	Y
Trav. Required	Y	N	Y/N	N
Profile Required	Y	N	N	N
Equations in P-line Trav.	N	N	Y	Y
Horizontal Distance	Y	Y	Y	Y
Slope and Horizontal Distance	Y	Y	Y	Y

Table 1. (cont.)--Micro road design software features.

Features	LVRDS	HANS_ON	LUMBERJACK	FLRDS
<u>Preliminary Data (cont.)</u>				
Slope and Slope Distance	Y	N	Y	Y
Percent Slope/Slope Distance				
Topography	Y	Y	Y	Y
Use of Turns in Topography	Y	N	Y	Y
Use of Same Slope Topography	N	N	N	N
More Than 5 Shots per Side	N	Y	N Total 10	Y
Sequence of Shots				
(L to R or CL Out)	L-R	L-R	L-R	L-R
Entry by Electronic Data				
Collectors	N	N	N	Y
<u>Earthwork</u>				
Batch Computation	Y	Y	Y	Y
Interactive Computation	N	Y	Y	Y
Horizontal Self Balance	Y	Y	Y	Y
Vertical Self Balance	Y	Y	Y	Y
Full Bench	Y	N	Y	Y
Auto Shift to Full Bench	N	N	N	N
Manual Offset				
(Vertical/Horizontal)	Y	Y	Y	Y
Stripping Depth	Y	Y	N	Y
Auto Slope Steepening	N	N	N	Y
Mass Ordinate	Y	Y	Y	Y
Unit Mass	N	N	N	N
Earthwork Balance Points	N	Y	Y	Y
Borrow and Waste Adjustments	Y	Y	Y	Y
Compaction Manual	Y	Y	Y	Y
Compaction Automatic	N	N	N	Y
Adjust Cut	Y	Y	Y	Y
Adjust Fill	N	N	N	Y
Slough Widening Choice	N	Y	Y	Y
Clearing	Y	Y	Y	Y
Seeding	Y	Y	Y	Y
Compute Station Yards Haul	Y	N	Y	Y
Fill Heights on Fills	N	N	N	Y
			Y/N "P"	
"L" Grade Between Stations	Y	N	Dist	Y
Calculate "L" Length	N	N	N	Y
Ditch Either or Both Sides	Y	Y	Y	Y

Table 1. (cont.)-- Micro road design software features.

Features	LVRDS	HANS_ON	LUMBERJACK	FLRDS
<u>Earthwork (cont.)</u>				
Calc Culvert Excavation				
During Earthwork	N	Y	N	N
Daylight Fill Side	Y	N	N	Y
Run Only Portion of Project	Y	Y	Y	Y
Program Uses Section No. s	Y	Y	Y	Y
Optional Subtotals for Segments	N	Y	N	Y
<u>Slope Stake Reference</u>				
To "P" Line	N	Y	N	Y
To Design Line	Y	N	Y	Y
To Specified Hinge Point	N	N	N	N
<u>Plots</u>				
Traverse P-Line	Y	Y	Y	Y
Traverse L-Line	Y	Y W/P	Y	Y
P-Line, L-Line With Offsets	N	Y	Y	Y
				(Tics)
Traverse Contour Plot	N	N	N	Y
P-Profile	Y	Y	Y	Y
L-Profile	Y	Y	Y	Y
X-Sections	Y	Y	Y	Y
X-Sections With Temp	Y	Y	Y	Y
Fed-Aid	N	N	Y	Y
Mass Diagram	Y	N	N	Y
Line Diagram	N	N	N	N
Interactive Graphics	N	Y	Y	Y
Partial Plot	Y	Y	Y	Y

EFN

A Plastic Ford—You've Got To Be Kidding

Lester M. Pence, Jr.
Civil Engineer
Region 8 Regional Office

INTRODUCTION

No, we aren't kidding--Region 8 has installed a plastic ford. We have been searching for ways to cut costs on Traffic Service Level D roads, and there is a new product on the market called "GEOWEB," manufactured by Presto Products, Incorporated. Figure 1 shows a diagram of GEOWEB with its specifications, and figures 2 through 9 show the sequence of construction for Region 8's plastic ford.

1. Expanded Dimension	8 ft x 20 ft x 8 or 4 in
2. Collapsed Dimension	11 ft x 5 in x 8 or 4 in
3. Panel Thickness Nominal	0.047 in
4. Weight	114 and 57 lbs
5. Cell Area	41 in ²
6. Cell Seam Node Pitch	13 in
7. Welds/Seam	7
8. Seams Tensile Peel Strength	300 lbs
9. Installation Temperature Range	-16 °F to 110 °F

Polymer Material:
High Density Polyethylene
Color: Black
Carbon Black Content: 2%
Chemical Resistance: Superior

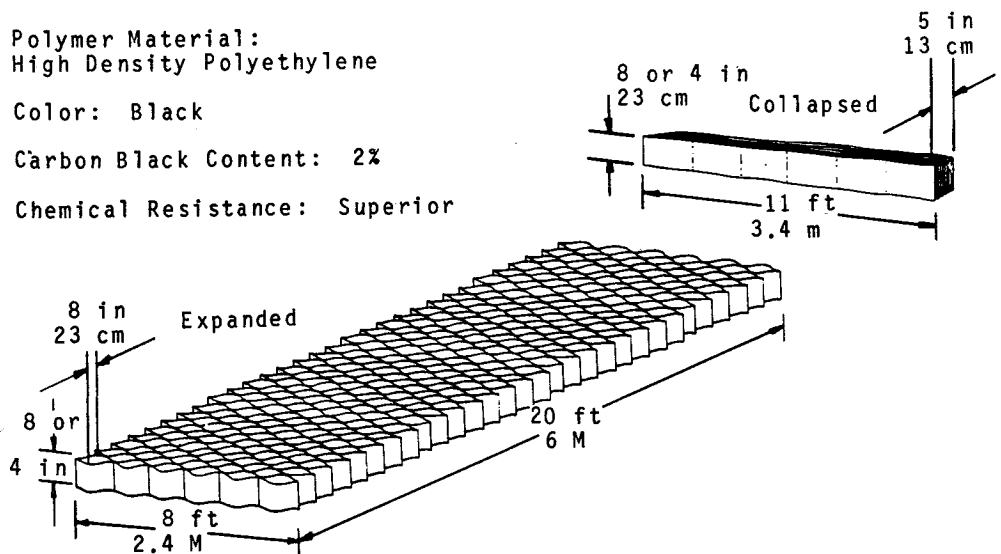


Figure 1.--Diagram of GEOWEB. (Diagram courtesy Presto Products, Inc., Appleton, WI.)

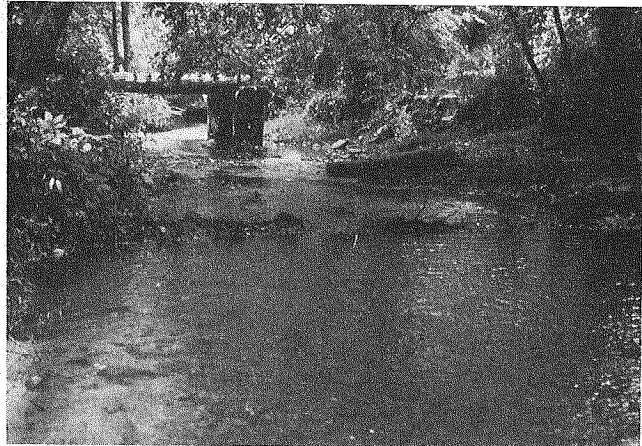


Figure 2.--Log stringer bridge to be replaced.

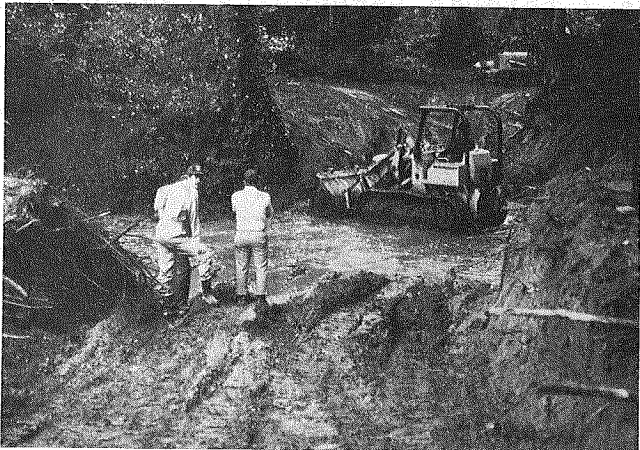


Figure 3.--Excavating the site.

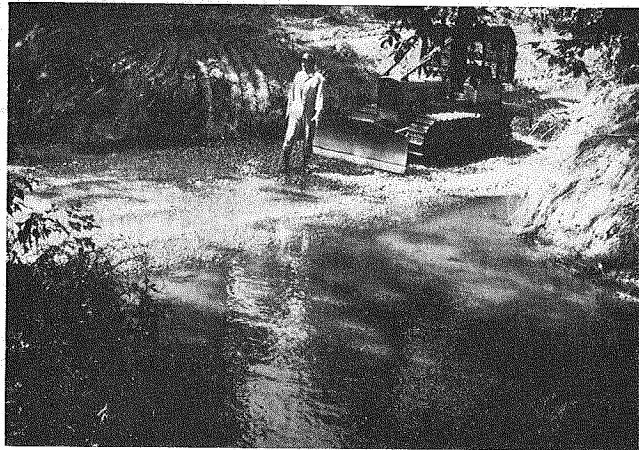


Figure 4.--The excavated site.

PROPOSED SYSTEM

To install this type of proposed system, place an 8-inch thick polymer GEOWEB grid confinement system on geotextile. Fill the grid with crushed aggregate, sand, or creek gravel. Top with a 2-inch minimum depth of the same material to provide a protective coating; approximately 6 inches would provide additional protection for consolidation of aggregate under traffic.

OTHER FORD OPTIONS

Normally, an 8-inch deep by 14-foot wide mesh reinforced concrete ford, possibly with an aggregate foundation, would be placed at this location. Depending on site conditions, the cost of a concrete ford in Region 8 ranges from \$6,000 to \$12,000.

SITE DATA

The ford is located on Road Number C0702 on the Chattahoochee-Oconee National Forests in north Georgia. It replaced a log stringer bridge. The GEOWEB ford is 16 feet wide by 40 feet long. The GEOWEB cells were filled and topped with a coarse aggregate.

GEOWEB FORD COSTS

The GEOWEB ford was installed by a force account for \$1,900. The GEOWEB and underlying geotextile (nonwoven Trivera 1127) were donated by industry manufacturers. The geotextile was used to separate the GEOWEB and aggregate from the underlying sandy clay soil. The estimated value of these materials is \$864 plus shipping, which would have made the total



Figure 5.--Materials for plastic ford.



Figure 6.--Installing geotextile (Trivera 1127, nonwoven).

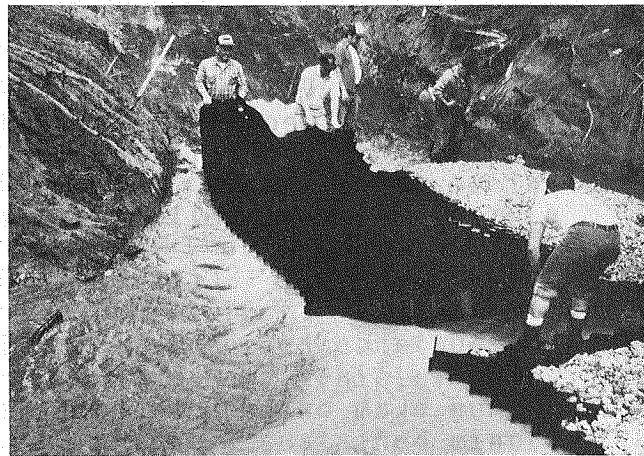


Figure 7.--Installing GEOWEB.

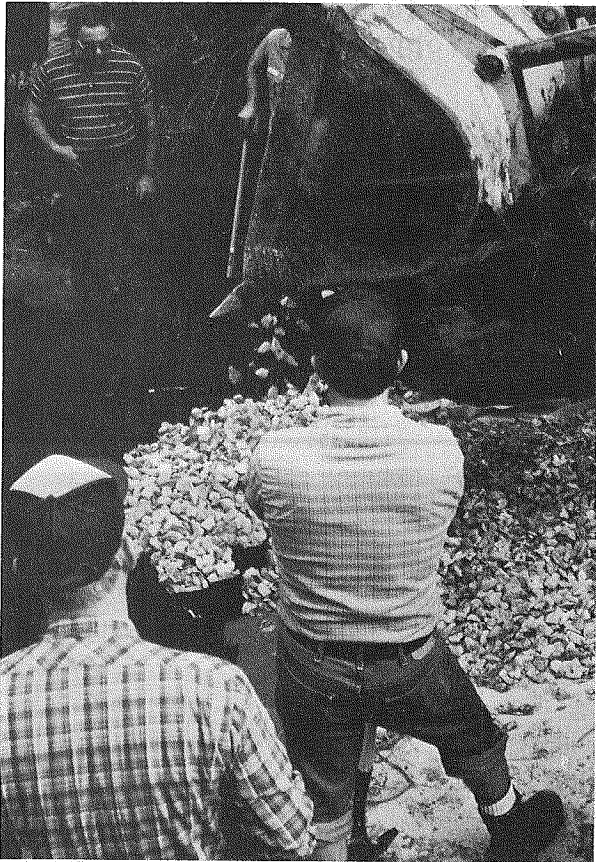
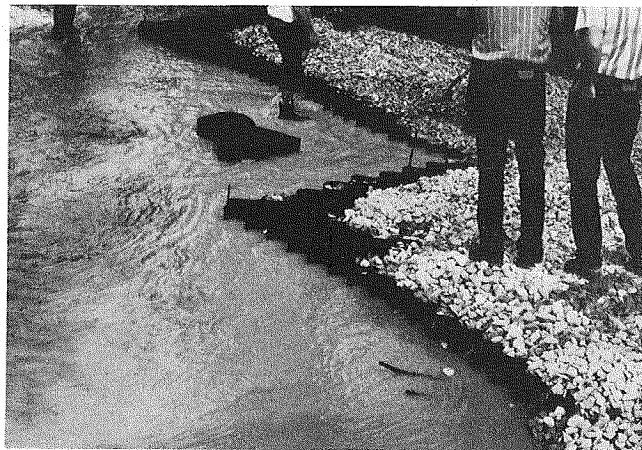


Figure 8. (left)--Filling GEOWEB with aggregate.

Figure 9. (below)--Nearly completed ford.



cost for the ford approximately \$2,800 had the Forest Service needed to purchase the GEOWEB and geotextile as well--still a substantial savings over concrete construction costs.

The following were the actual costs for this ford:

Crawler loader, operator, and laborer	\$ 595
Crushed aggregate	675
Forest Service crawler tractor	60
Overhead	200
Forest Service labor	270
Seeding	100

Total \$1,900

The crawler loader, operator, and laborer charge included removing the existing log stringer bridge and masonry rock abutments, excavating the approaches and subgrade, and relocating a metal bar gate.

INSTALLATION

Since this was a test project, several Forest Service Engineers and Engineering Technicians were on hand to get their feet wet and learn how to install the ford. Normally, three laborers are required for expanding the GEOWEB.

After the excavation was complete, it took $1\frac{1}{2}$ hours to install the geotextile, GEOWEB, and aggregate. After installation, a loaded dump truck crossed without settlement of the ford.

ADVANTAGES

The following are some advantages that this type of ford material has over concrete:

- (1) Less costly.
- (2) Short installation time.
- (3) Ford may be used immediately.
- (4) No stream diversion required.
- (5) Less inspection time.
- (6) No skilled labor, such as concrete finishers, required.
- (7) Reusable materials. (If creek gravel was used, the GEOWEB could be removed and used at another site. It might be undesirable to leave crushed aggregate in the stream.)

COMMENTS

Easy Transport

One interesting point is that GEOWEB for an entire ford can be carried in the trunk of a car or in the back of a small pickup. Two persons can carry a 20- by 8-foot collapsed panel of GEOWEB.

Durability

How long will the GEOWEB ford last? The Corps of Engineers conducted tests on a road constructed with GEOWEB on loose sand. Heavy test vehicles made 1,200 passes and other vehicles also made numerous trips. The grids and surfacing sustained minor damage along the road shoulders, where vehicles had

driven off and then returned to the road. The grid system should last for many years under normal timber sale, recreational, and administrative traffic.

OTHER USES

GEOWEB can be used for other installations as well:

- (1) Boat ramps. (Lowering the lake not required.)
- (2) Erosion protection.
- (3) Repair of weak roadbed sections.
- (4) Ditch liners.
- (5) Retaining walls.

CONTRACT SPECIFICATION

On public works and timber sale road contracts, the ford specification would be Subsection 203.12 and Pay Item 203(16).

(EFN)

Timber Bridges: A Manual To Detail Easily Built, Long-Lasting Structures

Gary Peterson
Public Affairs Specialist
Forest Products Laboratory

INTRODUCTION

When an Engineer decides to build a new bridge or replace an old one, the result is likely to consist of steel and concrete. Yet, with salt and corrosion factors having such an impact on existing structures, the service life of steel and concrete bridges, which has fallen from 30 to 35 years down to 15 to 20 years, often is less than that of a comparable timber bridge, which can last as long as 50 years. Other advantages of timber bridges include light weight, excellent reserve strength, strong shock resistance, and ease of construction and repair. Timber also is a renewable resource with distinct esthetic qualities.

Currently, 71,000 or 12.6 percent of the 656,000 bridges in the United States with spans greater than 20 feet are timber bridges. Of those, 61,400 are on secondary and rural roads, 9,800 are located on Federal-aid interstate and State primary roads, and approximately 5,000 are under Forest Service jurisdiction.

While the reasons for choosing a timber bridge over a steel and concrete one are many, there remain several problems. Many Engineers are not familiar with timber bridge designs or capabilities, and few publications on timber bridges are available.

But that's about to change.

TIMBER BRIDGE DESIGN & CONSTRUCTION MANUAL

Research projects currently underway in a cooperative effort by the Forest Products Laboratory (FPL) and the University of Wisconsin, led by USDA Forest Service Engineer Mike Ritter, will result in the Timber Bridge Design and Construction Manual, which is projected for publication sometime in the next 2 years.

The manual's 15 chapters will cover types of timber bridges, design concepts, fabrication, construction, and maintenance and rehabilitation, as well as other

subjects. Specific intended users of this information include Forest Service Engineers, the Federal Highway Administration, and State and local engineers, among others. The manual would provide a current source of technology, and considerable savings could result from the availability of new bridge concepts.

TYPES of TIMBER BRIDGES

Roundwood Stringer Bridge

Several types of timber bridges are now in use. One of these is the roundwood stringer bridge, which is built of logs bucked from trees felled in the area of construction, then decked with more stringers or with solid sawn lumber. Existing roundwood stringer bridges occur mainly on low-volume logging roads in Canada and Alaska.

Nailed-Laminated Bridge

Another type of timber bridge is the nailed-laminated bridge. The decks for these bridges are usually constructed with 2-inch thick dimension lumber, with the wide dimension in the vertical direction. The construction is simple and requires a minimum of skilled labor and equipment. The laminations are through-nailed and these are then toenailed to the stringers.

This design has some drawbacks, however. The fastenings between the laminations aren't sufficient to distribute loads beyond the loaded area, and vibrations, along with the shrinkage and swelling caused by moisture changes, eventually loosen the nails, which, in turn, opens up spots for water to get back into the deck and stringers, thereby causing additional problems.

Glued-Laminated Bridge

One of the most common modern timber bridges is the glued-laminated (glulam) bridge, which employs glue-laminating technology to fabricate the bridge components. Glulam consists of two or more layers of wood (laminae) glued together with the grain of all layers or laminations approximately parallel. Individual laminations cannot exceed 2 inches in thickness and typically are made from nominal 1-inch or 2-inch sawn lumber.

Glulam is resistant to decay because it is pressure-treated with preservatives. It also saves money in construction costs because glulam deck panels can be prefabricated and easily erected on the site, unlike concrete and steel bridges.

Stressed-Deck Bridge

Another type of timber bridge, the stressed-deck bridge, is being investigated in University of Wisconsin College of Engineering studies. Two stressed-deck bridges have been constructed on the University of Wisconsin campus and Engineering Professor Michael Oliva has supervised testing and analysis of the bridges by graduate students Al Dimakis and Jyou Lyang.

One bridge, funded by the Wheeler Construction Company, is of rough sawn heavy timber laminae and of medium span (48 feet by 9 feet) (figure 1). It has been tested, a preliminary report has been printed on the results, and a final report soon will be published.

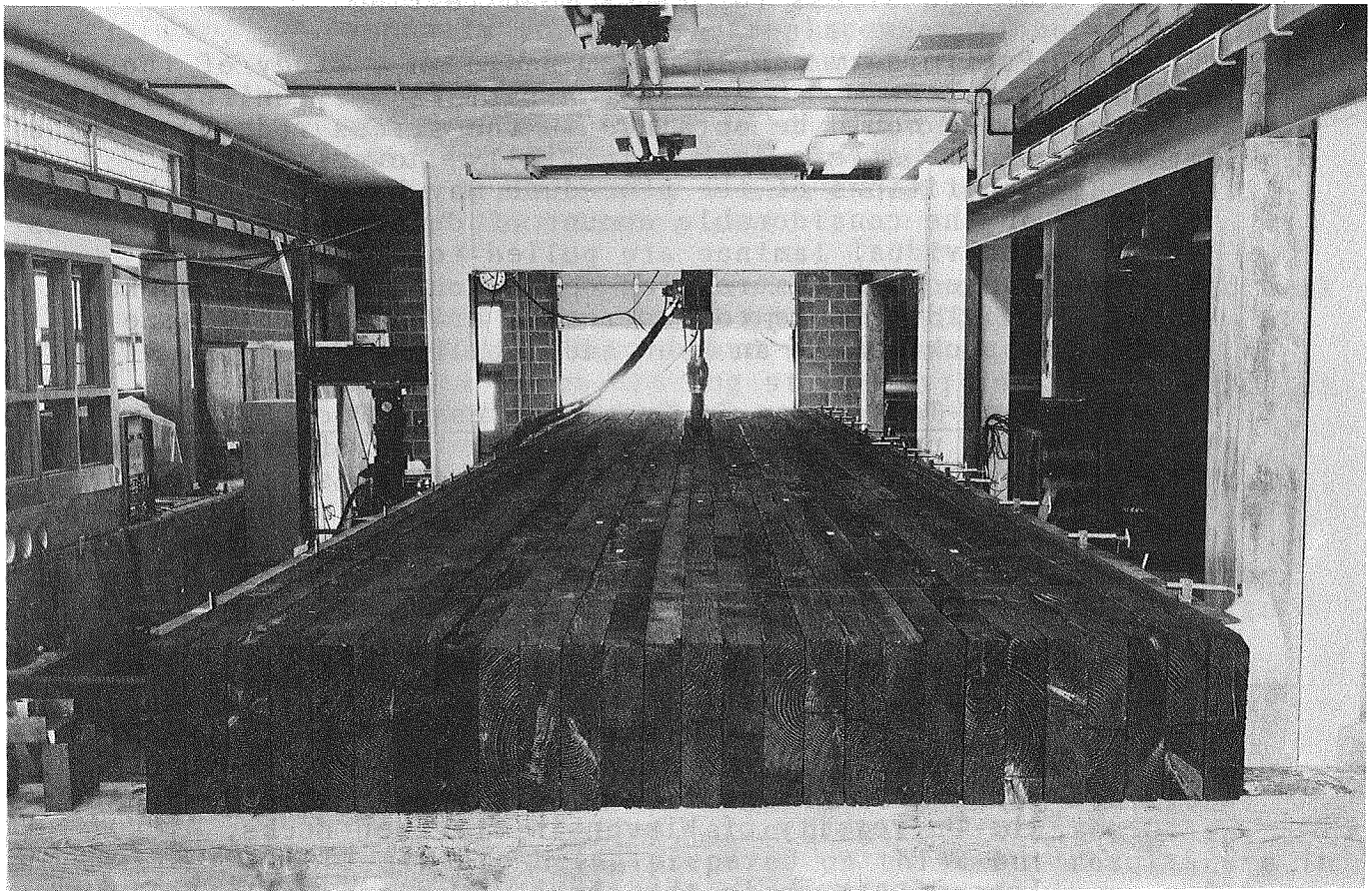


Figure 1.--Stressed deck of rough sawn heavy timber laminate (48 feet by 9 feet).

The 48- by 9-foot bridge consists of 27 vertical laminations of 4- by 16-inch material that is surfaced on one side to provide a constant thickness. The laminae are 8, 12, 16, and 20 feet long, with butt joints allowed, spaced according to certain rules. (Within any 4-foot length parallel to the bridge span, only one of any four adjacent laminae was allowed to have a butt joint, and adjacent butt joints had to be separated in the direction of span.)

Steel channel bulkheads also were used on both sides of the deck. Stressing steel rods, 1 inch in diameter, were spaced 4 feet apart, with 4- by 6.5- by 1.25-inch plates as anchorage plates. Initially, the rods were tensioned to 80 kips (80,000 pounds) causing 104 pounds per square inch (psi) to study the loss of stress from initial design value. The rods were later retensioned to 40 kips, 52 psi wood stress, to simulate their condition after possible loss of 50 percent of the stress for truck load testing.

Preliminary conclusions, based on a study of the first deck, showed that a satisfactory uniform stress force could be obtained in the stress rods by using a single stress jack. Initially, however, three repetitions of the procedure may be necessary because of the considerable amount of deformation taken up as individual laminae are pulled together. During subsequent restressing operations, a single worker should be able to restress a bridge of this size in approximately an hour and a half.

Post-Tensioning To Create Stressed-Deck System. The only previous research on this type of bridge was by the Ontario (Canada) Ministry of Transportation and Communication, investigating the use of post-tensioning to create a stressed wood deck system that would improve load distribution in both new decks and in the rehabilitation of deteriorated nailed-laminated decks. This technique resulted in Ontario Highway Bridge Design Code (OHBDC) specifications for stressed-deck systems. No American Association of State Highway and Transportation Officials (AASHTO) code yet addresses stressed wood decks, so OHBDC specifications generally were used in the design of the University of Wisconsin stressed decks.

Loss of stress in the stress bars generally followed the patterns observed in previous tests in Ontario. During a 210-hour period, 33 percent of the rod stress was lost as a result of wood creep and steel relaxation.

Steel channel bulkheads also were unnecessary if substantial steel plates were provided instead to spread the rod-bearing pressure over a satisfactory wood area. A 16- by 16-inch plate might be satisfactory. Removing the steel channels might reduce construction complexity and cost. The channels provided a considerable amount of stiffness to the entire system, but that same stiffness affected load distribution and led to the need for further research on a more economical and competitive system.

Another bridge, a short span (24 by 8.75 feet) of light wood laminae, has just been tested as a University of Wisconsin/FPL cooperative project. Evaluation of the results and development of analytical correlation should take roughly another 4 months to complete.

The stressed-deck bridge could be a boon to the Forest Service, which currently spends \$10 million annually for new and replacement timber bridges, and to the wood industry, because it is cheaper (estimated at 25 to 30 percent less than existing bridges) and even easier to build than other commonly used bridges. "The intent is to be able to use smaller, lower grade timber members that are readily available," Mike Ritter says.

The second FPL/University of Wisconsin stressed deck was built with No. 2 or better Douglas-fir 2-by-12's. Each board was checked for modulus of elasticity or bending stiffness, and then the boards were laid parallel to each other and stressed together with steel rods placed 2 feet on center. They also were tested later at 4 feet on center. Strain gauges measured the stress on the rods and the deflection of the deck for each loading condition during the laboratory tests. With some other types of bridges, Ritter points out, design generally is governed by stress, but with the stressed-deck bridge, deflection becomes the controlling factor.

Employing a parallel chord truss system instead of solid timber members could provide additional span capabilities, according to Professor Oliva. Tests are being prepared on this, but results are in the analytical stage and still preliminary. Oliva and University of Wisconsin Engineering student Lorraine J. Krahn recently completed a study called "The Effects of Oil-Borne Preservatives on Truss Plate Connection Behavior," in an attempt to

determine whether truss plated trusses would be suitable for constructing a parallel chord deck system. They made an initial evaluation of the effect of oil-borne preservative treatment (creosote) on truss plate connection strength and stiffness. Matched treated and untreated tensile specimens were made of dense Southern Yellow Pine using steel connector plates. The results indicated a significant increase of ultimate strength in the treated members. The stiffness of the joints was not affected if they were fabricated before treatment, but stiffness increased substantially if the joints were treated and then fabricated. The ultimate strength of the joints in both treated groups showed an increase of approximately 23 percent above the control group.

The effects of moisture variation on the prestress level also are being investigated in a current FPL study.

Many questions remain unanswered and further research on both stressed-deck bridges and parallel-chord systems is necessary before either form becomes viable. Meanwhile, patience and a view of the long run are required, though the goal of the overall project remains on target and in line with the FPL's statement of purpose.

"We're looking to better utilize our forest resource by using lower quality, shorter length materials in timber bridge construction," Ritter says.

(EFN)

Placerville Nursery Biomass Furnace

*Dan Totheroh
Assistant Forest Engineer
Tahoe National Forest
(Previously Assistant
Forest Engineer,
Eldorado National Forest)*

*Joe Olson
Civil Engineer
Pleasant Hill
Engineering Center
Region 5*

INTRODUCTION

The Forest Service nursery at Placerville, California, administered by the Eldorado National Forest, extracts seeds for germination from several species of pine and fir trees. Starting about September of each year and continuing through the end of the year, cones are dried to about 10 percent moisture content and then processed to remove the seeds. After the seeds are removed, the still-dry and now pulverized cones remain as waste. In the past, a 500,000 Btu per hour (Btu/h) liquefied petroleum gas (LPG) agricultural dryer was used to dry the incoming cones, and the chipped waste from the processed cones was stockpiled at a nearby site within the nursery for later disposal or spreading in the nursery beds.

In late 1982, the Eldorado National Forest proposed installing a furnace that would burn the dried and chipped cones--an ideal biomass fuel--to replace the LPG burner.

A search of available equipment revealed only a few suitable solid fuel burners in the desired range of 500,000 Btu/h to 750,000 Btu/h. Smaller residential units of around 100,000 Btu/h were commonly available, as were larger commercial and industrial units over 2 million Btu/h. A competitive bid offering resulted in three bids; the low bid was submitted by G&S Mill from Northborough, Massachusetts.

G&S Mill's burner system is unconventional in appearance. It consists of a heavy steel cylindrical combustion chamber, a separate air-to-air heat exchanger, and a hopper, stoker, and auger (figure 1). It was delivered in late summer, 1983. The

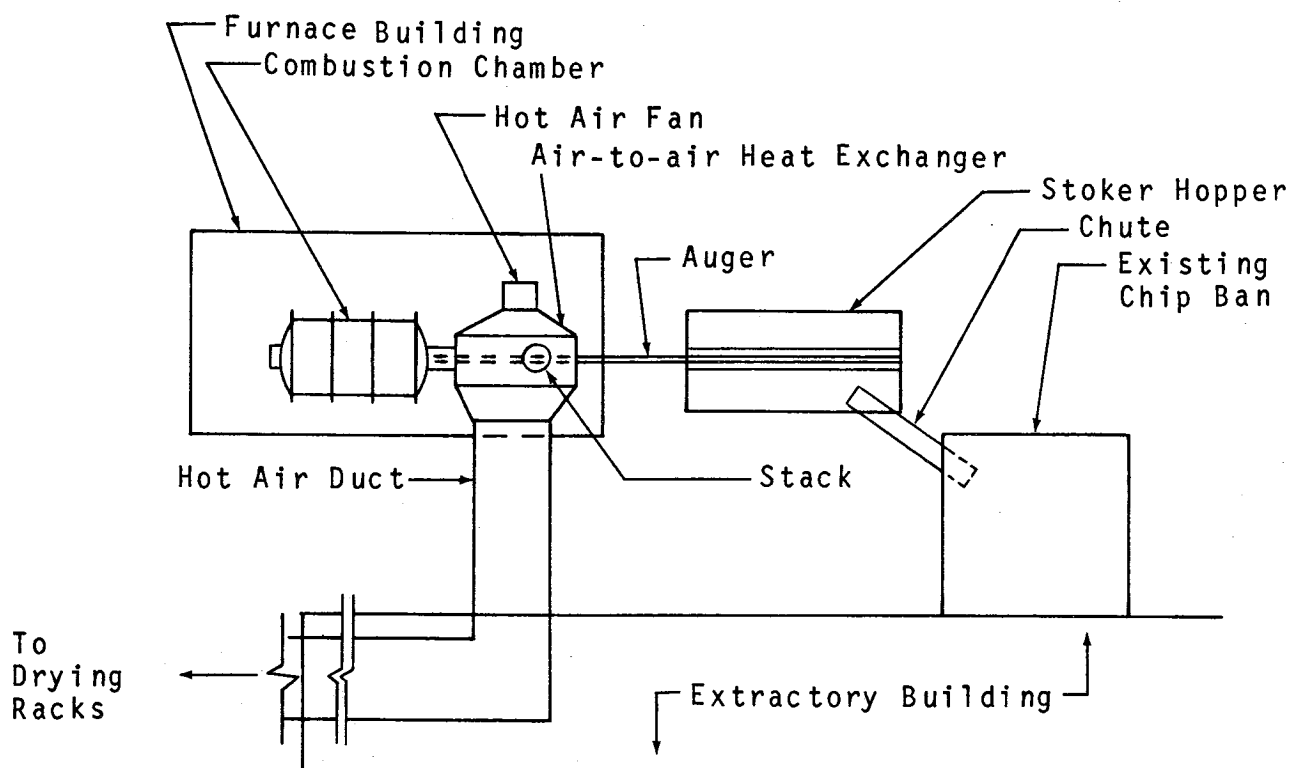


Figure 1.--Schematic diagram of furnace (plan view).

Forest constructed a building to house the furnace and heat exchanger and installed the burner along with ductwork to connect it to the existing cone-drying racks (figures 2 and 3). The installation and testing were done during the 1983 cone-drying season, so the first actual use was not until the fall of 1984.

FURNACE OPERATION

First in the sequence of operation, dried and chipped cones from which the seeds have been removed are expelled from the extractory building into a bin high enough for a dump truck to drive under for loading. The chips formerly were taken from here to a nearby disposal site, but now they flow down a chute from the old bin into the new stoker's hopper. A timer, which has been set by trial and error, operates the auger for a few seconds every few minutes, feeding chips into the combustion chamber. An induced draft fan on the stack moves the products of combustion from the burner, through the heat exchanger, and up

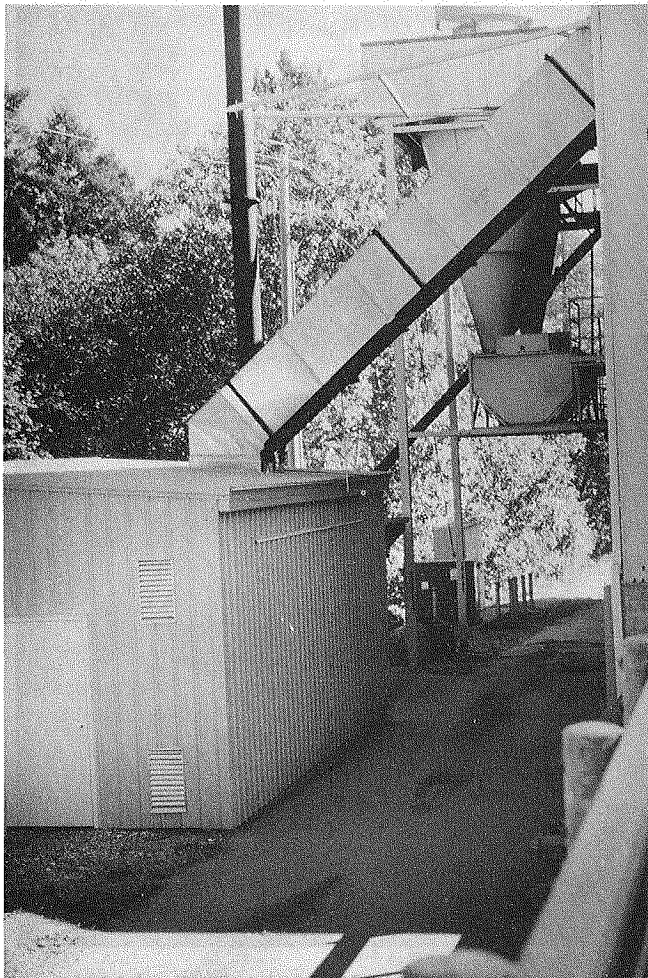
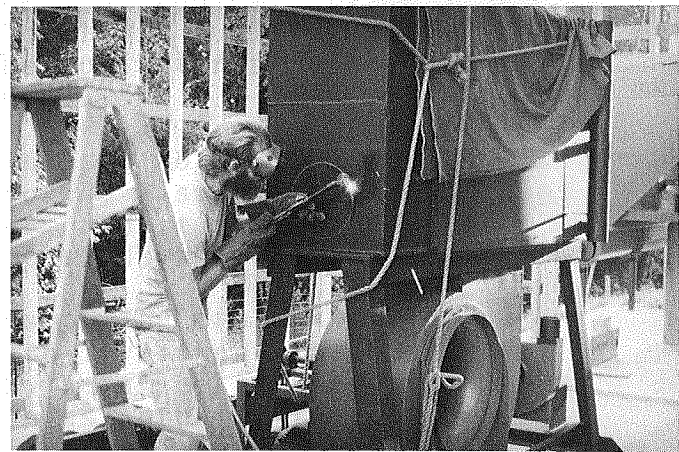


Figure 2. (left)--Completed installation, showing furnace building and hot air duct. Stoker hopper and auger are out of sight behind building.

Figure 3. (below)--Cutting hole in heat exchanger for connecting combustion chamber.



the stack into the atmosphere. Process and combustion air are taken from inside the furnace building (figure 4), which is insulated and has sufficient openings to provide the required air intake. Heat radiated and conducted from the surfaces of the combustion chamber and heat exchanger serves to preheat the air passing through the heat exchanger. Fans mounted on the heat exchanger force the heated air through insulated sheetmetal ductwork, which runs through the extractory building and on to the drying racks, where the heated air is passed through the trays of cones being dried. Depending on weather conditions and the number of cones being dried, there

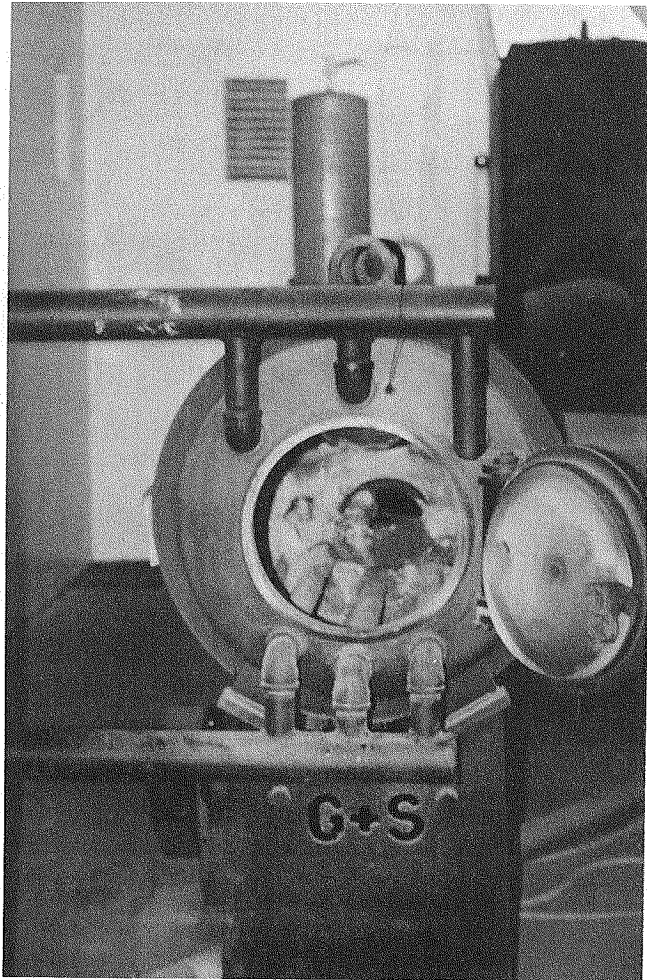


Figure 4.--Looking into combustion chamber. Pipes are for combustion air supply.

is sometimes excess heat capacity in the system, so a manually operated register in the ductwork inside the extractory building allows excess heat to be used to help heat the building.

SYSTEM PERFORMANCE

The system works quite well and is of rugged, substantial construction, but there have been a few problems to resolve.

The auger occasionally has plugged with chips when the system has been out of use overnight. This has been at least partially resolved by decreasing the capacity of the auger in the hopper.

At first, the system provided less than the anticipated quantity of heat. The high resin content of the fuel, which led to excessive fire box temperatures, seemed to be the key to the problem. After many months of frustrating minor changes, the insulating blanket between the inner and outer walls of the fire box was removed. This allows more fuel to burn and the increased heat to pass through the fire box walls and preheat air entering the heat exchanger. A larger fire box than that supplied with the furnace probably would have prevented this problem.

The system requires more attention and maintenance than the LPG burner that it replaced. Startup, shutdown, calibration of the stoker feed rate, and regular cleaning of the under-fire air grates all require some time, and the firebox and heat exchanger temperatures must be monitored regularly as well.

Emissions have not been a problem. Exhaust opacity has been good; the local air quality control district has not required other pollutants such as oxides of nitrogen to be measured.

The old LPG burner is used to dry the season's first batch of cones to provide a supply of fresh chips to start the chip burner, and it will be kept as a backup for high-use periods and emergencies.

ECONOMICS of OPERATION

Preliminary estimates of the project's viability indicated a savings-to-investment ratio of about three to one. Murphy's Law being what it is, the figure for the system as actually installed is smaller, but still favorable, as shown in the following analysis. A 25-year project life and no salvage values are assumed. A discount rate of 7 percent is prescribed for energy-related projects.

First Cost	<i>G&S Mill furnace, delivered</i>	= \$32,500
	<i>Installation, including furnace building and ductwork</i>	= <u>18,000</u>
	<i>Total first cost</i>	= \$50,500
Replacement Cost	<i>Assume complete replacement at year 15:</i>	
	<i>Present worth = \$50,000 x 0.3624</i>	= \$18,120

Maintenance Cost The chip burner requires cleaning every 2 to 4 weeks and also requires periodic attention that the LPG burner does not require, or approximately 2 weeks more maintenance per year:

Present worth of added maintenance cost at
7 percent, 25 years = $\$1,000 \times 11.65 = \$11,650$

Operation Cost LPG Burner

Approximately 10^9 Btu used per year.

Cost per year = 10^9 Btu/year
x 1 gallon LPG per 95,500 Btu
x \$0.85 per gallon = \$8,900 per year

Present worth at 7 percent,
3 percent escalation,
25 years = $\$8,900 \times 15.816 = \$140,762$

Chip Burner. The burner has a 2-horsepower induced draft fan motor and a 5-horsepower process air fan that operate whenever the furnace is in operation, about 2,000 hours per year. The 5-horsepower motor on the stoker auger operates a negligible percentage of the operating time. The total electrical load is approximately 7 kW at all times.

Annual cost of electricity = 2,000 hours
x 7 kWh per hour x \$0.09 per kWh = \$1,260 per year

Present worth at 7 percent,
3 percent fuel escalation,
25 years = $\$1,260 \times 15.816 = \$19,928$

Savings to Investment Ratio (SIR)

$SIR = \frac{(\text{Reduction in Energy Cost} - \text{Increase in Maintenance Cost})}{(\text{Investment Cost} + \text{Replacement Cost})}$

$SIR = \frac{(\$140,762 - \$19,928 - \$11,650)}{(\$50,500 + \$18,120)} = 1.6$

SIR is greater than one, therefore the project is cost-effective.

CONCLUSION

The shredded cone-burning furnace has provided a cost-effective solution to a situation where a ready-made source of an ideal fuel is available. The

technology of the system is not perfect, and there are significant maintenance requirements, but on balance the system is quite satisfactory.

Anyone wishing to comment on or to better understand the technology of the system described in this article can contact Joe Olson, Civil Engineer at the Region 5 Pleasant Hill Engineering Center, at (415) 825-9800.

EFN

NAP (Network Analysis Program)

Robert Sutton
Planning Staff Engineer
Region 5

INTRODUCTION

The January-February 1986 issue of Engineering Field Notes included a paper by John Sessions entitled "Network Analysis Using Microcomputers for Transportation Planning." The article described a new transportation network analysis model (NETWORK) that runs on microcomputers, which Region 5 had been considering using for some time.

The model appeared to be relatively easy to use. The data files were straightforward and easy to edit, and the program was menu-driven and very user friendly. The amount of data contained in a transportation network file can be quite large, however, and we were concerned that the data file consisted of cost data that would have to be updated several times each year. We wanted a system that would not require constant updating of large files. Our objective was to find or develop a model that could be used for timber sale appraisals and economic analyses of our transportation systems in a production mode. That is, we wanted to have a system that could be used by project level transportation planners for both complex transportation analysis and an average timber sale.

To that end, and with the help of John Sessions, we developed R5-HAUL. R5-HAUL is basically a front-end program and a report writer to be used in conjunction with NETWORK. Putting the two together, we call the system NAP (Network Analysis Program). It is a menu-driven program that is executable on IBM-PC-compatible microcomputers. The hardware must have at least 512K of memory and, while not entirely necessary, should also have a hard disk.

The FRONT END

NETWORK requires two files to run: the link file and the sales file. Each line of the link file contains four pieces of information for each link, including a node number for each end of a link, a variable cost to traverse the link (usually the haul

and maintenance cost in dollars per thousand board feet), and a fixed cost incurred when the link is first used (such as construction or reconstruction cost).

R5-HAUL uses a road log file, a variable-cost file, and a fixed-cost file to create the link file for NETWORK. The road log file consists of the physical attributes of each link, or road segment. These data include the node number, milepost, and elevation at the node, as well as the road type, speed, and maintenance responsibility for the road segment ahead. Following is a description of each data item:

- (1) Node Number. This is a number assigned to each end of each road segment, or link, in the transportation network. Road segments usually are divided at intersections and at significant changes in the road such as surface type, jurisdiction, or grade breaks. As many as 2,000 links and 3,000 nodes are allowed in the network.
- (2) Milepost. Mileposts are assigned to each node number in ascending order.
- (3) Elevation. Elevation is given for each node. The model uses mileposts and elevations to calculate grade, which is a major factor in determining speeds.
- (4) Road Type. This is a number from 1 to 60, which is obtained from a matrix and based upon surface type, number of lanes, and a measure of the horizontal alignment.
- (5) Speed. The model assigns speed to each link of the network. If the user wishes, a specified speed can be given to any link.
- (6) Maintenance Responsibility. The model can include maintenance costs on any link in the network.

While this seems like a large amount of data to collect for each road segment, data collection actually goes quickly. In the field, data are collected as fast as the user can traverse the network. Several Forests also have had success collecting data in the office from existing records. Road inventories, maps, air photos, and

maintenance logs all have been used to help collect road log data for the model.

Once the data are collected and entered into a road log file, they only need to be changed when there is a physical change on the ground. If a new road is built or a road is improved, then it may be necessary to update the road log file. Some Forests maintain only the arterial and collector networks. Local roads are added in as they are being analyzed. The model includes a user-friendly editor and a diagnostic routine that examines the data file for obvious errors.

The variable-cost file is relatively small. It consists of the cost per hour to own and operate a logging truck and the cost per mile per thousand board feet to maintain the roads of each surface type. A key to making this system work is a recent change in the Region's Timber Sale Appraisal Handbook. The handbook was modified so that the cost of haul is based on an hourly rate to own and operate a logging truck. These data are obtained through the auditing system, using timber purchaser's records. The same data then are used for timber sale appraisals and economic analysis. The results from analyses from this model now are being used to appraise timber, perform area analyses, and help analyze competing projects for the Region's capital investment program for roads.

The fixed-cost file is simply a listing of fixed costs associated with various links in the network. These are costs that are incurred the first time the link is used and are broken down into construction, reconstruction, and other (such as rights-of-way acquisition).

NET 3000

Once these files are built, they are merged together to create the link file for NET3000, the version of NETWORK being used in Region 5. A sales file is built for NET3000, which includes where the timber is, how much is there, and what year it is scheduled to be sold. NET3000 then uses a unique algorithm to determine the paths that will minimize total discounted costs. The model can also be used to maximize returns.

(John Sessions is still working on several enhancements to his model. These include a graphics package and the capability of the model to determine timing of the timber sales to minimize costs or maximize

returns. These changes will make this software a very powerful tool in area analysis.)

The REPORT WRITER

After NET3000 determines the least-cost paths for the timber in the problem, R5-HAUL can write two reports on the solution, the Alternative Transportation Summary and the Entry Analysis Report.

The Alternative Transportation Summary is designed for a single timber sale. It provides timber sale information for all the timber in the problem. This includes all transportation information for the sale, including the amount of haul, maintenance, surface replacement, dust abatement, construction, and reconstruction in the solution. That same information can be displayed for each iteration generated in NET3000's search routine.

The Entry Analysis Report is designed for an area transportation analysis. It provides economic information for each entry into an area. This includes the cost of road construction, reconstruction, haul, and maintenance in the solution for each year that timber is hauled. It also gives the volume sold and the miles of construction. For each link that carries timber traffic, it gives the sale node the timber is from, the volume, and the fixed and variable costs for that link.

These two reports are set up to provide the transportation analyst with all the data needed to perform an area analysis or produce the required information for a timber sale. The models are set up to perform sensitivity analyses easily. That is, after a solution is achieved, the analyst can rerun the program with an additional constraint imposed, for the purpose of generating alternatives. Reports can be written for each alternative generated. These data can provide valuable information for an interdisciplinary team.

SOUNDS PERFECT!

Not quite. NAP has been well-received on most timber Forests in Region 5, but it is not a panacea for transportation analysis. As with most systems of this type, data collection can be costly. Users are encouraged to collect data on the arterial and collector roads first; local road data can be added as areas are analyzed. Typically, Forests have had to invest a couple of person-months of time collecting data before gaining full use of the system.

Before NAP was developed, most models relied on linear programming to integrate fixed and variable costs into an analysis. While these systems are more difficult to use (structured input, use of Fort Collins Computer Center), they do result in an "optimal" solution. That is, for a given objective (for example, to minimize costs) and a given set of constraints, the result is guaranteed to be the best mathematical solution. NET3000 has a search technique that is quite unique and typically will find the same solution. There is, however, no guarantee that this model will find the optimal solution.

In one area analysis, a transportation planner was able to improve the NET3000 solution by constraining the network and rerunning the problem. The result reduced the cost of the original solution by about 5 percent. This points to the need to perform a sensitivity analysis on the solution. (This, of course, is a good practice with any model.) The analyst should always constrain the problem to look for the next best solution.

The NAP model also is limited in its ability to handle environmental constraints. While the model can be tricked into handling some simple constraints, it does not lend itself to modeling some of the more complex constraints (such as adjacency constraints).

As mentioned earlier, the model does not yet have a graphics package or the ability to determine the best timing of timber sales. These enhancements are being developed and soon will improve the model's capabilities.

Finally, there is the obvious need for the appropriate hardware. The model runs on IBM-PC-compatible systems with at least a 512K memory, and it could be converted to other systems. Many transportation planners do not have adequate hardware systems available to them, and they find that obtaining these systems is difficult if not impossible. Even though the model has proved itself capable of paying for the needed hardware many times over, the difficulty in obtaining hardware persists.

CONCLUSIONS

For years, the Forest Service has been in the transportation network analysis business. The complexity and expense of some systems has limited use to a few special situations by highly skilled analysts. Other

systems have been relatively simple, but have not had NAP's capability to integrate fixed and variable costs. In the past, data management was awkward and large files had to be changed as costs were updated. These factors led to limited acceptance of transportation network analysis within the Forest Service.

Now, however, it appears that with NAP a system has finally come along that combines fixed and variable costs while remaining user-friendly. The model has the capacity to perform large, complex area transportation analyses. It will find very good solutions, and performing sensitivity analyses can almost always achieve the same solution as those found by linear programs. The report writer makes displaying the transportation-related economic effects of various land management alternatives easy.

The NAP model lends itself to obtaining transportation-related data for timber sales as well. Again, the report writer can be used to generate costs of various alternatives. The model is so easy to operate that planners are using it to appraise even the most simple sales. Most transportation planners can be trained in the use of NAP in approximately 8 hours, and after several applications they become fully proficient.

Project planning is becoming more complex, and the need for strong economic analyses is apparent. As we face this situation in light of our decreasing budgets, we need to take advantage of new technology to improve the quality of our planning.

For transportation, the answer may be to take a NAP in the Forest.

EFN

Using Fabric To Pave Over Wood Bridge Decks

Allan A. Johnson
Supervisory Civil Engineer
Nicolet National Forest
Region 9

INTRODUCTION

The Nicolet National Forest had two bridges that needed protection from traffic wear, Armstrong Creek Bridge and Peshtigo River Bridge. These bridges were constructed earlier with an eventual bituminous wearing surface planned for in the design. Peshtigo River Bridge was constructed in 1975 and widened to two lanes in 1980. Armstrong Creek Bridge was constructed in 1977. Because of concerns that preservatives bleeding from the 4-inch-thick glued-laminated wood decks would be detrimental, the bituminous wearing surface was not made part of the original bridge contracts. Past experience has shown that pentachlorophenol and creosote will adversely affect the asphalt mixture as well as prevent bonding between the asphalt and the wood bridge deck.

By 1982, the preservatives had leached out or been removed by traffic. Also, traffic had pulled roadway gravel onto the wood decks and was beginning to wear grooves in the laminated wood decks. This made placing the bituminous wearing surface a high priority. Funding to overlay the two decks was received in fiscal year 1983, and we combined these two into one project.

DISCUSSION

In designing the asphalt overlay, we had the following concerns:

- (1) Both decks have 4-inch-thick glue-laminated deck panels placed transversely over wood stringers. We were concerned that heavy log truck traffic would cause considerable deflection of the deck. This deflection would cause cracks in the hot bituminous overlay.
- (2) If cracking did occur, water might penetrate the cracks and cause premature decay by keeping the treated wood wet.

- (3) We were unsure of how well the hot bituminous mix would bond to the wood deck.

A nearby National Forest (Chequamegon National Forest, Park Falls, Wisconsin) had used geotextile fabric in conjunction with paving over wood decks (see "Use of Geotextiles as Bridge Paving Underlayment;" Engineering Field Notes, February-March 1984). Though the fabric had been in place only a short time, their results were good.

At about this time, we found a new product called PETROTAC. This product is by Phillips Fibers Corporation, a subsidiary of Phillips Petroleum Company. PETROTAC consists of a rubberized asphalt membrane bonded to a nonwoven fabric. Its total thickness is 75 mils. A paper release sheet covers the bottom of the rubberized asphalt and is removed before installation.

We decided to try PETROTAC on our projects for the following reasons:

- (1) Using the fabric might reduce the amount of cracking in the overlay pavement.
- (2) By overlapping the fabric, we would have a waterproof membrane to cover the entire wood deck. Water could not reach the wood deck or keep it wet.
- (3) The sticky rubberized asphalt would bond well to the wood deck. A prime coat over the fabric would achieve a good bond to the pavement.

Figure 1 shows the bridge paving cross section that was used. Figure 2 shows the treated 2-by-4 edging placed at the curb line to provide a neat edge joint. We called for a minimum overlap on the fabric material of 2 inches to get a waterproof surface. The fabric also was carried 2 feet beyond the bridge ends onto the gravel approaches to provide a bridging from the deck paving to the roadway paving. The paving was extended 75 feet beyond bridge ends on both bridges. Table 1 gives the Engineer's estimate and bid summary for the bridge paving project. Since this project was completed, the price of PETROTAC fabric has increased substantially, so expect much higher bid prices for the fabric now.

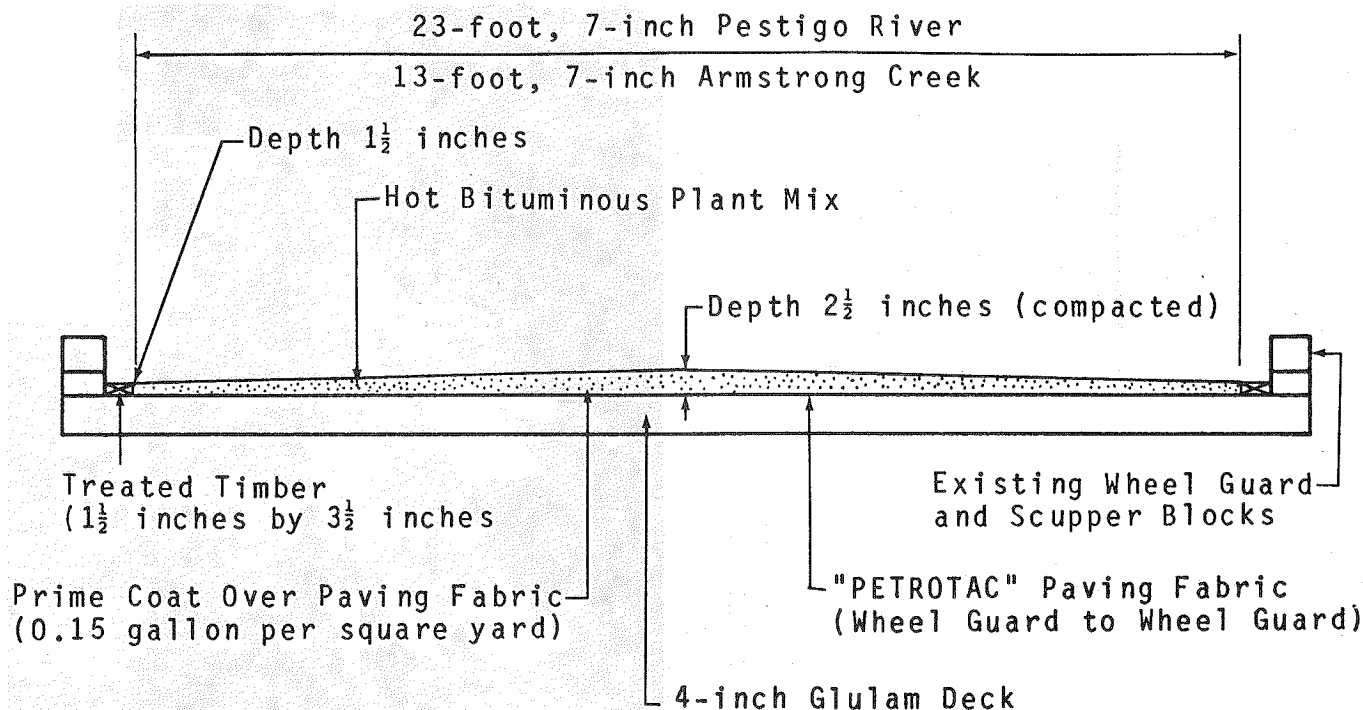


Figure 1.--Bridge paving cross section.

CONSTRUCTION

The decks were cleaned off thoroughly using shovels, brushes, and compressed air before applying the fabric material. Because of damp weather conditions, we placed a small amount of CSS-1 prime coat under the edges of the fabric and a narrow band in the middle of each width. In better conditions, this would not be necessary.

A prime coat of about 0.15 gallons per square yard of CSS-1 was placed on the gravel bridge approaches and over the fabric material on the deck. After 2 hours or so, the prime coat was set up enough for paving to begin.

A hot bituminous mix using 5.7 percent asphalt, 120-150 grade asphalt cement, and $\frac{3}{4}$ -inch minus aggregate was used. No additives were used in the mixture. A standard paving machine was used to place the bituminous material, and the paver was adjusted to give the desired crown section. One pass was used on the single-lane bridge and two passes on the double-lane bridge. The paving process went

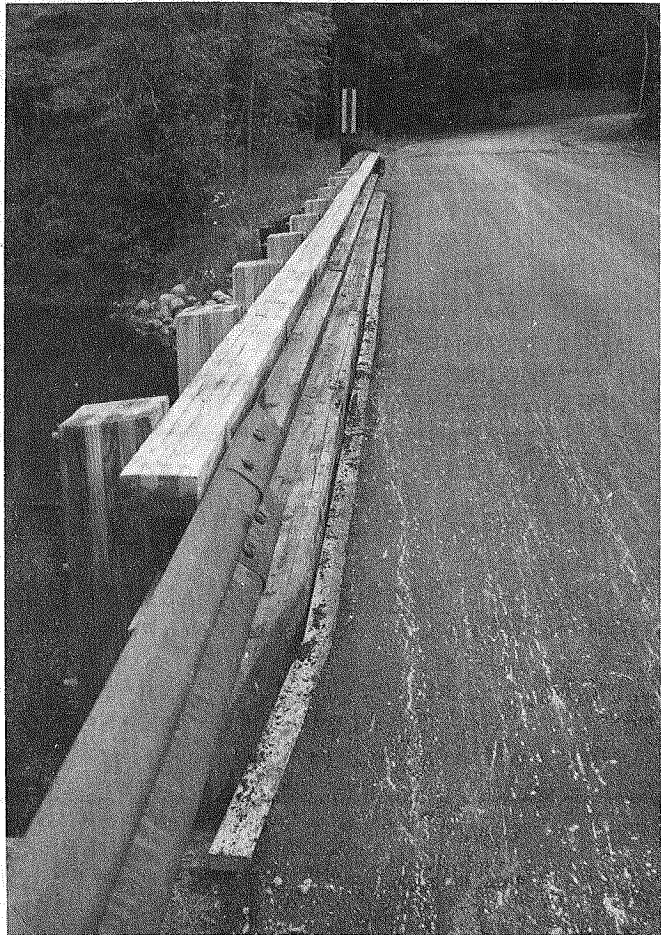


Figure 2.--Treated 2- by 4-inch edging
on Peshtigo River Bridge.

well, with no particular problems. The hot mix on the decks needed to set up a while before the rolling, to avoid pushing the material with the roller.

Construction on this project was accomplished during July 1984. Figures 3 and 4 show the Peshtigo River Bridge and Armstrong Creek Bridge after paving. As of May 1986, the bridge paving is performing satisfactorily. We have had a moderate amount of pavement cracking on both bridges--as expected, cracks developed where the roadway approach meets

Table 1.--Bridge paving bid summary (bids opened 8/11/83).

Item	Description	Unit	Quantity	Eng. Estimate		Bidder A		Bidder B	
				Unit Cost	Total	Unit Cost	Total	Unit Cost	Total
<u>Peshtigo River Bridge</u>									
406(06)	Hot Bituminous Plant Mix	Square Yard	573	6.50	3,274.50	8.00	4,584.00	6.50	3,274.50
408(07)	Paving Fabric	Square Yard	171	9.00	1,539.00	8.00	1,368.00	6.75	1,154.25
408(04)	Emulsified Asphalt	Gallon	84	5.00	420.00	4.00	336.00	4.00	336.00
557(01)	Treated Timber	Lump Sum Quantity	1		200.00		150.00		225.00
601(01)	Mobilization	Lump Sum Quantity	1		1,000.00		500.00		1,800.00
	Subtotal				6,433.50		6,938.00		7,239.75
<u>Armstrong Creek Bridge</u>									
406(06)	Hot Bituminous Plant Mix	Square Yard	329	6.50	2,138.50	8.00	2,632.00	6.50	2,138.50
408(07)	Paving Fabric	Square Yard	89	9.00	801.00	8.00	712.00	6.75	600.75
408(04)	Emulsified Asphalt	Gallon	47	5.00	235.00	4.00	188.00	4.00	188.00
557(01)	Treated Timber	Lump Sum Quantity	1		150.00		150.00		195.00
	Subtotal				3,324.50		3,682.00		3,122.25
	Grand Total				9,758.00		10,620.00		10,362.00 ^a

^aFinal payment for contract was \$9,961.60 after +\$40.00 change order and -\$440.40 penalty for late completion by Bidder B.

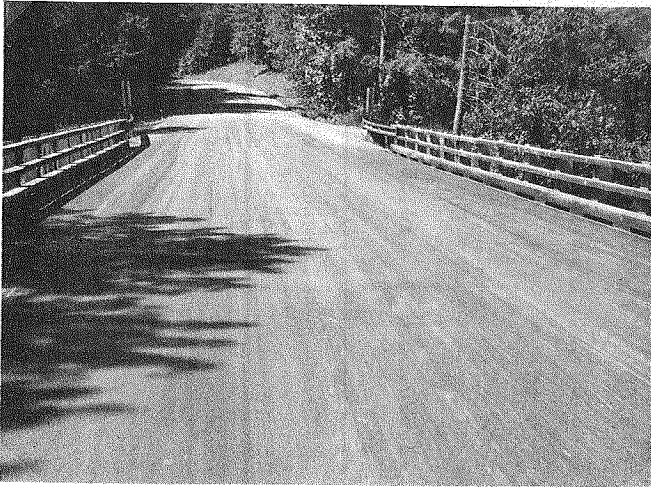


Figure 3.--Peshtigo River Bridge after paving.



Figure 4.--Armstrong Creek Bridge after paving.

the bridge deck. Figure 5 shows the pavement crack on the end of Armstrong Creek Bridge. Lateral cracks also developed at various other locations on both bridge decks. Figure 6 shows some typical lateral cracks on Peshtigo River Bridge. Almost all pavement cracks were lateral (90 degrees to bridge centerline) and varied from $\frac{1}{32}$ inch to $\frac{1}{8}$ inch in width. The average width of the cracks would be about $\frac{1}{32}$ inch.

SUMMARY & CONCLUSIONS

We think that this method of paving over wood bridge decks has worked well, and we will consider it again for wood-decked bridges needing a protective surface. We will fill cracks that have developed in the bridge deck pavements with crack sealing material. This should be the only action needed now to protect and maintain the bridge pavements.

We have considered whether using PETROTAC under bridge paving would allow placing pavement immediately on a new treated timber deck. Currently, we do not know what effect creosote or pentachlorophenol would have on the PETROTAC rubberized asphalt membrane. Until this is tried or tested, it would be best to allow some time before placing the PETROTAC and pavement on a wood bridge deck.

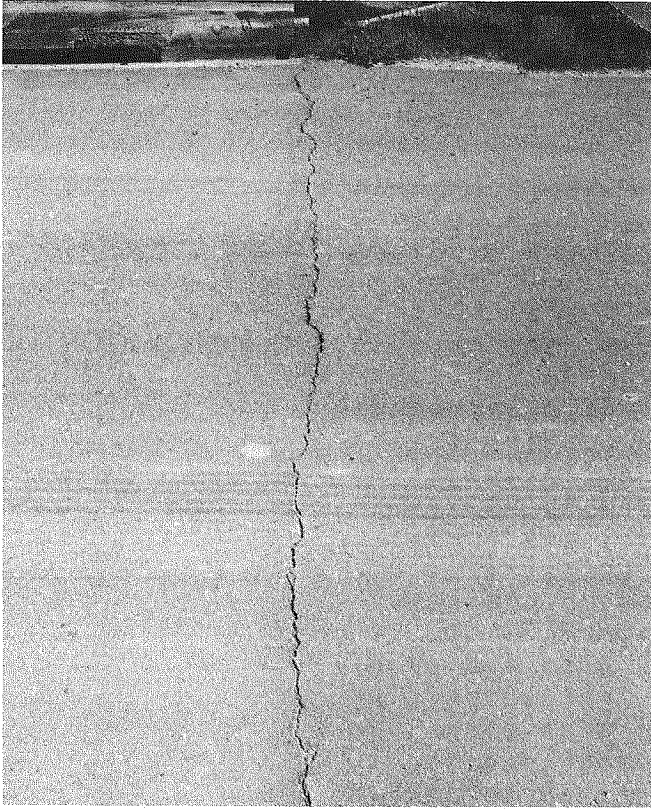


Figure 5.--Pavement crack on end of
Armstrong Creek Bridge.

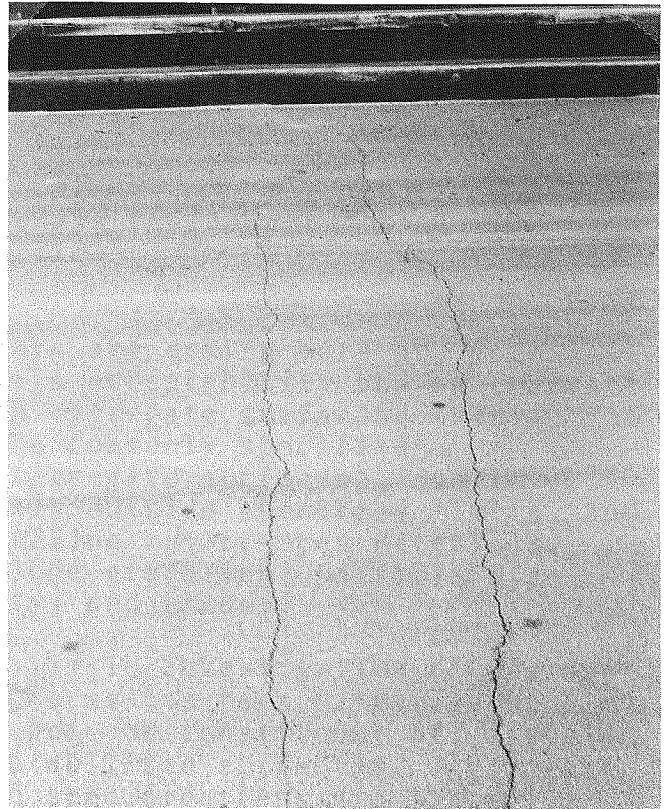


Figure 6.--Lateral cracks on Peshtigo
River Bridge.

Aggregate Surfacing Acceptability

*Skip Coghlan
Construction & Materials Engineer
Region 9 Regional Office*

INTRODUCTION

Construction Engineers are asking more and more questions on materials acceptability and on contract changes dealing with aggregate surfacing. This article discusses the commonly specified characteristics of aggregate surfacing, quality tradeoffs of materials outside specified limits, and alternatives for handling out-of-spec materials. Characteristics include gradation; particle size, shape, and durability; and binder.

There has been very little investigation of aggregate as a surfacing--the focus has been primarily on aggregate as a base for, or constituent of, asphalt or portland cement stabilized surfacing. Aggregate surfacing design and specifications are strongly influenced by knowledge of aggregate as a base. Accordingly, decisions are based largely on judgment, observation, and experience rather than on measurements or standard formulas. Suggestions made here are the author's and are not Forest Service policy.

GRADATION

Desirable aggregate surfacing gradation is represented by a sweeping curve on the gradation chart, indicating the presence of all particle sizes. This optimum, most dense gradation has successively smaller particles filling the spaces between larger particles. Figure 1 shows this "well-graded" material distribution, which is represented by the following equation:

$$p = 100(d/D)^n$$

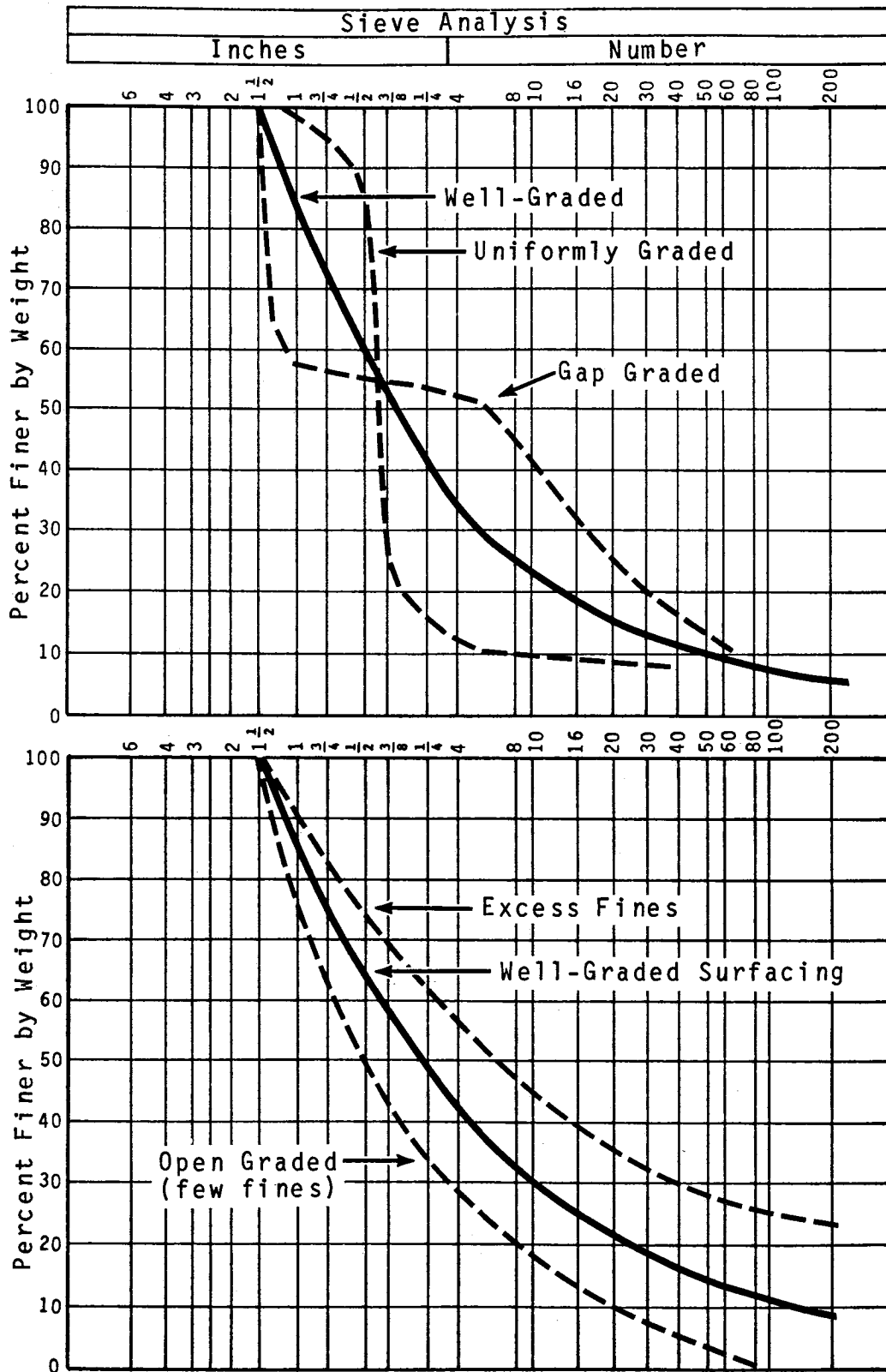
where

p = percent material finer than sieve size d ;

d = sieve size being considered;

D = maximum aggregate size;

n = exponent, usually taken as 0.5.



Variations from the optimum gradation curve usually represent a loss in quality, that is, strength and/or lateral stability. Common variations are "gap-graded" (missing a range of aggregate sizes) or "uniformly graded" (mostly one size). Both these variations will decrease lateral stability. Aggregate with a shortage of small particles, or fines, is called "open-graded" and also decreases lateral stability. Excess fines prevent grain-to-grain contact of larger particles and result in the mixture exhibiting the properties of the fines, which usually leads to a loss of strength.

Loss of quality here refers to the aggregate used for surfacing. An open-graded material is free-draining and makes good, strong base when confined by some surfacing. Even gap-graded or uniformly graded materials may make an adequate base when confined by surfacing. Chips or sand for an asphalt surface treatment usually are uniformly graded.

Gradation specifications usually are developed as a band down either side of an ideal well-graded material, starting from some maximum particle size. The maximum particle size and width of the limits are selected based on cost, road standard, users, maintainability, material availability, and local experience. Ideally, the surfacing material supplied by a contractor can be charted down the middle of the band, paralleling the limits. Being "well-graded," the material does not jump from side to side of the limits--that would indicate gap or open grading. Within the limits of the specified range, jumping from side to side should not be seriously detrimental. That is the reason for that band width. If a supplied aggregate did jump from side to side within the limits, the material would be accepted, but the problem would be pointed out and the supplier asked to correct it.

A common gradation problem arises when the supplied material follows closely along one of the specified limits, maybe with only one or two points that do not follow the curve. Following a limit indicates a well-graded material, and that probably is better than having a material totally within the specification but jumping from side to side. The material following a limit with only a couple of points outside the limit might be considered acceptable, although the supplier would be encouraged to bring the material into the specified range and an appropriate notation made in the diary. The decision

might even be made with the Contracting Officer to accept this as "or equal" and to formalize it with a contract change.

A material that jumps from outside one limit to outside the other limit constitutes a major deviation from the quality intended by the design. This material might be rejected, modified in place by blending, or accepted with a reduced price. Acceptance or a reduced price would depend on the extent of lost serviceability and a review of the original criteria for specifying this particular gradation.

The percent of the aggregate that is finer than the No. 200 sieve is particularly important to the strength and stability of aggregate surfacing. The optimum CBR (California Bearing Ratio, a measure of strength) occurs at about 6 to 7 percent passing the No. 200 sieve. At 4 to 10 percent passing the No. 200 sieve there may be 10 to 20 percent decrease in the CBR. At 2 to 12 percent passing the No. 200 sieve there may be 20 to 40 percent decrease in CBR. Beyond the 2 to 12 percent range strength falls off quickly. Note that, for larger maximum size aggregate, the ideal gradation curve formula may not provide sufficient fines for surfacing.

Typical aggregate surfacing specifications allow 6 to 15 percent of the aggregate to pass the No. 200 sieve. Apparently the tradeoff of increased stability at 12 to 15 percent warrants the strength loss over 12 percent. Based on the strength loss, aggregate material with less than or more than 15 percent passing the No. 200 sieve should be rejected. For aggregate with between 2 and 6 percent passing the No. 200 sieve, a price adjustment might be acceptable. Alternatives include removal and replacement, modifying fines content by blending in other aggregate, or stabilizing with some additive.

PARTICLE SIZE, SHAPE, & DURABILITY

Aggregate Particle Size

The gradation curve formula varies according to the maximum aggregate size. Thus, an ideal or well-graded material can be developed for any maximum particle size. Specification of maximum particle size is somewhat arbitrary. The larger the maximum size, the lower the cost should be because less rock must be crushed. Rock larger than 1 inch will begin

to deteriorate riding quality, but for low-speed roads, even rock with a 4-inch maximum size may be acceptable. The larger aggregate is more difficult to blade smoothly. Loss of a large stone often creates a pothole or washboarding. Finer aggregates contain proportionately more fines and become progressively more susceptible to dust, erosion, water, and frost. Below $\frac{1}{2}$ -inch maximum particle size, obtaining a well-graded material without excessive fines may be impractical. Dusting, erodibility, and water sensitivity of the surfacing may be unacceptable.

Requests for changes in aggregate gradation typically address a change in maximum size. If the change is to a smaller size (not below $\frac{1}{2}$ inch) and still provides a well-graded material, the material probably is to the Government's advantage and a no-cost change would be appropriate. If the change is to a larger size, but still a well-graded material, we need to review our original criteria for maximum size. A change from 1-inch to $1\frac{1}{2}$ -inch particles may be a more significant change than from $1\frac{1}{2}$ inches to 2 inches because of the relative change in riding quality and maintainability. If 2-inch particles are acceptable, probably 4-inch particles are almost as acceptable. After reviewing original criteria, the Forest Service might accept a price adjustment, providing the material is well-graded.

Aggregate Particle Shape

Angular aggregate particles provide significantly more interparticle friction than round particles. Flat or elongated particles are more stable than square, blocky particles. The basis for selecting crushed aggregate or pit-run gravel is an economic analysis of the cost of crushing versus the costs of lower stability, increased maintenance, and increased gravel surfacing loss rates. This should be well thought through before specification and should not be a construction change issue. Crushed surfacing specifications usually include 50 percent of particles having at least one fractured face. Well-crushed material easily meets this requirement. However, where the raw material is pit-run gravel with only a little oversized material being crushed, it will be difficult to meet the 50-percent fractured face criteria. A borderline material will not exhibit the desired properties of an angular, crushed aggregate. If we know that we will be screening and crushing gravel and will have only minimal fracture, we should not include the 50-percent fracture

criteria, or possibly we should raise the fracture percentage. If we know we will start with gravel, failure to achieve 50 percent is a minimal change covered by a minor cost change. On the other hand, if we fully expect a well-crushed material, failure to meet the fracture requirement is a good reason to reject the aggregate.

Aggregate Particle Durability

Particle durability includes both physical strength and weathering resistance. Typically, the Los Angeles Abrasion (LAA) Test (AASHTO T-96) provides a measure of physical strength, indicating resistance to breakdown from interparticle friction under traffic. Good quality aggregate, such as granite, basalt, or limestone, will give LAA values of less than the commonly specified 40-percent maximum loss. Very poor material, such as soft shale, siltstone, or calcite, might show 60 percent or higher LAA losses. There are many marginal materials (for example, limerock, sandstone, and hard shale) that may have LAA losses of 40 to 60 percent and that perform very adequately as surfacing for low-speed roads. Those marginal materials that generate nonplastic fines are particularly acceptable.

Pit-run marginal materials often are specified based on local experience with no strength test requirements. However, occasions arise where LAA has been specified and the material is outside the limit. U.S. Department of Transportation Standard FP 85 Specification permits LAA loss up to 50 percent. Losses of 40 to 50 percent might be handled with a minor price reduction. Losses of 50 to 60 percent might be handled with more significant price adjustment and/or treatment with an additive. Losses greater than 60 percent are best rejected, although special conditions may warrant treatment with an additive.

Particle weathering resistance may be specified for evaluation by the production of Plastic Fines Test (T-210) (also called the California Degradation Test or Durability Index), the Soundness by Sodium Sulfate Test (T-104), and the Sand Equivalent Test (T-176). Weathering resistance is not often used, except for particular local problems, such as marine basalts. Evaluation by these tests is usually overshadowed by gradation, plasticity of fines, and LAA. Should weathering be a deciding factor, price adjustment or treatment are possibilities. However, the situation should be evaluated specifically by a specially qualified individual.

As an aside, the Sand Equivalent Test is a good test for evaluating a pit-run source where the amount and nature of fines could be important, as with cherty gravels.

BINDER

Lateral stability of aggregate surfacing depends on gradation, particle shape, and binder. Binder may be obtained by plasticity of the fines (minus No. 40 material). The plastic fines contribute molecular bonding and hold moisture for surface tension binding. Plasticity indexes of 2 to 9 are generally specified. Less plasticity may not provide adequate stability. Higher plasticity may result in decreased strength, loss of stability, and slipperiness.

It is important to recognize that there are some well-graded materials with very good stability but with nonplastic fines. Also, there are some naturally cementitious aggregates such as limestone that have excellent lateral stability with nonplastic fines. Experience with local material should be used in developing the aggregate surfacing specification. Plasticity should not be specified if it is not needed, or if it will not be tested for and enforced.

Where plasticity is specified and needed, failure to meet this specification will be serious and may require a significant price adjustment. Alternatives to plasticity shortage, in addition to rejecting the material, include mixing a lightly plastic soil or ground bentonite at the plant or on the road. Excess plasticity may be improved by treatment with lime.

PRICE ADJUSTMENT

Price adjustment is not a cure-all for aggregate surfacing that does not meet specifications. In some cases, rejection may be reasonable and necessary. However, treatment, modification, or increased depth of the aggregate may be economical alternatives.

There is no "formula" for price adjustment for aggregate surfacing that does not meet specifications. Too many variables are involved and each situation is unique. Determining a reasonable price adjustment requires a blend of science, judgment, and fairness. The price adjustment should not give the contractor an advantage over other bidders for that project. A price adjustment should cover loss of service to the Government, increased cost, and decreased life. Local experience with difficult materials may provide an idea of lost strength,

added maintenance cost, or increased surfacing loss rates. The costs of removal and replacement or of correction provide benchmarks against which to check price adjustments.

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