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Shoulder Maintenance

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VALUE ENGINEERING STUDY OF HIGHWAY SHOULDER MAINTENANCE

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SUMMARY

This report summarizes the results of a cooperative Value Engineering Study of shoulder maintenance undertaken by the State Highway Agencies of Arizona, Idaho, Iowa and West Virginia under sponsorship of the Federal Highway Administration. The study was limited to unpaved shoulders.

Implementation of the recommendations in the four study States would result in a total estimated improved service value in excess of $1,000,000 annually. Cost of the study was $100,000.

Specific recommendations varied among the States according to local conditions. Among the recommendations are the use of larger trucks for hauling, use of side-discharge shoulder spreaders, modifications to the standard motor grader, and spot paving of shoulders in high maintenance locations.

The coordination meetings attended by study participants at intervals during the project yielded significant benefits beyond their immediate function of maintaining unity among the four State investigations. These sessions provided many chances for the team members to observe and discuss equipment and methods being used by others. Useful information was exchanged in several other highway operational areas besides shoulder maintenance.

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RECOMMENDATIONS

Specific recommendations of the individual State teams were developed in response to local conditions and some may not be suitable for blanket application. The set of recommendations given here is not intended to be a unified plan for revising shoulder maintenance. Instead, the intent is to present a selection of techniques for reducing the unit cost of shoulder maintenance activities with the hope of covering a variety of local situations. Some individual State circumstances are described in the comments accompanying the recommendations. Some of the suggested changes can be put into practice using existing general purpose equipment. Purchase of additional units may be desirable in some cases. Other recommendations require modification to existing equipment or possibly the fabrication or purchase of specialized machinery.

1. Shoulder Reshaping Without Adding Material

Recommendation: Add auxiliary blade behind moldboard of grader.
Comments: The front blade would smooth the shoulder and fill the edge depression, spreading excess on pavement. The rear blade would clean the pavement, eliminating one machine pass. A photograph of a light-duty version of such a blade appears on Page 5.

Recommendation: Add wing plate to grader blade.
Comments: This controls material flow at the blade tip, allowing the operator to fill the dropoff with little or no spillover onto the pavement. Its use would be limited to situations where sufficient material is available within one blade length away from the pavement edge. The photograph on page 9 shows such a device installed on the shaper blade of a side delivery spreader.

Recommendation: Tandem operation of motor grader and truck-mounted blade.
Comments: Maintenance units in snow regions have truck-mount plows on hand. The truck blade removes material spread on the pavement edge by the grader, thus eliminating a grader pass. Operating cost for a small to medium size dump truck with blade is lower than for a grader.

Recommendation: Permanently relocate delineator posts.
Comments: This applies chiefly to maintenance of the shoulder slope rather than the shoulder. Increased production could be obtained by permanently offsetting delineator posts, if compatible with delineation policy.

Recommendation: When only light reshaping is needed, use a light-duty maintenance device rather than a grader.
Comments: The tractor-drawn shoulder maintenance drag developed by Iowa DOT is illustrated on page 6. This equipment is less expensive to operate than a motor grader.

2. Shoulder Reshaping With Material Added

Recommendation: Increase the size of haul trucks, while reducing the number of trucks used on each job.
Comments: This generally reduces the unit cost of hauling. This recommendation would also apply to other maintenance operations involving hauling. The Arizona team has recommended increased use in that State of bottom dump semitrailers of the general type shown on page 10.

Recommendation: Where applicable, require each truck driver to load his own truck at the stockpile.
Comments: This generally applies to small jobs where loader operation is intermittent. It does not usually apply to situations where loader operation is continuous. Members of the Iowa team mentioned safety regulations require their drivers

to leave the truck cab during loading. In this situation, they would prefer to have the drivers operate the loader even though production might be slightly reduced.

Recommendation: Improve the locations and management of stockpiles.
Comments: This can have a significant effect on the costs of materials handling and hauling. It is applicable to any maintenance activity involving stockpiling and hauling.

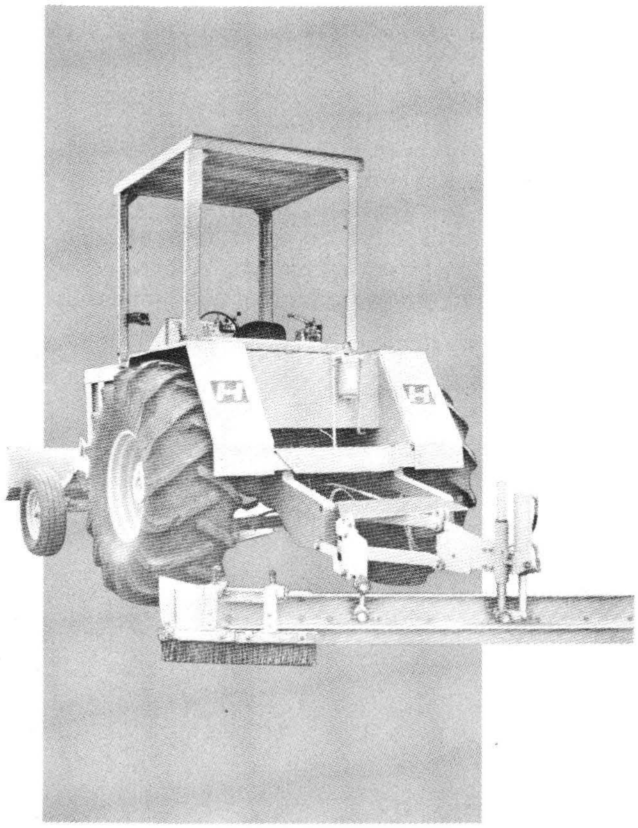
Recommendation: Deposit and shape the material in one operation using a side delivery spreader.
Comments: This is a single-pass operation. Traffic conflicts are minimized and costs reduced, largely because multiple grader passes and grader deadheading are eliminated. Iowa DOT has developed a truck mounted spreader for this purpose. Suggested improvements to the present design have resulted from Iowa's participation in this VE project. Photos of the present Iowa machine and commercial spreaders which could be used in this activity appear on pages 7, 8 and 9.

Recommendation: Use bottom dump semitrailers or conveyor dump bodies to place the repair material directly on the area needing repair.
Comments: This is an improvement over the use of conventional dumptrucks. The spread is relatively narrow, concentrating the fresh material in the area of the edge depression. The beds do not rise, so these units are more stable than conventional raised bed dumptrucks when operating on or partly on the shoulder slope. Typical units are pictured on pages 10 and 11.

3. Pavement Widening In Selected Locations

Recommendation: At locations where frequent edge repair is needed, reduce or eliminate dropoff maintenance by spot paving of shoulders, approaches, or turnouts.

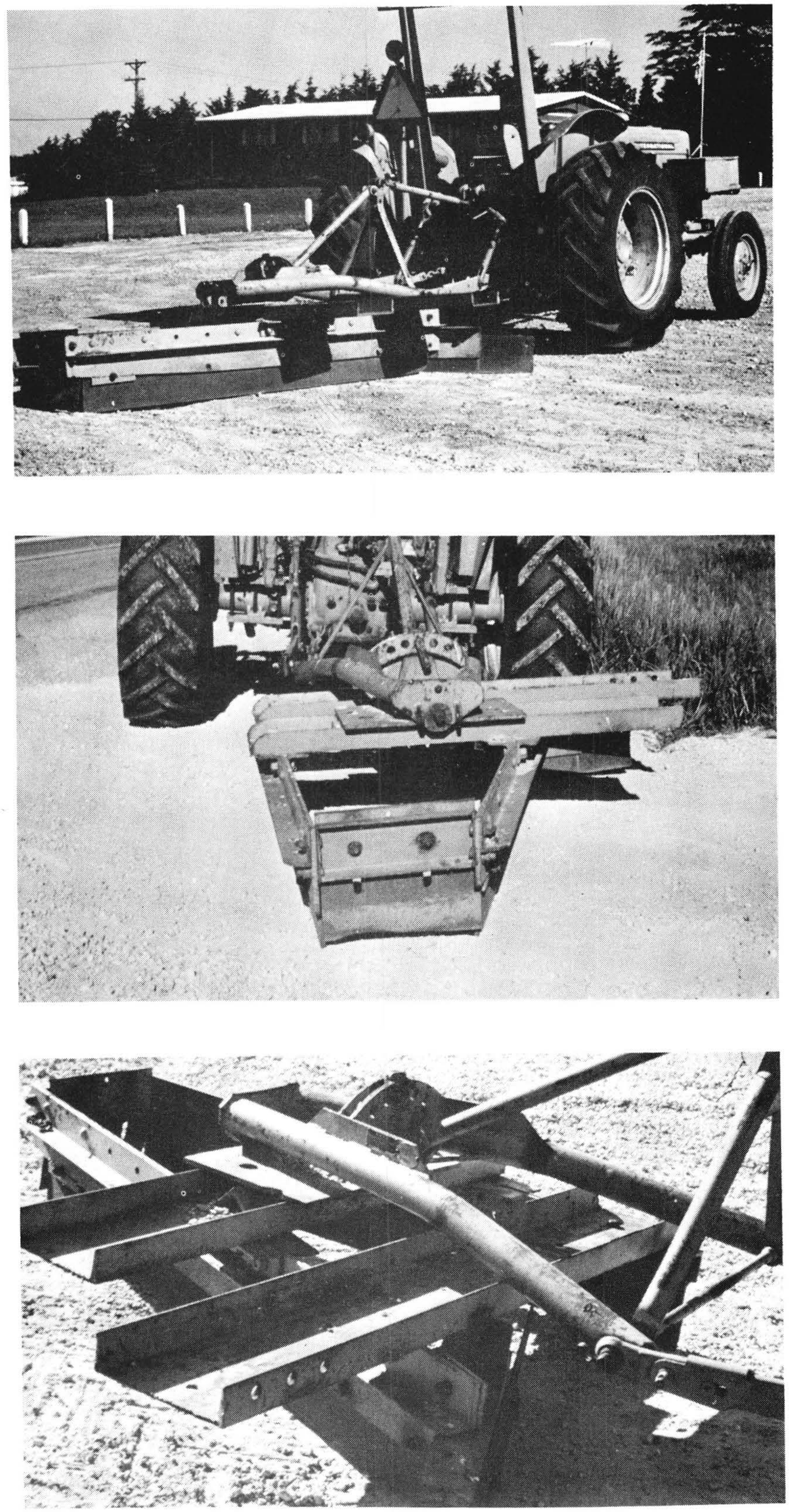
Comments: In some cases, the cost of spot paving can be justified by long-term maintenance savings. Additionally, pavement widening near approaches or turnouts can provide extra space for acceleration or deceleration on the pavement. This reduces the speed of traffic crossing the pavement edge, thus likely retarding development of the dropoff and reducing the risk of vehicle damage when the dropoff does form.



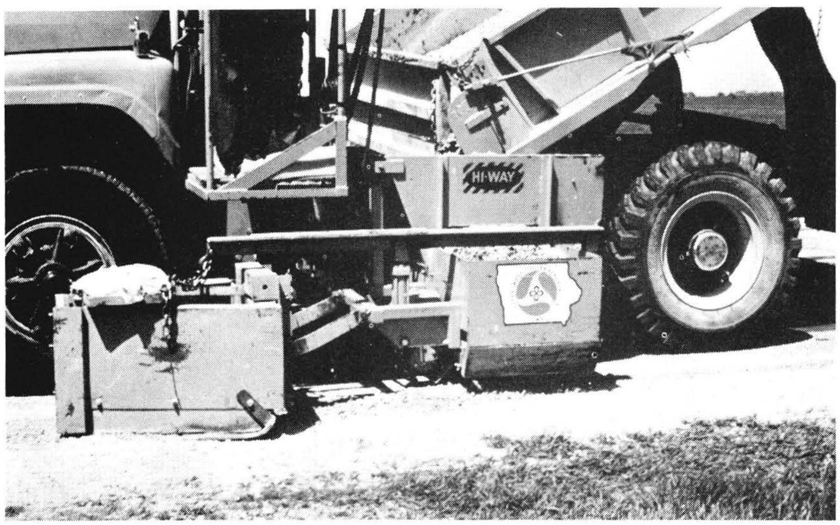
Huber Corporation, Marion, Ohio

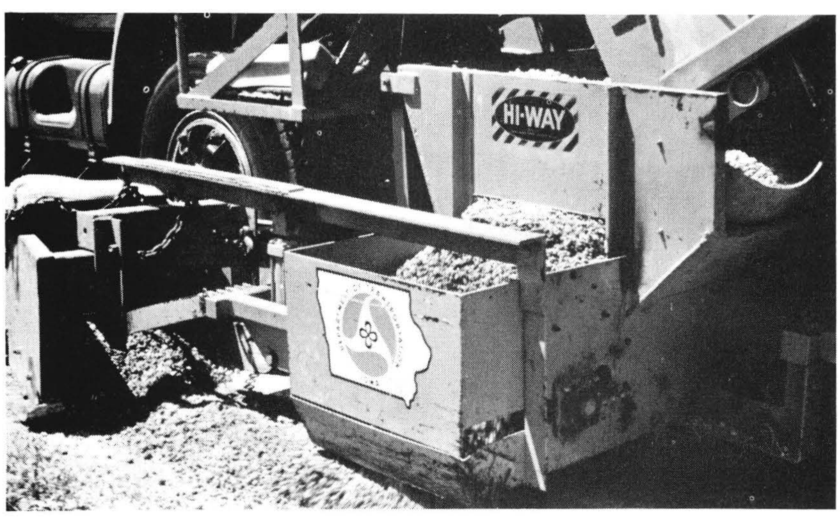
The auxiliary blade respreads material spilled from the end of the underbody moldboard, thus eliminating one machine pass normally required for pavement cleaning.

A Commercially Available Light-Duty Auxiliary Blade

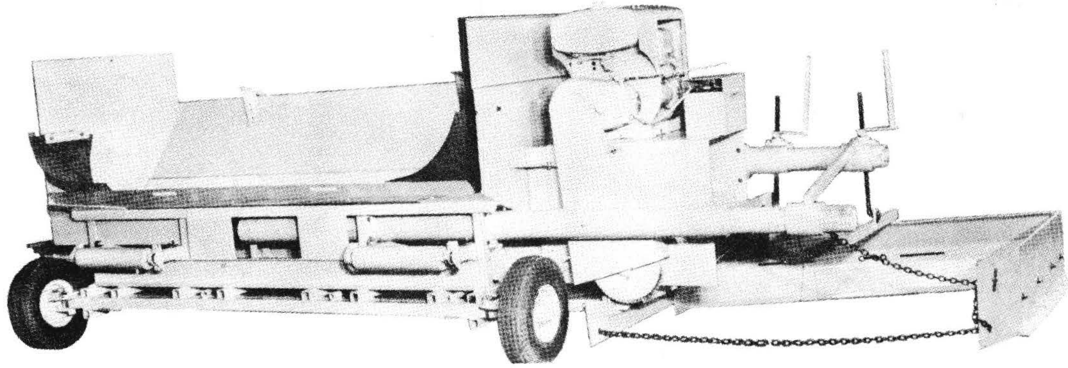


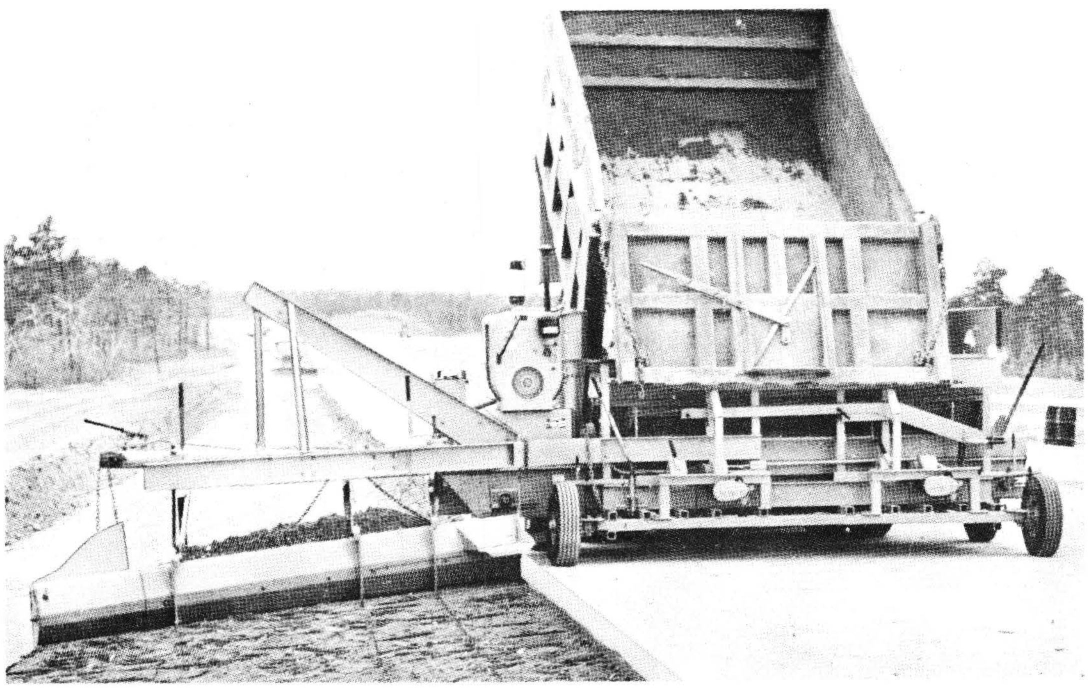
Light Duty Shoulder Reshaper
Developed by Iowa DOT





Side Delivery Shoulder Spreader
Developed by Iowa DOT

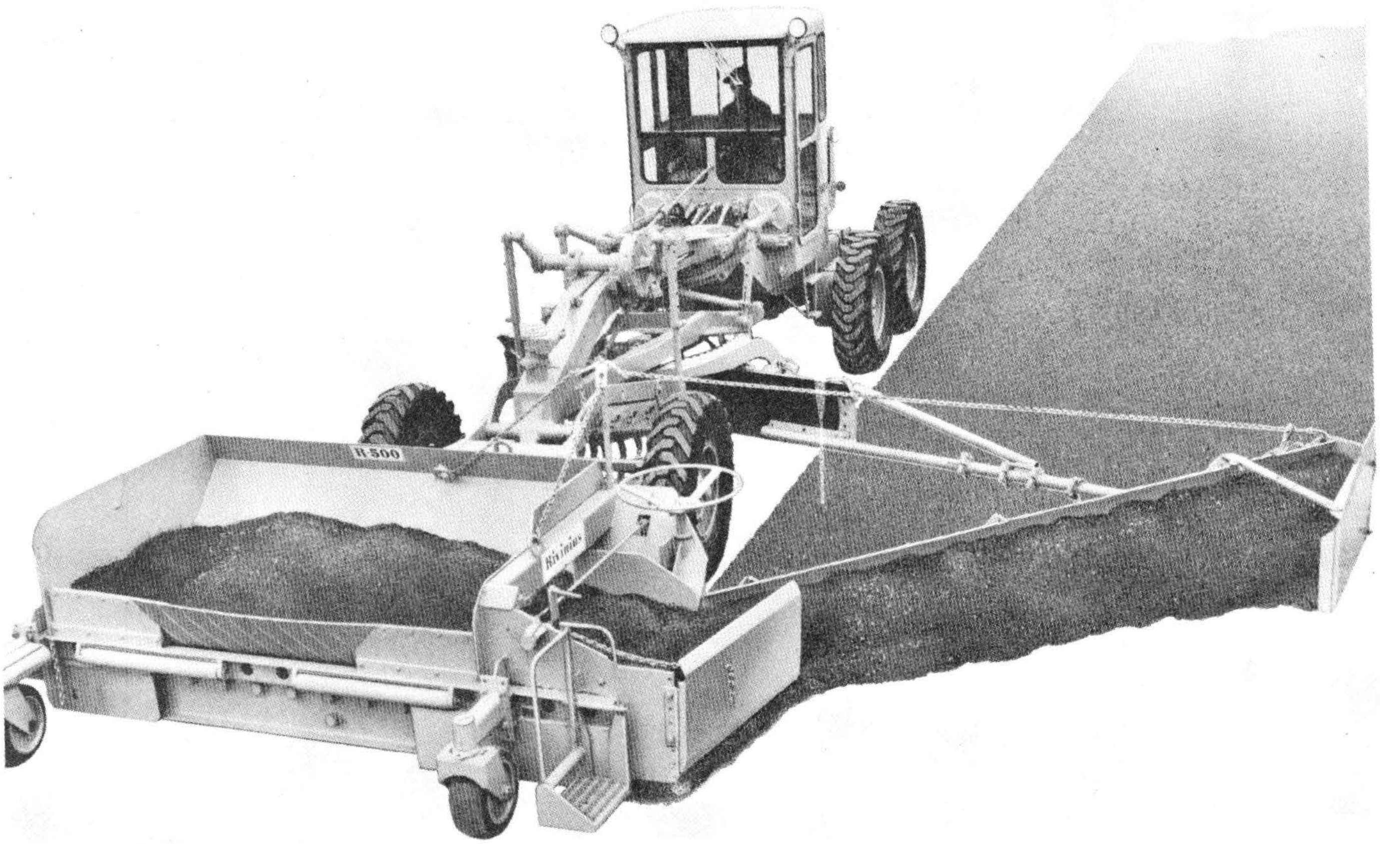




POWER-PACK®
CONVEYOR COMPANY 836 EAST 140th STREET•CLEVELAND, OHIO 44110

Width of spread is adjustable. Spreader Attaches to Truck Chassis by Means of Cables.

A Commercially Available Shoulder Spreader



Rivinius, Inc. EUREKA, ILLINOIS

Width of spread is adjustable. Conveyor is powered by a gasoline engine mounted behind the hopper.

A Commercially Available Shoulder Spreader

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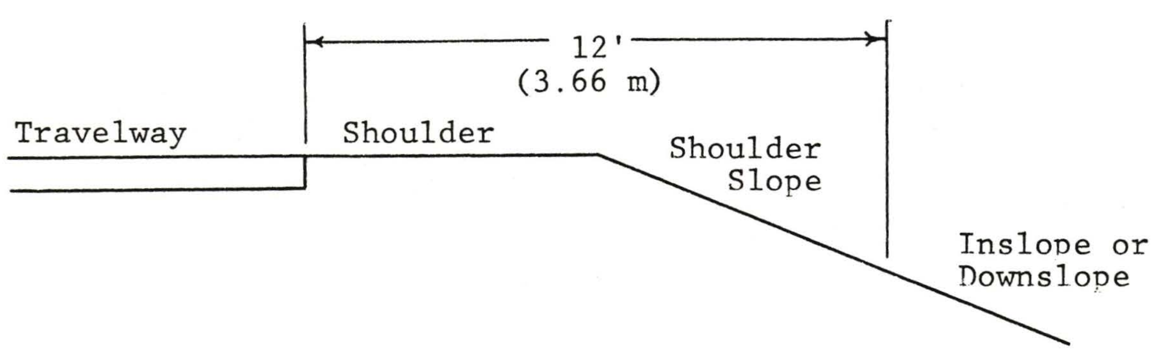
BACKGROUND

A recent study (1) by the Transportation Research Board (TRB) identified a number of highway maintenance research needs. One topic recommended for study was optimizing the expenditure of maintenance resources. Value Engineering (VE) is a system of analysis which can be used for this purpose. The Federal Highway Administration (FHWA) is sponsoring a series of State conducted maintenance research studies to promote the optimization of maintenance resources and to demonstrate VE techniques. This report summarizes one such project.

Value Engineering technique consists of an engineering team approach in which all basic functions of a process are defined, analyzed, and assigned values according to their worth in obtaining the end product. The low value/high cost functions are further analyzed to see if they could feasibly be done less expensively by alternate means or in some cases completely eliminated.

AASHTO definitions relating to the roadway cross-section (3) were used in this study. Pertinent definitions are detailed in the following sketch:



Maintenance of paved shoulders was not included in this study. A separate Federally-sponsored study on pavement patching is in progress, and the results should apply to paved shoulders as well as travelway pavement. Even when the shoulder is paved, however, maintenance is required on the unpaved shoulder slope. Some of the recommendations given here can be applied directly to maintenance of the unpaved shoulder slope next to a paved shoulder; others may require modification.

Two main shoulder maintenance activities were included in the study. The first is reshaping the shoulder using material which is in place on the shoulder or shoulder slope. The second major study activity is reshaping the shoulder using material hauled in from a separate source.

Sod shoulders were excluded from the study because maintenance of this shoulder type is not a high cost activity in any of the four study States.

Study agreements between the States and FHWA stipulated that maintenance of the joint between portland cement concrete (PCC) travelway and asphalt concrete (AC) shoulder be discussed. This activity is minor in terms of the overall maintenance budgets of the participating States, so it was not included in the value engineering part of the study. Instead, existing maintenance techniques were outlined for informational purposes only.

STUDY APPROACH

Once a VE study topic has been chosen, the next step is to identify the essential functions of the item or service being studied. Then several different ways of furnishing the item or service are systematically evaluated to determine how unit cost might be reduced without sacrificing any essential functions.

Value engineering uses a team-oriented approach to problem solving, so an early step in this project was to set up a VE team within the transportation agency of each of the four participating States. Each team made VE study of selected shoulder maintenance activities used in its State. All four teams and FHWA were represented at a series of four coordination meetings. One such gathering was held in each of the participating States. These meetings facilitated information exchange through personal contacts and also helped insure that all teams followed a common work plan.

At the initial coordination meeting in April, 1976, value engineering principles were briefly reviewed. Also, there was considerable discussion about which portions of the shoulder and shoulder slope should be included in the study.

Under the AASHTO definition of a highway shoulder, shoulder maintenance would include only the work done between the travelway edge and the point where the steeper shoulder slope begins. In Iowa and West Virginia, shoulders are seldom paved except on freeways, but in Arizona and Idaho, they are nearly always paved. Maintenance of paved shoulders is the same as travelway pavement maintenance, and the Arizona and Idaho team members could not accurately separate the costs of paved shoulder maintenance from overall pavement maintenance. Also, a separate FHWA sponsored study on pavement maintenance is underway and the results should apply to paved shoulders. For these reasons, the Arizona and Idaho teams chose to study maintenance of the unpaved area next to the pavement edge. Therefore, the study activities are generally performed on the shoulder slope rather than the shoulder in these two States. Interim goals were established for completion before the next meeting.

The second meeting was held two months after the first. Each team presented descriptions of three State maintenance operating units (station, shed, area, etc.) representing diverse conditions within the State. In addition, each group used audiovisual aids to demonstrate existing shoulder maintenance practices. Each team member was furnished a copy of the FHWA value engineering manual (2) to serve as a work guide.

The third coordination meeting took place the last week of August. At this point, the teams had collected cost data and had begun analyzing the selected maintenance activities. Much of the meeting period was devoted to the VE technique of "brainstorming". This consists of identifying as many methods as possible for carrying out the essential functions of the activity being studied. The ideas are later analyzed for cost and probable effectiveness and compared with existing methods.

The last week of November 1976 was chosen for the final meeting. Most recommendations were in their final form or nearly so and were presented at this session. A schedule was established for completion of the individual team reports and for preparation of the final report.

FINDINGS

Reshaping Without Adding Material

In seeking to improve this activity, an effective approach is to reduce the number of grader passes needed to carry out the function. The findings reflect two basic ways of doing this. One is to modify the grader and the second is to substitute a less expensive piece of equipment to carry out one or more of the operations commonly performed by the grader.

The most extensive grader modification proposed is the attachment of an additional blade behind the moldboard and offset to one side. The moldboard would cut and windrow the material and the secondary blade would respread it, thus eliminating one pass with the machine. This idea had not been tried in any of the four States before the study began, but generated considerable interest, particularly among the Iowa and West Virginia representatives. The photograph on page 5 shows a light-duty commercially produced blade of this general type.

A less elaborate grader modification is to attach a wing plate to the blade to allow more accurate material spreading. Such a device is shown at the end of the shaper blade in the photograph of the shoulder spreader on page 9. This controls the flow of material at the blade tip, allowing the operator to fill the dropoff with little or no spillover onto the pavement surface, eliminating a grader pass. This would be suitable only for moderate reshaping where sufficient material is available within one blade length away from the pavement edge.

Shoulder maintenance can be improved without modifying the grader by using it to pull material up the slope into the dropoff, then following with a truck mounted blade to clean the pavement. Either a front mount or underbody truck blade might be used. In snow areas this equipment is already on hand. Since a small to medium size truck with blade typically has a considerably lower operating cost than a grader, overall function cost is reduced by substituting the truck for one pass of the grader.

Reshaping with a grader is slowed and made more costly by obstructions in the shoulder area. The shoulder is ordinarily free of obstructions but the shoulder slope often contains delineator posts, signposts, mileposts and culvert ends. In areas where delineators are used, they are generally the most numerous shoulder slope obstructions, and relocating them further out would facilitate maintenance operations on the shoulder slope. This, however, may conflict with delineaton standards.

When only light reshaping is necessary, the grader can be eliminated entirely. This finding is illustrated by the tractor drawn shoulder maintenance drag used by some maintenance units of the Iowa DOT. It consists of a series of shaping blades joined to a framework and connected to the tractor by a three point hitch. The working elements are a blade to pull loose material from the shoulder surface into the edge rut, a blade to remove excess material which the first blade deposits on the pavement and a final blade to smooth the shoulder surface. This device is illustrated on page 6. The existing design is not suitable for heavy shoulder reshaping due to light construction and the lack of control over cutting depth.

2. Reshaping With Material Added

One area where significant improvement can be made in this activity is crew size. The number of operators on a given job can be reduced with no reduction in output by assigning fewer but larger trucks to the activity. This benefit would also carry over to other maintenance operations involving hauling. Arizona DOT has a number of 20 $yd.^3$ ($15.3m^3$) bottom dump semitrailers and the Arizona team recommended increased use of such units on shoulder maintenance in that State. Idaho and West Virginia representatives expressed some uncertainty whether such large trucks would be sufficiently maneuverable for use in the confined areas typical of some mountainous terrain. The Arizona team reported no such problems when using these trucks in the mountainous northern part of Arizona.

A second possibility for reducing crew size is for each driver to load his own truck. Equipment operators are generally trained to operate several equipment items including the loader, so no retraining will usually be needed. No full-time loader operator will be required, reducing crew size and freeing one man for other maintenance tasks. In Iowa, the truck driver is required by safety regulations to leave the cab during loading. Under these conditions a potential source of public complaint is eliminated if the driver is involved in the loading operation instead of merely standing by and watching. The Arizona team members, on the other hand, stated that their operations often require a full-time loader operator. When truck arrival times are such that the loader is working continuously, changing loader operators can create a bottleneck.

Aggregate for this activity is sometimes hauled from production site to permanent stockpiles throughout the maintenance area. It is then loaded and hauled to maintenance jobsites as needed. Material handling costs will often be reduced if arrangements can be made to haul directly from production site to the point of use, eliminating the extra handling associated with intermediate stockpiling.

If intermediate stockpiles are used, they should be located to allow a minimum number of trucks for transporting material to the maintenance jobs. However, there is a point of diminishing returns when stockpiles are so small and close together that loading equipment must be continually moved from location to location.

Often it will be more economical to arrage for the supplier to stockpile the material at selected locations instead of using highway agency men and trucks to haul from supplier to stockpile site. This is due at least partly to the fact that suppliers generally use larger trucks, thus reducing the unit cost of hauling.

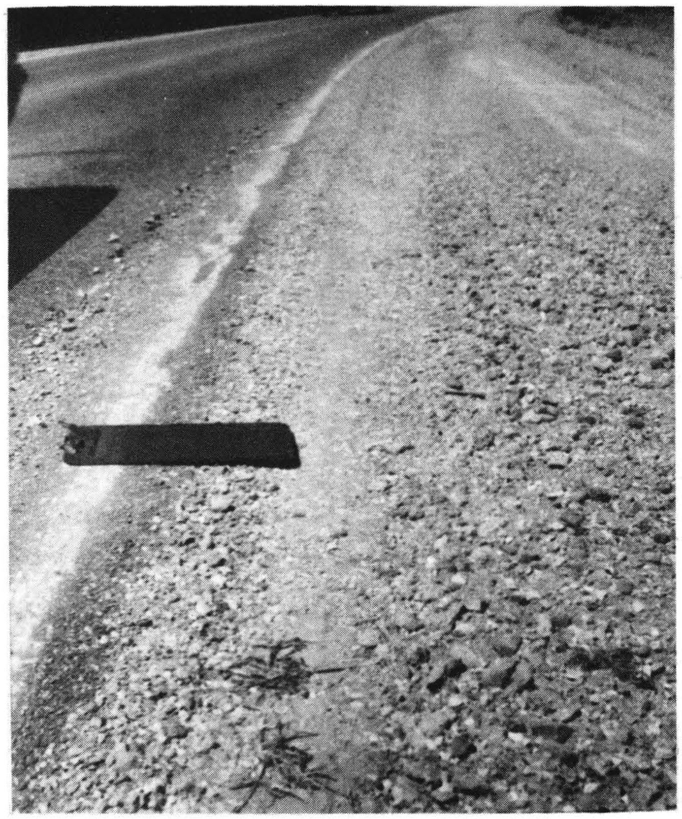
Material placement methods also present possibilities for improvement. The practice of dumping fresh material on the pavement, then blading it off to fill the edge depression, is inefficient. It also creates considerable interference with normal traffic because one lane must be closed during the activity. This procedure also leaves material on the pavement, requiring cleanup.

These undesirable features can be minimized by depositing the material directly on the area to be repaired, using a side delivery spreader. Suitable equipment is illustrated on pages 7, 8, and 9. These devices all include shaper blades, so placing and shaping is done in one equipment pass. Compaction can be done by routing haul trucks over the shoulder.

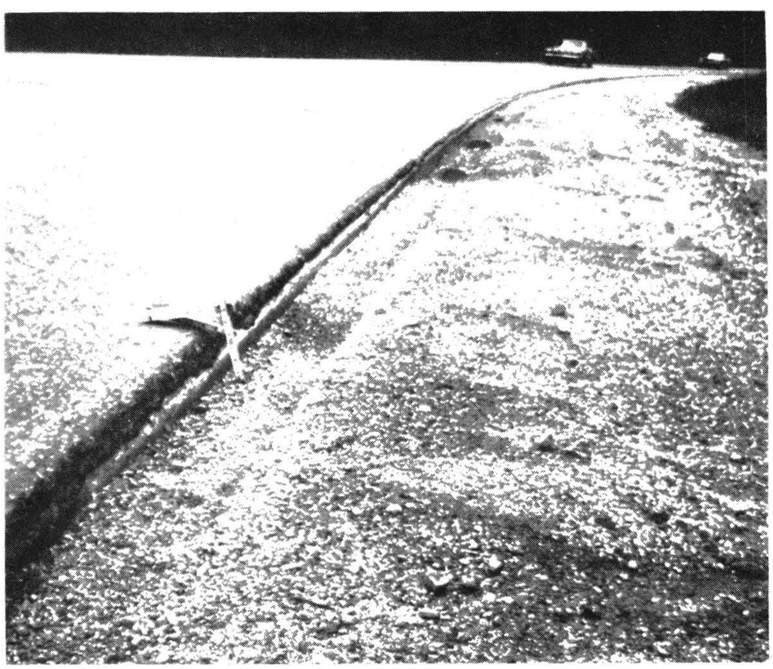
Another way to place the material directly on the area needing repair is to use bottom dump or conveyor dump haul units of the types illustrated on pages 10 and 11. These units permit a relatively narrow spread width, concentrating the fresh material in the edge dropoff area where it is most needed. In addition, the beds do not rise, so these units are more stable then conventional dump trucks with beds raised. This can be an advantage, particularly when the repair material is to be spread on the shoulder slope rather than the shoulder. Even so, these trucks can be used only on relatively gentle shoulder slopes.

3. Pavement Widening In Selected Locations

Some locations require very frequent shoulder repair. Typical examples are sharp curves (inner edge), unpaved commercial approaches, and scenic or delivery turnouts. To



Unpaved Commercial Approach Immediately
After Shoulder Reshaping



Same Approach 90 Days Later

illustrate, it was observed during this study that a severe dropoff developed at an unpaved commercial approach less than 90 days after shoulder reshaping. Only a short distance from this commercial approach, the reshaping repair had suffered very little deterioration after 90 days. This situation is illustrated on page 20.

Spot pavement widening at locations such as scenic or delivery turnouts could eliminate the problem by keeping the traffic entirely on the pavement. Spot widening near approaches and/or paving of approaches to the right of way line would allow extra room for acceleration or deceleration on the pavement, thus slowing the traffic crossing the pavement edge. This would likely retard development of the dropoff and would certainly reduce the possibility of tire or suspension damage caused by crossing the dropoff. It would also reduce the potential for greater damage due to loss of control when crossing the dropoff.

4. Maintenance Of The Longitudinal Joint Between PCC Pavement And AC Shoulders.

Three of the participating State agencies use specialized techniques to maintain this joint. In the fourth State, Idaho, this type of construction has been used for only a few years and no significant maintenance has been needed.

In Arizona, the problem which has been most troublesome is the formation of a longitudinal ridge in the shoulder next to the joint. It is believed the problem begins when cold weather contraction opens the joint. Dirt and pebbles enter the joint, preventing closure during hot weather. The AC shoulder pavement is, therefore, deformed upward in hot weather because it cannot expand sideways as it would if the joint were open.

The problem is prevented from developing by sawing, routing, or plowing this joint to a minimum 1/2" (1.3 cm) width, preferably full depth but at least twice the width; then filling it with a mixture of hot asphalt-rubber. This mixture consists of a light (A R 1000) paving grade asphalt and granulated rubber combined under heat to a reaction which results in a relatively economical, but resilient material. This creates an expansion joint which keeps out foreign material. Life of this treatment is considered to be in excess of 6 years.

The first joint maintenance procedure described by the Iowa team is filling the open joint when travelway and shoulder pavement surfaces are at the same elevation. The joint is simply filled with bituminous emulsion, then blotted with sand. The repair is effective for two to three years.

A different method is used in Iowa when a dropoff exists between travelway and shoulder pavements. The maintenance procedure used in this case is to place a slurry seal fillet about 18 inches (45.7 cm) wide on the shoulder next to the travelway pavement to smooth the transition. Service life is anticipated to be greater than five years.

In West Virginia longitudinal cracking has sometimes developed in the shoulders. The cause is believed to be base failure due to poor drainage. Drainage is improved by installing a drainage network consisting of trenches backfilled with fine granular material. A continuous longitudinal trench 4 inches (10.2 cm) wide and 16 to 20 inches (40.6 to 50.8 cm) deep is first dug along the joint. Transverse trenches are then dug from the main trench to the shoulder slope for lateral drainage. After backfilling and compacting, the trenches are repaved to a minimum depth of 4 inches (10.2 cm). This is considered to be a permanent solution to the problem.

The West Virginia team also described a highway section where the shoulders were paved with penetration Macadam rather than ordinary AC. Construction cost was said to be competitive with regular AC plantmix and no joint separation or differential settlement has occurred over a period of about 12 years.

ECONOMIC CONSIDERATIONS

A major emphasis of value engineering is cost reduction. If implemented, the recommendations of this report can be expected to reduce the unit cost of highway shoulder maintenance. This, however, would not necessarily be reflected in budget reductions. Instead, it is likely that more miles of shoulder would be well maintained at the same overall cost or that some resources would be transferred to other critical maintenance activities. Any reductions in the unit cost of shoulder maintenance would, therefore, probably be reflected in improved service rather than cash savings. For this reason, the term "improved service value" has been used instead of "cost reduction" in describing the estimated monetary benefits of implementation.

The recommendations made in this report result from studies of local conditions in the participating States. The recommendations are believed to have relatively wide applicability, but an agency considering adoption of any of them should conduct a short internal analysis to judge the potential economic benefits to the individual organization. In addition to checking the potential benefits of the recommendations, such analysis may reveal possible improvements not covered in this report.

Detailed cost estimates developed by the 4 teams have been omitted from this report, partly in the interest of brevity and partly because direct comparisons among them are clouded by differences in the estimating methods used. As an example, the existing unit cost of shoulder reshaping with material added was estimated as \$3.53/yd.^{3} (\$4.62/m^3) in Arizona, \$142/shoulder-mi. (\$88/shoulder-km) in Idaho, \$136/shoulder-mi. (\$84/shoulder-km) in Iowa, and \$7.79/ton (\$8.59/tonne) in West Virginia. Even if these were adjusted to a common production unit, differences would exist due to variations in equipment operation costs, varying practice on compaction and pavement cleanup, differences in assumed crew size, differing practices on computing appropriate loaded wage rates, and other factors.

Similarly, the improved service values estimated in these 4

States are not likely to be directly applicable to other agencies. Nonetheless, the following table is presented to illustrate the potential for improved service value resulting from implementation of recommendations in this report.

STATE	ACTIVITY	RECOMMENDATION	ESTIMATED ANNUAL IMPROVED SERVICE VALUE
Ariz.	Repair Gravel or Dirt Shoulder	Side Delivery Spreader	$140,000
Idaho	See Note	Various	$58,000
Iowa	Continuous Repair With Aggregate	Modify Spreader, Use Larger Trucks, Improve Stockpile Management	$135,000
Iowa	Blade Shoulders and Approaches	Auxiliary Blade on Grader	$100,000
W. Va.	Aggregate Stabilization of Shoulders	Side Delivery Spreader, Larger Trucks	$348,000
W. Va.	Blade and Shape Shoulders	Auxiliary Blade on Grader	$263,900

Note: In Idaho, reshaping and reshaping w/added material are reported under the same activity code, making it difficult to separate the costs. The estimate is based on the assumption that an overall improvement of 20% can be attained.

When studying the economics of shoulder maintenance, the possibility of reducing the maintenance by paving the shoulder area should not be overlooked. Paving is initially much more expensive than gravel or chemically stabilized shoulder construction but generally has lower maintenance requirements. In addition to a greater surface durability, paved shoulders retard the formation of a dropoff or edge depression next to the pavement. This is true because the vehicle encroachments which contribute to the formation of ruts on aggregate shoulders would not harm paved shoulders. At locations where traffic enters or leaves the highway, pavement widening could provide room for acceleration or deceleration lanes, thus reducing the speed of traffic crossing the pavement edge. This would also be expected to retard formation of the dropoff. Estimates of the economic effects should be made based on local data, if available.

Shoulder paving may provide economic benefits beyond maintenance reduction. The extra paved width may improve traffic capacity and safety, representing economic benefits to users. The effects should again be estimated using local data if possible.

Firm data about the economic effects of shoulder paving on maintenance, vehicle operating cost and accident rate is unfortunately not widely available. Therefore, such factors can usually be evaluated only in a subjective way during the shoulder type selection process. Improvement in this aspect of shoulder type determination would be desirable.

OBSERVATIONS

Many study team members were unfamiliar with the details of value engineering at the beginning of this project. As experience was gained, it became apparent that the systematic, comprehensive analysis which is part of the value engineering framework can very effectively pinpoint areas of possible improvement.

A second important aspect of VE was also demonstrated as the study progressed: the in-depth analysis associated with VE can be very time consuming. Because of this, the scope of a VE study should be narrow if a short completion time is desired.

Most of the recommendations of this report could be put into practice in a short time and at moderate initial cost. Benefits from implementation would not be of a delayed type but instead should be evident shortly after recommendations are adopted.

The coordination meetings held during the study provided an excellent chance for maintenance personnel from widely separated parts of the country to exchange views and information on topics of mutual interest. One item which received considerable discussion is the maintenance management system. All four participating State agencies have adopted such systems, which are intended to improve management of the maintenance function.

An essential component of any effective management system is feedback, or information returning from the managed function to indicate how well the function is being performed. Reports of work units and resources used to accomplish them constitute such feedback and are universal features of maintenance management systems. A feedback item not frequently measured quantitatively is the level of service being provided. Among the four study States, only Iowa has a formal procedure for estimating the degree of compliance with maintenance standards. This additional feedback item helps managers judge the overall effectiveness of the maintenance program so they can make timely adjustments in standards, procedures, or re-source allocation as needed. Unfortunately, maintenance standards are sometimes written in such a way that quantitative measurement of the degree of compliance is very difficult. This makes it difficult to ascertain the actual quality of service being provided. Quality of service is a topic recommended by TRB for further research (1).

In a broader sense, much of the record keeping associated with maintenance management systems can serve as feedback to be used in overall management of the highway agency. Detailed records permit maintenance cost comparisons among various design features and various operating conditions. Such information can provide the planning and design functions with rational life cycle costs of various shoulder types (and other roadway features). This life cycle cost would include maintenance cost data by type and quality of material, performance, frequency of maintenance required, initial construction costs, safety of user data (accident reports), etc. This, of course, could be very helpful in highway planning and in choosing optimum design features. What is significant is that with the advent of maintenance management systems, the basic data to feed such a process is available for the first time. In addition, data furnished by the maintenance management system provides the capability to apply VE concepts to total highway planning, design, construction and maintenance functions. It is evident that through such applications, based upon quantitative data, considerable savings can be effected that were heretofore not possible.

The benefits of this project have not been limited to shoulder maintenance and value engineering. Ideas were exchanged on a number of other subjects. Among these were snow removal equipment and policies, mowing policies, signing and traffic control, and others. Several special purpose maintenance items are used by the participating State agencies and could be of interest to others. Some examples are a small trailer for carrying warning signs and traffic cones to the work site (Iowa), portable concrete median or edge barrier rail having the "New Jersey" cross section (Idaho), and an air deflector mounted horizontally above the tailgate of a sand spreader truck to prevent snow from accumulating on the tail-lights (Arizona).

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