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CURRENT PRACTICES IN SHOULDER DESIGN, CONSTRUCTION, MAINTENANCE AND OPERATION

A Joint Activity by the Committee on Shoulder Design
and the Committee on Operational Effects of Geometrics

FOREWORD

Knowledge of much unreported research and development work on shoulder construction and maintenance equipment and methods, on design and operational requirements, and on cost effectiveness led these two Committees of Groups 2 and 3 to cooperatively develop a Conference Session on these subjects. The Session was a part of the Board's 51st Annual Meeting, and the summary of the Conference Session presentations in this Circular was prepared in order to circulate the state of the art and concepts to a much larger audience than was able to attend the Session. A wide range of highway administrators, designers, operation and maintenance specialists and safety professionals will find food for thought and application in this summary.

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CURRENT PRACTICES IN SHOULDER DESIGN, CONSTRUCTION, MAINTENANCE AND OPERATIONS

Neilon J. Rowan, Texas Transportation Institute

Much unreported, in-house State research and development work has been done on shoulder maintenance methods, equipment and requirements, construction equipment and methods, design requirements, traffic control regulations, markings and warrants, and cost effectiveness. This research and development work cuts across many of the disciplines represented in the two HRB committees, "Operational Effects of Geometrics" and "Shoulder Design." There is some concern that variables of greatest concern to each of these individual committees may be improperly appreciated or controlled in the research and development work fostered by the other HRB committees concerned with construction, operations and maintenance. Accordingly, what follows is 1) a survey on shoulder design and operation practices, 2) desirable criteria for the geometric design and operation of shoulders, 3) shoulder structural design and construction considerations, 4) shoulder maintenance considerations and 5) shoulder practices and performance in two States.

SURVEY ON SHOULDER DESIGN AND OPERATION PRACTICES

Neilon J. Rowan, Texas Transportation Institute

In an attempt to determine the extent of technological advances employed in current practices, the Highway Research Board Subcommittee on Primary Stopping and Recovery Area of the Operational Effects of Geometrics Committee, A3E02, conducted a questionnaire survey of the design and operation considerations of highway shoulders. The questions were selected in order to obtain comparable data on shoulder design characteristics relating to warrants and guidelines, natural contrast, use of edgelines, shoulder widths, and structural quality of shoulders as compared with that of the main lanes. From the questionnaire sent to the 50 States and the District of Columbia, 47 responses were received.

Several factors concerning shoulder design criteria and operation practices become evident from this survey and the research background. First, the survey results indicated general agreement on the basic need for good shoulders. In addition, a majority of respondents expressed agreement regarding shoulder criteria for the Interstate Highway System; however, this may simply be due to an adherence to imposed standards.

In other areas of design criteria, dissenting opinions appeared. For example, 13 percent of the respondents indicated that they did not have any design criteria. The reasoning for such lack of warrants requires further study.

The survey also revealed that four States permit slower traffic to use the shoulder area to facilitate a passing maneuver. The reasons for allowing this maneuver should be analyzed, and a basis for allowing or forbidding this maneuver established.

Although all respondents endorsed the use of edgelines, there was very little consistency in the lateral placement of these edgelines. Research is warranted in this area to determine the effect of various placements of edgelines.

Still other areas of design criteria, such as natural contrast, require investigation. The 77 percent of the respondents endorsing natural contrast between the shoulder and the main lanes must have some reason for this action. On the other hand, what is the reason that 23 percent do not strive for natural contrast? Research is needed to determine if the result created by natural contrast is actually beneficial to the driving environment.

Another controversial area is that of shoulder width. Although there is general agreement that shoulders are beneficial, there has been no agreement on the most desirable width for shoulders. This is definitely an area where technology has not only preceded research, but in some instances technology actually contradicts certain research findings.

All of these inconsistencies lead to a very important point. If such concern about the effect of standardization and continuity of design has led to the development of a Manual on Uniform Traffic Control Devices, then why are standards not established for shoulder design? It is true that shoulders form a very real part of the driving environment and, even though technology has apparently outdistanced research in this field, the results of the application of this technology should be studied to determine its effectiveness. If effective criteria have truly evolved from technological experience, then these results should be communicated and applied among the States. In any case, it is imperative that this phase of highway safety be thoroughly investigated and, if at all possible, specific recommendations presented.

DESIRABLE CRITERIA FOR THE GEOMETRIC DESIGN AND OPERATION OF HIGHWAY SHOULDERS

D. W. Loutzenheiser, Federal Highway Administration

A shoulder is defined by AASHO as "the portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses." It varies in width from only 2 feet or so on minor rural roads where there is no surfacing, or the surfacing is applied over the entire roadbed, to about 12 feet on major roads where the entire shoulder may be stabilized or have an all weather surface treatment. Along divided highways, the median side or left shoulder may differ from that on the outer or right side.

In the highway cross-section, the term "shoulder" applies to the width from the edge of through lane to the intersection of the shoulder slope and the side slope plane. As may be needed, modifying adjectives are used with the term shoulder to describe functional or physical characteristics. The "graded" width is that just described, as distinct from the "surfaced" (or paved) shoulder, the meaning of which is obvious. Also designated is the "usable" width which includes the upper portion of the rounding where the side slope is not steep.

Features

From what is known today, what are the desirable elements and features of a highway shoulder? For a shoulder along a high-type highway they can be described as follows:

(1) provide clear delineation from the through lane pavement by an inherent good contrast, both color and texture;
(2) have a cross slope sufficient to drain effectively yet not affect vehicle operation thereon;
(3) furnish enough width to accommodate stopped vehicles, with some clearance, as for tire change, or temporary standing of a maintenance vehicle;
(4) furnish additional outer width as may be needed for berm (outer) curbs to control drainage or guardrail installation;
(5) be flush and level at the through lane edge to permit pull-over at highway speed without major steering effort to retain control;
(6) have inherent structural stability to assist in pavement edge support and to carry the expected types of vehicles under all weather conditions without rutting or other surface variations;
(7) have a structural surface and base course design that permits construction processes complementing those of through-lane pavement;
(8) have a pavement-shoulder interface (joint) design that remains sealed to prevent infiltration of surface water where the shoulder is of different structural type than the traffic lane;
(9) be of a type to permit efficient, economical maintenance;
(10) have a total low construction-maintenance cost that is in keeping with the actual infrequent use at any one point; and
(11) provide continuity of all of these features along the highway, without abrupt change in character or width when passing over or under structures.

Some of these features involve trade-offs, and it is not always practical to obtain all of them even on our highest-type highways. On low-volume highways some of them remain economically unattainable, even though highly desirable.

Functions

The basic functions of a highway shoulder are largely evident in this list. There are four main ones: delineation, drainage, structural support, and emergency and safety uses. Each of these needs further explanation.

Regarding delineation, a highly visible, contrasting shoulder is important so that drivers clearly and easily can discern their proper paths in the travel lane. Color distinction is essential, but equally significant is a texture or appearance contrast with that of the travel lane. Delineation is needed during bright, sunny daytime hours, but is even more vital during the hours of poor visibility, namely night-time and wet weather conditions.

The shoulder, as the outer part of the roadway, is the governing area for surface drainage. Whether surfaced or not the shoulder must insure that surface water will drain rapidly from the pavement. For the most part, this drainage is a lateral sheet flow over the shoulder and down the side slope, requiring a cross-slope suitable for the shoulder surface character. However, for some earth slope and climatic conditions, the shoulder area along highway sections on profile gradient also functions as a longitudinal drainage channel to the proper discharge point in the storm drainage system, with outer curbs to prevent over-the-slope flow.

The shoulder strip, if properly designed to do so, furnishes structural support to the pavement base and surface courses by serving as a buttress along its edge. The structural composition of the shoulder itself provides both vertical and lateral support to the outer strip of pavement so that it remains integral under extreme edge wheel loads. An important part of this role doubtless is the umbrella effect, serving to prevent moisture from edge penetration into the pavement structure.

The emergency-use function of a shoulder is the one most commonly cited, especially that whereon a vehicle can stop in a position clear of the traffic lane when there is motor trouble or a flat tire. To serve this purpose the shoulder should be of adequate width and capable of supporting the vehicle (including large trucks). Such clear stopping space not only is essential for safety on other than low-volume highways, but is a means of contributing to full traffic capacity. The shoulder also provides operating space for some maintenance activities and vehicles which must remain clear of the travel lanes. A flush, smooth shoulder area also is valuable when a driver unintentionally edges off the travel lane; in effect it is an auxiliary lane on which he corrects his path. Further, the shoulder is the most useful part of a clear roadside area on which the driver of an out-of-control vehicle has a chance to begin to regain control or reduce the severity of an impending accident. The shoulder width also functions as very desirable clearance area, contributing to the comfort and ease of motion in the travel lane, all rails, signs and slopes being outside of it.

Geometric Details

Width--Geometric design involves the three-dimensional (lateral, vertical and longitudinal) arrangements of each highway element and all of them in combination. Shoulder width is a very important element. For safety a shoulder should be of sufficient width so that a stopped vehicle clears the traffic lane by at least 1 and preferably 2 feet. Additionally there should be some similar clear space on the outside, not necessarily surfaced. For passenger vehicles an 8-foot shoulder width is minimal and a 10-foot is desirable. For bus and truck vehicles, a 10-foot width is minimal and 12 feet is desirable. These needs are reflected in the widespread practice for freeways and other high type highways of providing 10-foot surfaced right shoulders. Also it is common practice on freeways with 6 or more lanes where there is a large percentage of trucks, to provide 12-foot surfaced right shoulders. In most cases the graded shoulder is some 2 to 5 feet wider than the surfaced width. This provides the needed usable space outside that surfaced, and also permits guardrail installation where needed.

Highway design always entails judgment in those infrequent cases where land space or cost restraints make even minimum design dimensions questionably large. The Interstate standards themselves state --- "in mountainous terrain involving high cost for additional width, the usable width of shoulder may be less (than 10 feet) but at least 6 feet." For the very tight conditions on rural highways in mountains, which usually do not involve high speeds or volumes, the 6-foot shoulder continues to appear functionally acceptable for high-type highways, including freeways. However, wider full-stop sections or bays should be included at reasonable intervals. At the other extreme, a few long freeway structures with 6-foot shoulder carrying heavy urban traffic are viewed by some engineers, but not all, as entailing operational problems. Specific data are lacking, but a prevailing view is that 6-foot shoulders are inadequate for urban traffic, even the special case conditions. Where the desired 10 to 12 feet cannot be attained, a width of at least 8 feet appears to be needed.

On highways carrying low volumes and/or lower speed traffic, narrower shoulders are acceptable and probably necessary. Here a 4-foot shoulder width is minimum and a 6- to 8-foot width is desirable. The continued widespread use of this 4- to 8-foot range usually in relation to speeds and volumes, indicates general acceptability for these conditions. Paved or surfaced shoulders may not be necessary on low volume highways. Graded widths of about 10 feet are desirable where good turf cover is climatically feasible.

On freeways and other divided highways the left shoulder width is not always the same as that on the right. On 4-lane highways, motorists needing to stop should not be encouraged to use the left shoulder. Instead they can and should use the right shoulder, having to cross only one traffic lane. However, traffic on an 8-lane highway usually makes it both difficult and hazardous for a vehicle on one of the inner two lanes to reach the right shoulder for an emergency stop. Accordingly, a usable left shoulder is considered to be a proper part of an 8-lane freeway. A 10-foot surfaced width usually is desirable for the left shoulder. Since trucks normally are restricted to the right lanes, left shoulder usage will be primarily by passenger vehicles, for which an 8-foot width is acceptable. However, most 8-lane freeways are urban, with fairly heavy volumes around the clock, making all maintenance and emergency vehicle operations difficult. It is now viewed that these conditions support a 10-foot left shoulder to provide essential space for them.

Stopping conditions on 4-lane freeways and divided highways are sufficiently different, and a full-width left shoulder is considered to be not only unneeded but also undesirable. Since only one traffic lane must be crossed to reach a shoulder on the right, and since it is operationally hazardous to encourage stops adjacent to the higher-speed left traffic lane, a full left shoulder is not provided. A surfaced left strip usually is included for delineation and pavement structural support. While it is called a left shoulder, functionally it is not. A surfaced left strip of 2-foot width is considered a minimum to furnish the structural support features, but a 4-foot width is generally accepted as being more practical. As a part of clear roadside design for safety the median cross-section should furnish a left-graded shoulder width of 8 to 12 feet or equivalent flat-rounded area.

The case for left shoulders on 6-lane divided highways is intermediate to the 4-lane and 8-lane cases. It is generally accepted that the 4-lane treatment is most applicable and obviously suitable for rural sections with reasonably wide medians. However, recent experience on 6-lane facilities in and near urban areas, especially on routes carrying many trucks, shows increasing support for providing surfaced left shoulders of the same width as on 8-lane sections.

Shoulders also are essential parts of ramps at interchanges, which may vary from sharply curved loops to high-type alinement directional roadways. The variety of curve, superelevation, curbs and other controlling conditions do not permit a brief summary. In general, each ramp should furnish enough pavement plus shoulder width to permit passage around a stalled vehicle.

Cross Slope--Shoulders are an important part of the surface runoff system. Normally, shoulders are sloped to drain away from the traffic lanes. Their cross slope should be steeper than that of the traffic lane to drain the surface water rapidly, but not to the extent that they appear disturbingly pitched to drivers or actually hazardous in use. The applicable shoulder slope is dependent on the surface type. The following shoulder slopes in general use have proven to be functionally suitable:

Hard surfaced	.03 to .05 foot per foot
Gravel or crushed stone	.04 to .06 " " "
Turf	.08 " " "

On horizontal curves, the shoulder on the high side of a superelevated cross-section may require adjustment in its slope design so as to avoid too large a grade break (algebraic difference in cross slope grades) at the outer edge of traffic lane. This calls for a special design solution for each case.

Where curbs are used on the outside of shoulders, the cross slope on the outer portion of the shoulder may be made somewhat steeper to provide the needed flow channel.

Continuity--A highway shoulder should be continuous. The basic roadway section desirably should be carried without change under or over structures, across high fills and through large cuts. This principle now is being applied widely on high-type highways. The lateral dimensions to carry approach roadway shoulders over or under structures required several years of analysis before resolving the economic versus operational features. It is now generally agreed that the safety gains out-weigh the previous concerns over cost increments to widen bridges or lengthen overpass spans to continue shoulders unchanged on all high-volume and high-speed highways. To the extent feasible, these same objectives are being strived for on lower volume roads, but usually are not attained.

Delineation and Contrast

The shoulder should truly contrast with the traffic lanes during day and night, and in good weather or bad, yet still be within reason on construction and maintenance costs. It should be noticeably different in color.

It should have surface texture obviously different from that on the traffic lane, with small aggregate surfaces that reflect light. Desirably the shoulder surface should produce a different sound effect when a vehicle drives on it and also a vibration effect that through finger tips or seat-of-the-pants advises the driver that he is off the traffic lane. A turf shoulder offers much of the desired delineation and contrast with either concrete or bituminous traffic lanes, but lacks essential structural qualities. Surfaced shoulders that give the structural quality needed at practical costs either do not have or do not retain all of the other desired features.

Bituminous shoulder surfaces are dominant in the construction, stability and maintenance features. They offer excellent initial contrast with portland cement concrete traffic lanes but with many aggregates the distinction diminishes with time. It is difficult to attain a good contrast initially between bituminous shoulders and bituminous concrete traffic lanes and even more difficult to retain the contrast. Seal coating shoulders with light color stone chips has been an effective start, but the contrast wanes after several years in operation. The shoulders begin to darken and the dark traffic lanes lighten. Trials of colored concrete and colored bituminous courses likewise faded to unnoticeable distinctions. As a whole, this is an unsolved materials problem. The best answer so far is a form of repeated treatment, which has distinct limitations.

A variety of forms of jiggle bars or strips laid transversely or diagonally across the shoulder have been considered and tried. These offer vertical elements which contribute to the delineation. Likewise shoulders of stone block, rough brick or rubble surface, or conventional types with corrugated surfaces have been tried. These are costly to build and are not compatible with the usual maintenance equipment and processes. In some cases they have been provided to deter use of an otherwise smooth shoulder as another traffic lane. It appears that a desired contrast solution will not be attained for widespread use through any of these forms.

Delineation can be added to the pavement and shoulder types that have proved practicable and durable. The Manual on Uniform Traffic Control Devices (MUTCD) now specifies a standard pavement edge stripe (a continuous stripe 4- to 6-inch wide) which has proven quite effective and has gained highly favorable motorist reaction. It is effective during daytime and darkness when dry, but as with any paint stripe, it loses visibility when under a film of water. Also, it must be renewed frequently. Thermo-plastic lines having a slight vertical dimension possess some other better characteristics but are not generally accepted as being cost effective. Raised pavement markers, with a "hot" reflection are also highly effective, but they do not mix well with current snow removal operations.

Continuous shoulder delineation and contrast is highly desirable but as yet we have not developed practical and long life materials or systems that will continue to provide it.

SHOULDER STRUCTURAL DESIGN AND CONSTRUCTION CONSIDERATIONS

Lloyd J. McKenzie, Illinois Division of Highways

When considering the structural design of highway shoulders, the functions of shoulders obviously must be taken into account. Their prime purpose is to provide a safe all-weather refuge for those few vehicles that must leave the main traffic stream. Secondarily, they can enhance pavement performance by providing lateral support and by retarding the subsurface infiltration of surface runoff.

Although the number of stops per mile of shoulder for a given traffic volume can be expected to vary from time to time and place to place, shoulder usage, in general, is quite small in relation to the traffic volume on the pavement, but the size of axle loadings is the same. Shoulder usage studies indicate that shoulders can be designed less strong than pavements with respect to axle-load repetitions, but they must be capable of supporting the same axle weights as the pavement without structural damage.

The advent of modern paved shoulders has not been accompanied by the development of any rigorous method of structural design. It seems that, as a general rule, the same factors that govern the structural design of lightly traveled pavements should govern the structural design of shoulders, but experience suggests that this is not completely true. For example, dense-graded granular materials, that have had good records in trench-style roads, have proved to be totally inadequate in shoulder service because of water entrapment when they are placed in trenched sections adjacent to pavements.

The method adopted for designing Illinois pavements was developed from the AASHO Road Test equations. These equations describe the structural design requirements for a specific level of performance at a particular load and traffic volume under the Road Test conditions. Modifications were then made, based on experience, to cover a broader range of Illinois conditions than those that prevailed at the Road Test site. Attempts to make use of the AASHO Road Test structural design approach in shoulder design, considering the limited number of axle-load applications, have not produced results consistent with experience.

It is believed that paved shoulders need not have the structural capacity of the adjoining pavement, nor should they cost as much, either initially or on an annual basis. Still experience has shown that skimping in the initial design of the shoulder system can be costly. One important factor here is the need for an underdrainage system that is at least equivalent to that for mainline pavements if detrimental frost action and moisture movement are to be prevented. Another factor is the durability of the shoulder paving materials. Materials that are used for paved shoulders must be highly durable to resist the freeze-thaw effect in the presence of de-icing chemicals, particularly, near the pavement edge.

When traffic volumes are low, shoulders constructed of natural soils have usually proven adequate. Such shoulders should be compacted during construction to avoid later unwanted settlement and trimmed to offer quick surface drainage.

Slopes of 1/2 inch per foot have been found to provide adequate drainage without interfering with the primary use function. A good growth of turf is desirable to add structural stability, reduce erosion, and provide a dustless surface. Natural soil shoulders have served adequately adjacent to many miles of pavement where traffic volumes are less than 750 vehicles per day. With greater traffic volumes, stability of the earth shoulders was improved by addition of granular materials or other stabilizing additives to the natural soils and by use of dense graded granular shoulders in trenched section. Then interest turned to the more needed heavy duty, paved shoulders now in use on modern, heavily travelled, high speed, expressways.

The search for inexpensive paving materials for heavy duty shoulders led to experimentation with stabilizing binders to accompany the granular materials. Experimentation and comparison of bituminous-aggregate mixtures (BAM), cement-aggregate mixtures (CAM), pozzolan-aggregate mixtures (PAM), and plain portland cement concrete for use as shoulder paving materials have yielded the following results:

Freezing and thawing in the pavement-shoulder joint result in collapse of the PAM and CAM base courses at the pavement-shoulder interface permitting the bituminous surface to be cracked by traffic. Accordingly, they can best be used as pavement subbases and as the base course in secondary road construction where they have given excellent service in the past.

Both bituminous-aggregate mixtures and plain portland cement concrete have proved to be adequately durable for use as shoulder paving materials.

The bituminous-aggregate mixture, although durable, required a minimum thickness increase from 6 to 8 inches to alleviate alligator cracking and rutting when the mixture was placed directly on frost-susceptible soils. The 6-inch portland cement concrete shoulders proved to be structurally adequate, and maintenance requirements have been minimal.

For good shoulder performance, the first need in construction is a firm foundation on which to place the shoulder pavement. The subgrade should be iniformly compacted and graded to the shoulder side-slopes with sufficient lateral slope to provide satisfactory drainage.

Crushed stone and crushed gravel are superior to natural aggregates for use as open-graded subbase. Interlocking angular crushed aggregate provides better support than natural sands or gravels for placement of superficial layers.

Stabilized aggregate mixtures, used as shoulder base, were placed with machines that operated on the pavement. The procedure permitted rapid, continuous placement of the materials. Conventional equipment and procedures were used for compaction. With the BAM materials, bond failures occurred when dust was allowed to accumulate on the surface of the lower lift prior to placement of the final lift. Superficial BAM lifts should be placed before dust has time to collect on lower lift surfaces. The surface of each CAM or PAM lift was scarified and maintained in a moist condition until the overlying lifts were placed.

Portland cement concrete shoulders were constructed with a slipform riding on the pavement edge. Concrete, which was wet-batched from a central mixing plant to the slipform in trucks, was spread, consolidated, struck-off and finished in one continuous operation.

Shoulder surfaces should be finished at least 1/4 inch below the pavement edge so that surface drainage is not impeded.

Well documented labor and equipment costs assignable to actual shoulder construction under normal operating conditions as well as shoulder maintenance costs are badly needed to properly evaluate costs and benefits assignable to paved shoulders. The costs that were reported were obtained under experimental conditions and are not directly applicable to normal construction practices, but they did show that, although the PCC shoulders were the most expensive of the four experimental types, the construction cost differential between the BAM and PCC shoulders was surprisingly small.

SHOULDER MAINTENANCE CONSIDERATIONS

Lionel T. Murray, Missouri State Highway Commission

In the late 1950's, Missouri became concerned about the performance of shoulders on facilities with light to moderate traffic. As a result, a variety of shoulder designs were constructed to study their relative performance. These shoulder test sections have been surveyed periodically for the past eight years. In addition, construction costs and accurate maintenance costs were recorded.

Missouri's evaluation of shoulder designs stresses the performance of the shoulder with regard to the safety and convenience of the driver. Still, many of the defects noted below which affect safety, also reflect the structural strength and durability of the shoulder.

In the evaluation, the following items--drop-offs, loose material on the shoulder, delineation, roughness, rutting, softness and depressions--are given a rating from five to one depending on conditions observed and multiplied by an arbitrarily assigned weighting factor to obtain a composite numerical performance rating for each shoulder ranging from five to one. A shoulder in perfect condition would be considered excellent and rated near five.

Only the structural or physical durability of the shoulder is considered in the rating system. Other important factors also considered are the cost of constructing and maintaining the shoulder. Construction costs were estimated from bid prices for the best test sections. Maintenance costs for the study were obtained from District maintenance personnel who submitted reports on type and cost of all maintenance performed each year. Findings to date are as follows:

A sod shoulder initially costing an estimated $750 per mile, with maintenance consisting largely of mowing and blading is justifiable where traffic is less than 750 vehicles per day.

A 3-inch compacted granular shoulder, costing an estimated $6,000 per mile, where maintenance involves mowing, blading and adding more aggregate, is considered adequate for ADT between 750 and 1700. Grass does grow in this shoulder tending to bind the granular material and providing some delineation. Maintenance cost of this type shoulder for the ADT recommended is about $50 per mile per year.

A 6-inch granular seal-coated-shoulder compacted at 95 percent AASHO T-99, costing an estimated $16,000 per mile, used adjacent to concrete pavement is considered useful in the ADT range from 1700 to 3500. At higher traffic levels (20,000 ADT) it is almost impossible to maintain this type shoulder. Maintenance consists generally of patching, adding asphalt to regain color differential, repair of ravelled or map cracked areas and eventually reseal. Maintenance costs for the recommended ADT are about $220 per mile per year.

The 6-inch granular shoulder, when color-coated rather than seal-coated, costs slightly less to construct, but does not perform as well for equal traffic. Maintenance cost soon exceeds the initial first cost advantage.

The 6-inch granular shoulder treated with calcium chloride (10 pounds per ton) with no color differential, has initial costs approximately the same, and lower maintenance costs but poorer performance under the same ADT.

A 6-inch granular material stabilized with asphalt hot plant mix costs approximately $24,000 per mile, some 50 percent higher than the standard seal coated shoulder. To date, 7 years after its installation, no maintenance has been required and the performance has been excellent.

Comparable 6 year old shoulders with soil cement and sand asphalt are nearly comparable in initial cost, maintenance cost and effort, and have performed very well.

A full depth granular shoulder consisting of a sealed dense-graded granular shoulder on an open graded aggregate base with 2 foot x 2 inch edge strip of asphaltic concrete is considered useful for an ADT range from 3,500 to 20,000. The initial cost of this shoulder is approximately $25,000 per mile. Maintenance consists of sealing the crack between pavement and shoulder, spot sealing, and patching. Annual maintenance cost is about $125 per mile.

The recommended high-type rigid shoulder is for ADT's in excess of 20,000. It consists of a 2 inch AC surface course on a 5 inch bituminous stabilized base on a full depth open graded aggregate base. This shoulder requires little maintenance but is expensive to construct - approximately $37,000 per mile.

The shoulders recommended above, for ADT's greater than 1,700 are for concrete pavement. Missouri constructs flexible pavement full width from inslope to inslope, providing stone chips on the shoulder portion for delineation. For less than 1,800 ADT, the designs are nearly the same.

SHOULDER EXPERIENCE IN ILLINOIS

John E. Burke, State of Illinois

Illinois' theory has been that the shoulder structure, called upon to carry only occasional traffic, should not need to cost as much as the mainline heavy-duty pavement. However, these lower costs have not been realized. While the shoulder structure itself can be of lighter section, durability requirements and underdrainage requirements are such that no important savings can accrue through reductions in these areas.

During Illinois' early experience with CAM, PAM and BAM stabilized shoulders, a dense-graded trenched granular subbase was used under the pavement. In some instances, it was extended under the shoulders, and on a few sections carried out to the side slope for drainage.

Winter heaving of the shoulders above the pavement has been a problem where designs include the use of stabilized mixtures in the shoulders in combination with the granular subbase under the pavement, especially in the northern portion of the State. CAM and PAM shoulders have also experienced major durability problems at the pavement edge.

A change from the use of unstabilized dense-graded granular material to the use of cemented subbase under the pavement partially alleviated the shoulder heave problem. The use of open-graded granular material as subbase in the shoulder area and extending to the side slope has further improved the situation. The durability problem associated with PAM and CAM mixtures as shoulder bases has not been solved; accordingly, only the BAM mixture is now used in shoulder base construction.

Illinois has come to believe lately that longitudinal pipe underdrains placed at the pavement edge (actually at the edge of the pavement subbase which extends 18- to 24-inches beyond the pavement edge) may serve as an acceptable alternate for the open-graded subbase in removing unwanted water. The State is presently preparing plans offering these two systems as alternates. Neither alternate has appeared on a letting, costs are unknown, although estimated to be close.

Experimentation during the past few years with portland cement concrete shoulders adjacent to concrete pavements has convinced Illinois that this type shoulder should not be overlooked as an alternative. The opportunity to tie these shoulders to the pavement offers a unique feature that removes the sometimes troublesome problem of open longitudinal joints that resist sealing.

All of the experiences with special shoulder treatments described are concerned principally with shoulders placed in conjunction with portland cement concrete pavements on new construction. For bituminous concrete resurfacing work, of which there has been a considerable amount, the State has for many years used a gravel or crushed stone wedge at the pavement edge to bring the shoulder up to the desired grade. Recently, Illinois has included an 18-inch overhang of bituminous concrete 3 inches thick to move the unpaved shoulder

area out further from the mainline wheelpaths. Edge-striping is used to help retain traffic in the pavement area. Experience soon showed that the 3-inch thickness was not sufficient to serve without early distress, and this thickness was increased to 6 inches, which appears adequate.

SHOULDER PRACTICES AND PERFORMANCE IN TEXAS

John F. Nixon, Texas Highway Department

Since 1954, when traffic volumes justify, it has been a general policy of the Texas Highway Department to provide wide paved shoulders wherever possible. Specifically, the policy requires that two-lane facilities with an existing ADT of 1,000 vehicles or more be constructed with either 13-foot lanes and 9-foot paved shoulders or 12-foot lanes with 10-foot paved shoulders.

On Interstate Highways where Federal-aid participation is limited to paving only 4 feet of the inside shoulder, it has been the Texas practice to pave an additional 2 feet of shoulder with State funds to provide 6 feet of paved interior shoulder. On divided highways where shoulder paving is eligible for Federal-aid participation, the State has always practiced paving the entire 10-foot outside shoulder and the entire width of the inside shoulder.

In addition, to reduce the hazardous transition at approach guardrail installations and structures, Texas has encouraged the use of crown-width bridge structures which provide full shoulders plus offset for continuous guard fence installations. Thus, a two-lane roadway with 12-foot lanes would have two 10-foot shoulders, each with an additional 2-foot offset to yield a clear roadway width of 48-feet across structures. On a divided four-lane facility, a 6-foot inside shoulder and a 10-foot outside shoulder are provided with an additional 2-foot offset on the outside shoulder for the positioning of continuous guard-rail producing a crown width total of 42 feet.

Until recently the use of edge striping to delineate the edge of the pavement has been used very rarely in the State. Instead, the shoulder has been differentiated by the use of aggregate with contrasting color and texture. The construction of shoulders in Texas employs the same structural section as do the main lanes. Supplemental benefits derived from the full depth shoulder section are:

1. It enables two-lane facilities, which through the years have become congested and unable to accommodate the increase in traffic volumes to be very simply converted to four-lane facilities. With a seal coat application or overlay and lane striping, the two-lane road is transformed into what is commonly referred to as a four-lane "poorboy" design.

2. It enables the shoulder to be used intermittently by slow moving vehicles to allow faster vehicles an opportunity to overtake and pass. Through the years this courtesy has become widespread in rural areas of Texas and has gained legal acceptance.

On multi-lane facilities use of the shoulder by slow-moving vehicles is discouraged and this is accomplished by signing, contrasting color and texture, and other methods. As a result, the State has had very little difficulty with traffic misusing shoulders on divided highways.

It is felt that one of the greatest achievements accomplished in shoulder design in Texas in the past 20 years has been the provision of uniform width, all weather type shoulders on primary highways. There is perhaps no other single design aspect of the Texas Highway System which has received such wide acclaim by the travelling public.

CONFERENCE SUMMARY

John W. Hutchinson, University of Kentucky

In summary, a need has been shown for 1) construction of full depth monolithic pavements throughout the entire width of the shoulder area so as to avoid the costly problem of maintaining a longitudinal joint just outside the right-hand edge line, 2) eliminating the "drop-off" or "raised shoulder" at the right hand pavement edge and 3) eliminating shoulder structural distress due to traffic loadings.

The preceding needs are supported by the frequent use made of the first foot of width of the shoulder just outside the pavement edge; California actually uses the entire shoulder as a designated through traffic lane during rush hours in Los Angeles, and has done so for years. Further, such use of the shoulders will likely continue and even increase in response to the need for operational flexibility during maintenance and reconstruction; during accident clean-up; during rush hour; during lane closure for any one of a number of reasons like flooding, truck load spillage, restriping, sign erection, stalled vehicle(s), research instrumentation, installation of energy attenuating devices, removing backslope slide debris, keeping traffic out of dangerous fill settlement areas or slide depressions, etc.

The one big question not answered here is: "Why do we continue to pretend to face the dual realities of important shoulder uses and high maintenance costs and yet continue to build new shoulders to such low standards that we perpetuate high maintenance costs?" We should, of course, also address ourselves to the question of what to do about improving a substandard system with shoulders constructed thrity or forty years ago. But we must not so confuse these two separate questions that we continue to build substandard shoulders in spite of knowing how to do better. One cannot help but agree with Neilon J. Rowan's statement that technology in shoulders is ahead of research. However, it should also be noted that technology appears to be considerably ahead of implementation. This being the case, insufficient attention has been devoted to the design and construction of shoulders on new Interstate highways and urban expressways so as to avoid known past mistakes for which we are still seeking stop-gap maintenance solutions at a greater annual cost than original construction of full depth monolithic pavements throughout the entire width of the shoulder. Constructing shoulders of the same pavement as the through traffic lanes has been noted to create enforcement and operational problems.

It should also be noted that nowhere in the discussion of "enforcement problems" related to unauthorized shoulder uses was there mention of any accident costs or the cost of any reduced capacities resulting directly from unauthorized shoulder uses. This is indeed an interesting omission.

CONFERENCE SUMMARY

R. N. Hunter, Missouri State Highway Commission

Neil Rowan indicated that technology in shoulders has been out ahead of research. This was not intentional, as there were many times during the development of the present shoulder designs that many of us throughout the country wanted very much to have answers to some of these problems that only research could give. The substandard shoulders which were depicted during this session, however, are not being constructed by any highway department in the country at this time.

Regarding shoulder development, it has been noted that historically, the travel lanes have increased in width from 9 to 12 feet. Much of the old 18-foot pavement developed on a 34-foot roadbed originally provided 8-foot shoulders but has since been widened and resurfaced to provide 12-foot driving lanes at the sacrifice of the shoulder width. Thus, "substandard" shoulders have evolved from the improvement over the years of a lesser design and that shoulder area has been sacrificed for improved travel lanes within the existing right of way.

With regard to improving these "substandard" shoulders, too much attention has been given to the interstate freeway system particularly in the urban areas. It is in the urban areas where it was recognized that there would be a great deal of use of the emergency parking lanes or shoulders and they were constructed of the same pavement as the thruway lanes. Considerable operational problems have been observed even though the shoulders were tinted or otherwise delineated. Apparently drivers do not mind the color so long as the surface is smooth. As a result, enforcement is a problem.

Certainly extension of the travel lane pavement throughout the width of the shoulder can properly support traffic loads and ease some of the operational problems. However, there are insufficient funds to accomplish this and maintain a reasonable highway improvement program. Highway administrators throughout the country are faced with demands to improve a system constructed thirty to forty years ago and substandard in many areas with no apparent increase in highway funding. Therefore cost effectiveness of shoulders as well as other features of the highway improvements must be considered.

Expertise within HRB and other associated agencies should be directed toward developing a procedure to determine cost-effective highway improvements, particularly with respect to shoulder design.