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

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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.