Elements in the Design of Shoulders

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As integral parts of the roadway or travel area, shoulders are tangibly important to the highway user and consequently are important to the engineer designing for the utility and safety of the user. They were not always so. On early roads shoulders were included only as means for lateral support of the pavement. Thus their function was wholly structural and restricted to the point where design considerations were few and simple.

With increases in size, weight, and number of vehicles using the highways, increasing need for shoulders to serve a greater and more complex variety of purposes arose. However, from the standpoint of fundamental design concepts and experimental data on which such concepts could be based, shoulders developed slowly. In contrast, there has been a mass of technical data on other features of the roadway such as subgrade soils, bases, pavements, pavement markings, and even signs. Granted that there are standards for width, slope, and sometimes composition of shoulders, yet to a considerable extent their development was by observation and intelligent estimate rather than by measurement and numerical calculation.

Shoulders lack glamor, and among the features which challenge the thought and effort of the designer they have little stature. Still, their importance has not been overlooked, and it is apparent that emphasis on shoulder design is mounting and will continue to do so in the near future. As the interest increases, it must be recognized that quality in construction as well as design is essential. Just as pavements or any other usable feature of the road, quality of the design can be no better than the quality of construction that follows. By the same token, a design may be theoretically good but actually poor if it is complicated and impractical to build economically.

These rudimentary yet significant observations are intended as background for a discussion of the elements that enter into design of shoul-
ders. The subject will be viewed from the standpoint of functional as well as structural value of the highway as a unit, for obviously separation of shoulders from other parts of the roadway ignores effects of one part on another—and these effects are vital.

FUNCTIONS TO BE SERVED

What functions are served by shoulders on a highway? One observation often cited is that shoulders are "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."* To these purposes one might add:

1. Removal of ditches, guard rails, and similar auxiliary items close to the pavement—a definite point in the interest of safety.
2. Esthetic value or pleasing appearance (assuming that can be accomplished), an aid to driver comfort and perhaps freedom from worry and fatigue.
3. Space for storing ice and snow removed from the pavement by power equipment in periods of blizzards or heavy drifting, a decided advantage to maintenance operations intended to keep the pavement open and unrestricted.
4. Under some circumstances a catchment area for fallen rock in locations of deep cut through mountainous terrain, an added safety feature but still a hazard for those occupying the shoulder at such a location.

Other minor reasons come to mind, such as a temporary shelter zone for children boarding or leaving school buses.

These functions that might be considered secondary to the main purposes are mentioned not to detract from the real sources of concern in design, but rather to recognize the broad uses that have developed for shoulders. Actually, both the appearance factor and the storage of ice and snow have entered indirectly into design heretofore. Seeding and mulching and particularly stabilized turf are examples on one hand, and elimination of lip curbs to facilitate snow removal is representative of the other. The latter may be more a feature of pavement than of shoulder design, but its purpose was equally related to both.

All the objectives both primary and secondary are generally included in the categories of geometric, drainage, and structural design. Through rather intensive study and gradual development over a period of several years, the geometric and surface drainage considerations have devolved

* Numbers refer to references at the end of this paper.
into sets of design standards fairly comparable in all states throughout the country. Minor variations are common, but usually these represent compromises with cost or individual preferences rather than serious differences of opinion over the requirements and best methods for meeting them. On the other hand, the structural considerations, or, perhaps more explicitly, the composition and arrangement of shoulder materials, are still very much in the development stage. There are considerable differences in opinion. That being the case, this discussion will emphasize the structural element of shoulder design; but first it is appropriate to review briefly the other considerations mentioned previously.

ELEMENTS OF GEOMETRIC AND DRAINAGE DESIGN

It is a well established fact that shoulders have a marked effect on the capacities of roads and particularly so on those carrying relatively high volumes of traffic. Early investigations on high volume roads led to the conclusion that on a highway having inadequate shoulders one disabled vehicle during a peak period could reduce the capacity as much as 60 per cent. Also, if the shoulders were wide enough to store a disabled vehicle yet provide no additional clearance, the effective width of lane may be reduced as much as 2 feet. In either case safety on the traveled lanes would be impaired, and the accident rate would increase rapidly.

Some of the most recent data reported by a committee of the Highway Research Board studying the effect of shoulders on speed and lateral placement of vehicle\(^2\) indicated that:

1. There was no effect when the shoulders were *clear* (unoccupied) and 6 feet wide; and there was substantially no effect if they were 4 feet wide.

2. When the shoulders were occupied, driver behavior was unaffected only if the clear distance from edge of the pavement to vehicle or other object (such as a bridge pier) was at least 4 feet.

A third phase of the study, and one from which there were little dependable data at the time of the report (1955), was the extent to which shoulders on rural highways are used by parked vehicles. Preliminary results from one state placed emergency stops at one for each 7,500 vehicle-miles of travel and one stop for any purpose at each 300 vehicle-miles of travel.

Assuming these conditions to be typical, on a road carrying 10,000 vehicles ADT there would be as many as 12,000 stops per mile per
year, 500 of which were for emergency purposes. If this use was also typical of the very high volume roads comparable to the New Jersey Turnpike, for example, the ADT might be in the range of 100,000 vehicles, there would be about 120,000 stops per mile per year, and emergency uses would total more than 5,000 per mile per year.

Factual information on points such as these, but of such scope that it will differentiate with regard to class of road, traffic volume, number of lanes, surface condition of pavement and shoulder, and like features are genuine elements in the design of shoulders. In contrast to the pavement which is designed to accommodate the traffic imposed upon it, the shoulder in serving its function must not only accommodate the vehicles which use it, but must do so in a way that will cause no interference with those using the main travel way.

To meet the requirements of design in a realistic way, geometric standards have been developed. These are so well known or so generally accessible to those who are interested they need no more than cursory review here. However, it is pertinent to note that not only design speed and volume but also terrain has a great bearing on the economic feasibility of shoulder widths. In general, on two-lane highways a 4-foot usable shoulder width is considered the minimum regardless of terrain or design hour volume. If the design hour volume is as great as 100, a minimum width of 10 feet is desirable but compromises as low as 6 feet might be acceptable in unfavorable terrain. As the volume increases, a minimum usable width of 10 feet but preferably 12 feet appears in most design standards—the latter being almost necessary if transport trucks are a factor and the 4-foot clearance from pavement to vehicle on the shoulder is the objective. Emergency services about the truck will further reduce this.

Usable width will vary slightly with cut and fill, and tangent and superelevated curve. Total width or distance from edge of pavement to the intersection of shoulder and side slope planes may be as much as 3 feet greater than the usable width, because the latter defines that portion of the shoulder which can be used when the driver makes an emergency stop. If, for example, the side slopes on fills are too steep, the intersection of planes will cause intolerable grade breaks and rounding will increase the total width but not the usable width of the shoulder.

Similar considerations sometimes enter in the design from the standpoint of surface drainage or the shoulder cross sections. Obviously the shoulder should slope in a way that will conduct water away from the pavement. Slopes to accomplish this effectively without creating hazards
for the driver coming onto the shoulder, are factors of concern. These would be influenced by the surface composition of the shoulder and the roadway section (i.e., superelevation, etc.), assuming no special drainage features such as shoulder curbs, flumes, and the like.

In all locations except the inside of superelevated curves, it is important that the slope of the shoulder be somewhat greater than the slope for crown in the pavement. Experience has shown that a maximum of $\frac{1}{2}$ inch per foot on bituminous surfaced shoulders; $\frac{3}{4}$ inch per foot on stabilized shoulders having a granular texture; and 1 inch per foot on turf shoulders are reasonable values for design. Some modification to avoid hazardous breaks in grade at the pavement edge would be necessary on the outside of superelevated curves where shoulder drainage is directed away from the pavement. The intent there would be drainage of the shoulder itself, and not drainage of water from the pavement. A rounded treatment of the shoulder consistent with use by vehicles in an emergency appears best suited under the circumstances.

Any other aspects of drainage are so closely associated with the structural considerations that they can hardly be separated from that element of design. So far as surface water is concerned, the most desirable composition and treatment is one that will not permit infiltration at the edge of the pavement and lessen to the greatest extent the softening of the shoulder itself by water from the pavement. But, of course, that is only one small feature in the overall structural design.

**ELEMENTS OF STRUCTURAL DESIGN**

Use of the shoulders by vehicles leaving the pavement implies adequate support of the load at all times in the year. On even the earth and sodded shoulder there is sufficient load-bearing capacity the majority of times; but during the season of concentrated spring rains, and particularly during periods of thawing in late winter or early spring, support is hopelessly inadequate for passenger vehicles, not to mention loaded trucks. This makes emergency repairs such as changing tires on passenger vehicles impractical, it leads to blocking of travel lanes by loaded trucks in times of emergency, and finally it creates excessive costs of maintenance in repairing damage caused by those cars that do use the shoulder.

These conditions are well known to those who have any reason at all to be concerned with shoulder design and maintenance. As a consequence, treatments to provide adequate shoulder stability have become about the foremost problem in road design today. Three general questions are implicit in the formulation of policies and procedures:
(1) The class of road or traffic condition under which the cost of stabilization can be justified.
(2) The width to which shoulders should be stabilized and have the benefit commensurate with the cost.
(3) The depth, arrangement, and composition of the treatment.

Policies regarding these questions—if there are well-defined policies at all—vary greatly among the states and sometimes on roads in different areas within states. The problem is too new and the factual data too scarce for uniform application of particular designs. On the other hand, the urgency inherent in current expansion of the highway system requires solutions even though they may be expedient rather than permanently correct.

Undoubtedly justification of a stabilized or paved shoulder lies mainly in the extent to which the shoulder will be used. One state, for example, has required stabilized shoulders in the construction of all roads having divided lanes, and alongside any two-lane pavements carrying more than 200 heavy commercial vehicles per day. This might imply a minimum ADT in the vicinity of 2,000 vehicles and perhaps as many as eight stops per mile per day as the minimum use justifying expensive shoulder treatment. Probably maintenance cost records, accident records, and the data on traffic flow are not available to substantiate this, but nevertheless the policy must begin somewhere and be broad enough to provide guidance for more permanent policies in the future.

In some cases the width of shoulder treatment varies also. On roads where traffic apparently justifies the use, yet where the volumes and design speeds are relatively low, sometimes the treatment is limited to a distance of 4 feet from the edge of the pavement, and it is extended to widths of 10 feet or more only when the traffic is extremely heavy. On the basis of data produced by the HRB committee studies, the narrow widths hardly appear warranted. Discounting benefits that may be derived from improved surface drainage, better contact between shoulder and pavement, prevention of erosion immediately adjacent to the pavement on steep grades, and particularly the increased load-carrying capacity of the pavement itself, there is little in favor of the narrow treatment. When the stable portion of the shoulder is not greater than the width of vehicle using it, almost invariably a portion of the outer travel lane will be occupied or affected. Exposure to accidents will be greatly increased, and the capacity of the road appreciably reduced. From that standpoint a little treatment is not better than none at all.

After it has been determined which classes of roads shall have shoulder treatment and to what widths, the most perplexing question of all
remains—what will the treatment be? Here again the solution is reasonably one that is graduated to fit the demands, with the basic considerations being:

(1) Design loading
(2) Thickness
(3) Subsurface drainage
(4) Composition
   turf
   stabilized aggregate or soil
   base and paved surface
(5) Surface contrast

With the exception of the last item these considerations are strikingly similar to some of those involved in design of pavements for the travel lanes.

Inasmuch as methods of flexible pavement design are about as numerous as the states in the Union, it is inconceivable that at this stage or in the near future there would be agreement on criteria for structural design of shoulders. For the present that is immaterial, so long as there is some systematic method on which designs can be based, the results evaluated from time to time through observation of treatments in service, and revisions made to fit the needs.

Design loading for pavements is normally a chosen static load above or below the legal load limit depending upon the class of road to which it is applied; or a determined number of repetitions of a given load or an assumed equivalent load. Regardless of whether the procedure employs the static load or the equivalent load repetition, it is reasonable that for shoulder design some modification of the loads used in design of the travel lane for the particular class of road is not only warranted but demanded.

In the case of the static load method, the reason for modification is the same one that justifies different design loads for pavements on high volume versus low volume roads. Obviously the legal or extra legal load will sometimes be carried on the lesser road, but this demand is too infrequent to require full protection against it. In other words, the design for the light road is a calculated risk, and the wrong combination of load and weather is recognized as a possibility. The same reasoning applies to the method based on equivalent load repetitions.

Probably if data were carefully collected on high volume roads in service, and a result such as the one emergency stop per 7,500 vehicle-miles of travel previously mentioned was confirmed, a statistical prob-
ability of peak load concentration at some point on the shoulder could be established. From this representative shoulder design, loads for different classes of roads might be developed. In the meantime, the risk in shoulder design should be made at least as great as it is in pavement design where the stakes are somewhat higher. However, flexible pavement design is used here as a guide only because shoulder treatments in all cases are assumed to have flexible characteristics. Where the accompanying pavement will be rigid, the shoulder design may be based on those loads applied to the determination of the rigid pavement.

Except in the states where frost penetration is a primary consideration, thickness of the pavement is dependent on load and subgrade bearing value. Obviously, wherever it is applicable, frost penetration should have the same consideration in thickness of shoulder treatment. Other factors may have a bearing on the selection. Modern practice often involves extension of insulation courses, subbases, or bases through the shoulder. With certain combinations of circumstances, extension of these courses may be conveniently linked to depth of shoulder treatment. However, thicknesses of pavements in current use on heavily traveled roads would generally involve excessive thicknesses of shoulder treatment if the two were combined in the manner indicated.

One solution in the case of a flexible pavement with several courses of base, for example, would be extension of only the bottom course through the shoulder to serve as the drainage outlet. Above that point soil would be placed in the usual manner to the level that would leave sufficient depth for this required thickness of shoulder treatment. If the extended course of base is intended for drainage—and presumably it would be—construction of the soil portion of the shoulder above must not disturb the base below nor cause silting to the point of blocking the drainage. Grading of the base is important, of course, as is the care in construction above it. In cases where pavement design calls for trench construction with only occasional bleeders from the base to the ditch, the same general problems apply, but it is even more important that the shoulder treatment itself be effectively drained to the ditch also. Otherwise water percolating through the shoulder may contribute to weakness not only in the shoulder but in the pavement as well. Undoubtedly it is in this connection that results of the WASHO Road Test showed such pronounced benefits in pavement performance derived from surfaced shoulders. Eliminating access of water along the edge of the pavement, or in effect extending the distance to the edge of the paved surface, greatly retarded deterioration in the outside travel lane under repetition of the heavy test loads. While it is largely surface water that is being excluded by the treatment, subsurface conditions are im-
proved as well—or at least the critical situation for subsurface stability is considerably removed from the area of concentrated loads.

A paved shoulder surface in combination with an underlaying base is one of the three general categories of composition. Probably the earliest and lowest in order of dependability is the stabilized turf. Here the intent is to provide sufficient depth of granular material to give moderate support for loads, and at the same time retain the advantage of a sod surface—relatively low initial cost, low maintenance cost, and superior appearance. It is significant that some of the earliest research in this field has been conducted at Purdue University, and the results have been presented in sessions of the Purdue Road School.4 Later and more comprehensive investigations were conducted by the Joint Highway Research Project and reported at the Purdue Road School and elsewhere.5, 6 Elaboration here would be superfluous; but in essence the problem is one of grading the aggregate in such a way that selected vegetation fed properly with certain nutrients can be sustained at the surface, and the gradation and depth of granular material supports the loads accommodated at the same time.

Considerable success with turf has been reported, so long as the top soil requirements at the surface are slight, and the frequency and weight of loading are not excessive. Hazardous conditions of slipperiness on the surface in wet weather have been reported in some instances, and "build up" of turf on the surface over a period of years with consequent defective surface drainage may also pose a problem in corrective maintenance.

Stabilized aggregate or stabilized soil treatments are next in order of cost and expected service performance. These usually consist of well graded stone, slag, or gravel, placed and controlled in the manner applied to subbases or bases; comparable materials treated with surface applications or integral additions of calcium chloride7 or sodium chloride and selected soils stabilized with portland cement or appropriate bituminous materials. In every case emphasis should be placed on quality of materials, careful proportioning, and control during construction. Specifications for construction of bases and surfaces using the same combinations of materials are appropriate and should be applied.

Some of the advantages of shoulders in this category are moderate initial cost, fairly low maintenance cost, and theoretically, at least, minimized shrinkage of material away from the edge of the pavement. As compared with a paved surface, the upper portion of stabilized granular material is readily accessible for addition and treatments, which is an advantage where there is concentrated use of the shoulder and high loss of surface material. Some of the disadvantages may be a less
The paved surface with a firm base, if adequately designed, should give maintenance-free performance for the longest period of time. In view of the cost a lesser service condition would not be tolerable. Here again the design should be comparable to that for a pavement expected to serve whatever traffic requirements are assigned to the shoulders through use of design elements previously mentioned. Temptations to slight the design, such as lessening the thickness of bituminous surface below usual pavement design levels, are seldom justified. Total thickness of the treatment might be lessened slightly if occasional but complete failure is considered part of the design, but the factors inherent in the life of bituminous surfaces and proved through years of observation on travel lanes are fully applicable to shoulders.

Most of the advantages of the paved shoulder have been mentioned before—unquestioned stability if adequately designed, improved surface drainage, superior contact between pavement and shoulder, and low maintenance cost. An obvious disadvantage is the high initial cost; and another, in cases where the travel lanes have flexible pavement, is the lack of contrast between travel lane and shoulder surfaces. This can be overcome with surface treatments on the shoulder, but with most types of surfaces that might be considered for the shoulders an additional operation is required. Where shoulders with bituminous surfaces adjoin rigid pavements, of course there is no problem. It should be stated in this connection that both the turf and the stabilized shoulders provide distinctive edges or surface contrasts.

SUMMARY

In summarizing the various elements of shoulder design it should be noted that the geometric aspects are well established in policies formulated by AASHO. Minimum width of 4 feet with 10- to 12-foot usable widths prevailing on all high type and heavy volume roads are general guides which should apply in design for several years to come. In a similar way the slopes of shoulders necessary to facilitate surface drainage have been well established. These are appropriately varied from \( \frac{1}{2} \) inch per foot for paved shoulders to a maximum of 1 inch per foot on turf or sod shoulders.

Significant elements in the structural design of shoulders are recognized but data for guidance in design are not abundant and with regard to some features they are essentially not existent. In general good
principles of design for comparable features of the roadway, such as sub-bases, should be observed in shoulder design. Evaluation of the need for treatments should depend on anticipated use of the shoulder by traffic leaving the pavement. In that respect there is great need for research and analysis of data.

Adequate support for loads in all weather is essential wherever traffic demand justifies shoulder stabilization or treatment. Design criteria applicable to flexible pavements are reliable approaches to the problem, but need for modifications in design loading are necessary to avoid excessive costs or haphazard reduction in thicknesses without a valid or rational basis for the change.

It is evident that a concentrated effort to provide new knowledge in this field is needed, and Indiana is one state contributing to the knowledge through experiments. Earlier work with turf has been mentioned, and experience gained from stabilized and paved surface treatments along those roads having highest concentration of traffic (including the toll road) will add materially to the results. In the meantime, test sections placed alongside U. S. 40 near Plainfield are designed by the Indiana Highway Department to give comparative answers.

Four different treatments in depths of 7½ inches each were placed last October in sections each 1,400 feet in length. Two are in the category of stabilized materials, one divided between the stabilized and the type with bituminous surface, and the fourth is wholly of the surfaced type. In essence they are as follows:

(1) Modified compacted aggregate (full depth).
(2) Modified compacted aggregate with CaCl₂ treatment.
(3) Soil-cement—a portion of the section full depth, the remainder partial depth and surfaced with approximately 1½ inches of hot asphaltic binder material.
(4) No. 63 aggregate base surfaced with approximately 2½ inches of hot asphaltic binder material.

It is too early to evaluate results from the experiments, but undoubtedly those concerned with shoulder design will observe them with great interest and a view toward application of results as soon as they are considered conclusive.
REFERENCES


