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# A Symposium on Highway Shoulders



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# *A Symposium on Highway Shoulders*

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## *Symposium on Highway Shoulders*

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# Foreword

Arterial highways are not safe for travel unless adequate shoulders are constructed so that in an emergency, vehicles can stop, out of the path of fast-moving traffic. A well-designed and well-constructed shoulder, providing free cross drainage of surface water from the pavement to the ditch or gutter and also ready drainage of subsurface water from underneath the pavement, gives lateral support to the surface and base. Such a shoulder should be designed, stabilized, and surfaced with as much care as the traffic lanes themselves.

Many types of shoulder have been evolved over the years and each has a place in the development of a highway system. To be satisfactory, all types of shoulders should be designed with proper pitch, with adequate drainage, and with care exercised in the selection and mixture of soils and materials for the surface treatment to be given the finished shoulder.

This symposium was planned to find the areas of agreement and to isolate, if possible, the points of difference among highway engineers cooperating on such questions as:

1. What purpose should a well-designed shoulder serve?
2. How may a shoulder best be designed, constructed, and maintained to serve these purposes?
3. What are the relative advantages and disadvantages of the several types of shoulder design and shoulder materials under various regional conditions of climate, soil, and traffic?

The symposium was sponsored by the Design Department in cooperation with the other five departments and several of their committees. One of the important phases of the work of the Highway Research Board is handled through some 66 committees organized under six departments: Economics, Finance and Administration; Design; Materials and Construction; Maintenance; Traffic and Operations; and Soils.

Although each committee generally works on a specific problem of the department under which it is constituted, there are instances where certain items may be of interest to several departments and committees. The subject of this symposium is a case in point. Not only are six of the committees of the Department of Design interested in various functions and phases of highway shoulders, but also committees of the other departments are interested in and have contributed greatly to certain aspects.

At the May 1955 meeting of Department Chairmen with members of the Highway Research Board staff, it was decided that a symposium on the subject in which all committees working on some phase of highway shoulders could participate would be a worthwhile endeavor. This symposium, where representatives of the various committees and departments had an opportunity to discuss the various problems of highway shoulders was intended to promote a closer relationship and integration of committee work of the Board. Further, this discussion should point the way for needed research.

Definition of certain items pertaining to elements of highway cross-section is a must. From "A Policy on Geometric Design of Rural Highways," as published in 1954 by the American Association of State Highway Officials, the following definitions are believed to be pertinent:

Roadway. (General) The portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways. (In construction specifications) The portion of a highway within limits of construction.

Roadbed. The graded portion of a highway, usually considered as the area between the intersection of top and side slopes, upon which the base course, surface course, shoulders, and median are constructed.

Traveled Way. The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Shoulder. The portion of the roadway contigious with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses.

Auxiliary Lane. The portion of the roadway adjoining the traveled way for parking, speed-change, or for other purposes supplementary to through traffic movement.

Parking Lane. An auxiliary lane primarily for the parking of vehicles.

T. E. SHELBURNE, Chairman
Department of Design

# Contents

# Cost and Benefit Problems of Highway Shoulders

FRED B. FARRELL, Chief, Highway Costs Section
National and Administrative Research Branch, Bureau of Public Roads

● WHAT do highway shoulders cost? After decades of building and maintaining highways, and keeping cost records, this question should be easy to answer. But it isn't. The fact is that construction records simply don't show the total amount of work chargeable to shoulders. Maintenance records are somewhat better, but frequently the expense is combined with the surface work, it includes extraneous items, or it is so loosely reported as to be of doubtful value.

Construction records may show certain costs chargeable to shoulders, such as stabilization and surfacing work. However, these are only part of the costs. They do not show the added expense of right-of-way, of excavation, or of drainage structures properly attributable to shoulders. The extent to which such costs are chargeable to shoulders should be covered by a standard definition. Such a definition does not now exist. One is needed.

But let a standard definition be assumed. If, then, all construction costs were analyzed for a given 2-lane road, it might be shown that 15 percent of the total job costs was assignable to shoulders. Would this be too much, too little, or just about right? To answer this question, it would be helpful to place a dollar value on the many benefits which shoulders provide. Then direct comparisons of benefits and costs could be made.

Consider, for example, just one phase of the shoulder problem — over-all width. Shoulder widths of 4 to 10 ft are in common use in present day design practice. But why does the width vary? The answer lies in the value of the benefits obtained. For example, a 10-ft shoulder in mountainous terrain for a low traffic volume road might involve such high cost as to be unjustified; hence less shoulder width is used. On the other hand a 4-ft shoulder in flat terrain for a high traffic volume road would be absurd in view of the added benefits to traffic that could be obtained at nominal added cost; thus shoulder widths tend to be wider in flat country. Considerations of cost versus benefits underlie each condition.

The shoulder problem involved in rehabilitating and widening old pavements on narrow rights-of-way warrants special comment. Here the situation can become quite awkward, because of the developed nature of the bordering right-of-way and delays in acquiring relatively small parcels. The construction cost can also be quite expensive. On one road section recently, the work of widening shoulders and constructing new ditches required 75 percent more excavation than was required in the whole road when it was first built 27 years earlier. In such instances as this, resistance can be expected to spending money for building shoulders along with pavement widening and resurfacing, because the most apparent deficiency in the road is the poor pavement condition, yet a substantial part of the expense goes, not to the pavement, but to the shoulders. Again, it would be helpful if a price tag could be placed on the value of the benefits received.

Further, shoulders give lateral support to the surface and base. Perhaps 2 to 4 ft of good shoulder would accomplish this at a certain cost. Such cost might be more properly chargeable to surface and base work than to shoulders. At any rate, this same 2 to 4 ft would also provide a measure of safety to the occasional vehicle which runs off the edge of the pavement. Some additional structural strength may be required for this circumstance. This, too, costs money. It has been suggested that any additional width, beyond the initial 2 to 4 ft next to the surface, constitutes the real shoulder. This additional width, amounting to as much as 8 ft, is needed for emergency use and accomodation of stopping or stopped vehicles. Stabilization and strengthening must be provided where necessary. Costs continue to mount, but so do such benefits as better drainage, added traffic capacity, fewer accidents, and time savings.

The engineer is aware of these problems. Much valuable research has already been done in providing him with the information needed to arrive at correct solutions. But there is still great opportunity for further research in many areas. The problem of developing better cost data and evaluating benefits in dollars and cents terms is one such area.

# Highway Shoulder Design from the Roadside Development Viewpoint

FRANK H. BRANT[1], Landscape Engineer
North Carolina State Highway and Public Works Commission

● THE word "design" in the title of this portion of the discussion includes geometric design and materials used as well as the wearing surface of turf which first comes to the mind of most when roadside development is mentioned. The concern here is not with just a turf wearing surface on any kind of soil, although there are many miles of this type of shoulder where turf is at least serving the useful purpose of preventing erosion.

A turf shoulder may or may not be stable, depending upon the structure resulting by chance, but a "stabilized turf shoulder" is designed and constructed to be stable. During the period 1945 to 1953 the Committee on Roadside Development made a study of stable turf shoulders, and enlisted therein the cooperation of construction, maintenance, soils and traffic engineers and agronomists. Reports were received on investigational projects at 23 locations in 11 central and eastern states.

A concluding report on "Stabilized Turf Shoulders" was made in January 1954, and was published as Highway Research Board Special Report 19, and an extensive bibliography is included. Further study was postponed until there could be an evaluation of the practical value of the study, and because there were several questions which would have to be answered by others than those directly connected with the study. From a panel such as this could come the answers.

Since it is acknowledged that the texture of turf requires a steeper slope to drain off water than a smoother shoulder surface, how steep a shoulder is permissible? Is the recommended 1 in. per ft too steep? Could it be steeper?

The work "stable" was defined as the ability to carry at all seasons of the year the maximum load permitted, without such damage to the shoulder as would require repair; and the recommendations on materials are aimed at this definition of stable. Is such a degree of stability considered necessary 24 hours a day, 365 days a year? Materials well beyond the limits recommended may give satisfactory performance except during occasional critical periods of moisture. Other materials beyond the limits recommended may allow rutting, but only to a small degree, on any day. What definition can be established as to the degree of shoulder rutting that is acceptable?

Also, what width of stability is desired? Must the entire shoulder width be stable enough for parking for maximum loads at all times or would a narrower strip be satisfactory to take the more frequent emergency swerving off from the edge of the surfacing?

If it is definitely determined by research that a shoulder must be completely impermeable to moisture, then turf shoulders cannot be considered. But if such is not the requirement, or if it is true to state that there is a great mileage of highways which cannot afford expensive shoulders, then stabilized turf shoulders can be considered because:

1. Turf can be grown on stabilized soil-aggregate materials where moisture is adequate and, under occasional traffic, will serve as an economical wearing surface having shear value and preventing wind and water erosion.

2. Turf can be established and maintained on soil-aggregate materials compacted to the densities required for stability for highway purposes. Stabilized turf should be constructed with consideration for stability of surface, base, and subgrade. For the surface course, materials within the limits of the specification of AASHO for "Materials for Soil-Aggregate Surface Courses" should be compacted to at least 95 percent maximum density. Turf should be established directly on the stabilized course by the appropriate procedures for turfing.

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[1] The author is acting as spokesman for the Committee on Roadside Development and for the special study group, headed by Harry H. Iurka, which has worked on the problem of shoulders from the viewpoint of roadside development.

3. Topsoil is not essential for turf and, if used without further definition as a soil material, might adversely affect stability.

4. With proper design, construction, and maintenance, the cost of construction and maintenance of stabilized turf shoulders is less than that of other stable shoulders. Build-up is not a characteristic of all shoulders of this type; when it does occur, it is less costly to correct than the constant erosion of an unsurfaced soil-aggregate material.

Of course, further studies are needed on design, materials, and methods for constructing and maintaining stabilized turf shoulders in other localities and on a more extensive scale than so far reported during the study, but it has been made clear that turf shoulders and stabilized turf shoulders are not the same, and that stabilized turf shoulders do not result from merely scattering a few seed.

# Highway Shoulders as Related to Surface Drainage

RICHARD ACKROYD, Drainage Engineer
Bureau of Public Roads

●THE design of highway shoulders and the surface drainage of highways are interrelated. That is, the design of the shoulder can have a definite effect on the surface drainage and, conversely, the method of handling surface drainage may have an important effect on the stability and durability of the shoulder.

Figure 1 shows eight typical shoulder designs with provisions for handling surface runoff from the pavement. Designs A, B, and C, which permit the water to drain freely off the pavement, are the preferred types. With low highway grades and when reasonably stable, such shoulders give little trouble from drainage.

Four different situations in which the stability and maintenance cost of the shoulders are affected by surface drainage can be discussed briefly.

1. There is the problem of conducting pavement runoff across the shoulder to the ditch or fill slope where the highway is on a substantial grade. Under these conditions, the runoff from the pavement has a directional component parallel to the highway. If the shoulder is erodable, the water erodes a small channel usually along the edge of the pavement and when sufficient water accumulates, it breaks over the edge of the fill slope and erodes a gully down the slope. This frequently occurs at a culvert or bridge abutment located at the bottom of the hill. There is need for the development of an effective and economical method for handling this water. Designs D and E show two methods for handling this longitudinal flow on embankment sections. Shoulder design D is widely used in the semiarid and arid sections of the country where vegetative protection can be established on fill slopes, only with difficulty. This design usually requires a paved shoulder and dike normally constructed with asphaltic concrete. The water must be intercepted and carried down the fill slope in a pipe or paved open flume. The frequent error in this design is making the entrance to the pipe or slope flume so small that the water overtops the edge of the flume or dike and erodes the slope along side the flume or over the pipe. A common fault in the use of the valley gutter (shown in design E, Figure 1) is that the horizontal curve in the paved channel at the bottom of the slope, designed to take the water across the shoulder, is made too sharp and the water jumps out of the channel. This curve must be very gradual and the valley gutter itself must be large enough to carry the water coming to it. Where the grades are continuous for several hundred feet, it may be necessary either to intercept the water in an inlet set in the valley gutter or carry it over to the top of the slope in the gutter itself, then down the slope in a flume or pipe at one or more points along the grade. The inlet probably makes the better looking design and considering its proximity to traffic a grate with long parallel slots should be used. Design F shows the use of a valley gutter in a cut section. ion..

2. The design represented by sketch G is considered undesirable from a drainage standpoint. Like design H, it holds the water on the pavement where it can interfere with traffic. It is difficult and expensive to intercept and dispose of such water. Where this design is used in a cut section, runoff from the shoulder and back slope not only brings additional water to the pavement but this water may also carry debris which clutters up the pavement and adds to the cost of maintenance. This runoff can be handled much more effectively and economically by intercepting it off the pavement as in designs A, B, and F.

3. In the case where an approach to a bridge is purposely depressed over a flood plain shoulder design is affected by drainage. By allowing the rising flood water to overtop the approach road before it reaches the underside of the bridge, the bridge is relieved of pressure, the velocity through it is reduced, and it is possible to build a shorter bridge than would otherwise be necessary. Where such overflow is frequent, such as once every one or two years or more often, it may be economical to protect the downstream shoulder by paving, riprap, or even sod, depending upon the difference in elevation between the water on opposite sides of the road at the time flow over the road started. Research now being done will permit more accurate predictions of the differ-

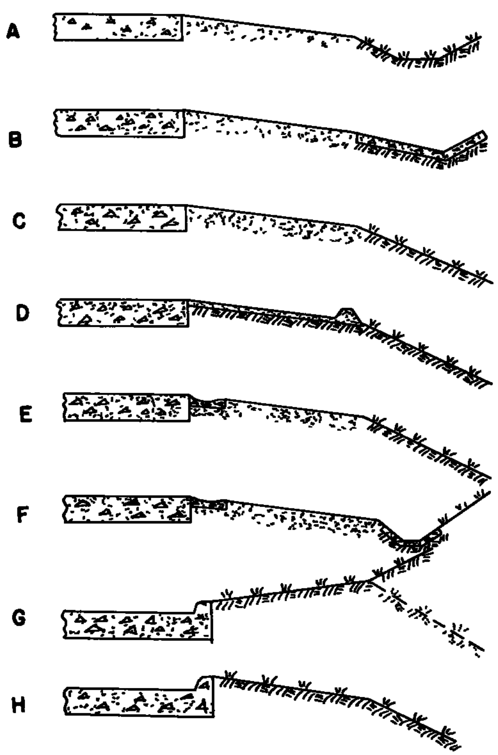


Figure 1. Typical shoulder designs.

ence in elevation and, thus, determinations of the type of shoulder protection needed.

4. A common cause of shoulder failure due to runoff is caused not by the design of the shoulder but by improper or inadequate culvert design, occurring at sidehill locations on long descending grades where runoff is intercepted by the ditch on the hill side of the roadway. This water and that from small streams running out of the hill must be carried across the highway. If the capacity of the culvert is inadequate, water will build up at the entrance and overtop the shoulder. The water running down the inside shoulder and ditch can cause serious erosion of the shoulder. Present research on the hydraulic operation of culverts should permit more accurate determinations of the capacity of different types and sizes of culverts and, through proper culvert design, great reductions in this type of shoulder damage.

These four conditions represent common causes of shoulder failures resulting from highway surface drainage. While present research will aid in solving the last two problems and the second can be corrected by avoiding a design where runoff is drained over the curb onto the pavement, more research is needed with regard to the handling of pavement runoff on steep grades and fill sections.

## *Discussion*

HARRY H. IURKA, Senior Landscape Architect, New York State Department of Public Works — Will you not accept the problem stated by Brant of determining desirable and safe slope of turf shoulders?

STIFEL W. JENS, 101 S. Meramec Avenue, St. Louis, Missouri — This discussion is limited to a few remarks relating to drainage as it affects or is affected by shoulder design. The paper delineates very clearly the major considerations in the relationship of surface drainage to highway shoulder design. There should be added to the discussion of design G the very serious result of this type of design occurring in winter when temperatures during the day may cause sufficient snow melt to result in sheet flow of water across the slab and freezing of such sheet flow in the late afternoon or evening, with the very serious hazard of a sudden slick in the vehicle path. The temptation to pitch shoulders toward the slab in cut sections, especially in urban expressways through high value areas, should be resisted, even though slightly wider rights-of-way and somewhat more excavation may be involved. Leroy F. Johnson also called attention to this, but it cannot be over-emphasized.

Designs A, B, and C which are the preferable types, do point to the desirability of satisfactory subgrade drainage to permit the moisture under the pavement to find its way out to either or both sides of the improved roadway. It was noted that some of the cross-sections indicated in slides showed the granular base continuous to the outer edge of the shoulders. While this is undoubtedly costly from a drainage viewpoint, it is highly desirable since, in addition to draining the moisture that might otherwise be trapped in the base course under the pavement, it drains the infiltrated and percolation rainfall and runoff that occurs over the shoulder surfaces. There have often been cross-sections in which the pavement has been constructed in a trench, with little or inadequate attention to lateral disposition of any moisture collecting beneath the pavement. Under such conditions, the moisture running off the pavement surface across the shoulder infiltrates to some extent and lessens the stability of the shoulder and possibly of the subgrade adjacent to the edge of the pavement.

Item 3, concerning the purposely depressed approach to a bridge, with a consequent lessening of length of bridge required, certainly deserves very careful and serious consideration in many instances, since the over-all costs of many small bridges and an occasional large one, could be significantly reduced by such means.

RICHARD ACKROYD, Closure — After considering Iurka's question, it is realized that the answer given during the sumposium was not adequate. As now interpreted, the problem stated by Brant, is as follows:

"Since it is acknowledged that the texture of turf requires a steeper slope to drain off water than a smoother shoulder surface, how steep a shoulder is permissible? Is the recommended 1 in. per ft too steep? Could it be steeper?"

Observation of highways in those states with which the author is familiar indicates that turf shoulders generally become soft and unstable, particularly during the spring season. They rut very easily and these ruts retain water — increasing the instability. Most of these shoulders according to state standards are apparently designed with a 1-in.-per-ft cross slope. If these shoulders could be more effectively drained, their stability should be improved. One way of providing better surface runoff would be to increase the cross slope to 1¼ in./ft or 1½ in./ft. This would reduce the depth of flow on the shoulder and the amount of water absorbed by the soil should be less. The shoulder would then be less likely to be soft and subject to rutting. Once ruts are formed, however, the small increase in slope will not help much. Ohio adopted a 1½ in./ft cross slope for turf shoulders in 1951 and used it until 1953, then returning to 1 in./ft. From a cursory observation, these shoulders with the steeper cross slope were apparently more stable. Unless it is determined that the 1½ in./ft cross slope is hazardous to traffic, it is preferable to the flatter slope for use with turf shoulders.

The author is not familiar with the experience record of the stabilized turf shoulders referred to by Brant and other roadside development engineers, but it would appear that, having a less dense growth of grass, such shoulders should offer less resistance to the flow of water and so perhaps the 1-in.-per-ft cross slope would be adequate. Acknowledging their esthetic values, it appears that turf shoulders still catch and hold cinders, sand, and other debris and thus tend to build up. They also require mowing.

A factor that appears to have a much greater influence on the stability of any type of shoulder than the cross slope is the practice adopted by many states of placing a permeable subbase under the pavement and extending it through the shoulder to the ditch line. This point was not mentioned in the original presentation because it does not strictly concern surface drainage; the assumption was that it would be covered by others. It was mentioned by the following speakers: Mr. Dent in connection with flexible pavements, Mr. Spencer in connection with pumping, Mr. Shepard in connection with construction practices in Ohio, Mr. Ridge in connection with maintenance, and Mr. Stokstad in connection with soils. These speakers all pointed out the value of having this permeable subbase under the shoulder, both for removing water from under the pavement and for stabilizing the shoulder.

Mr. Jens' discussion, submitted subsequent to the meeting, also pointed out the importance of this method of draining the subbase.

The author would also like to concur in the comments made by Jens regarding the possibility of ice on the pavement resulting from water draining off the shoulder onto the pavement, as it would in design G.

# Design of Shoulders for Flexible Pavements

GEORGE H. DENT, Benjamin E. Beavin Company
Baltimore, Maryland

●SHOULDERS for heavy duty flexible pavements should be paved with high type surfacing. Shoulder pavement for these highways should consist of either hot plant-mix, asphaltic concrete or penetration macadam. Thickness should be determined by the adequacy of the base course, but it should certainly not be less than 2½ in. The width of the paved shoulder should be a minimum of 5 ft or more in the case of heavily traveled roadways, and possibly of a sufficient width to provide for parking of disabled vehicles.

When the pavement on the traveled roadway is designed for light to medium traffic, the shoulders may be paved with a type of pavement that is commensurate with that used on the main portion of the highway. In other words, if the pavement proper consists of a road-mix, the shoulder should probably be the same type, or a bituminous surface treatment could be used.

No problem exists in delineating for the motorist which is the traffic lane and which is the shoulder. The two can be distinguished by one of a number of ways; a painted stripe can be used to separate them, or the shoulder can be distinguished from the pavement by the use of a different texture or surface, even sueh a coarse texture that a drumming sound will result when traffic uses the paved shoulder. Complete color distinction can be made by the use of light or dark aggregates, as the supply of local materials may dictate. Some highway departments have even gone so far as to make an improvised traffic line on the pavement edge by using ¾ aggregate in a thin ridge or line; the aggregate is fastened to the surface as in a surface treatment using bituminous material as the adhesive.

The beneficial effect of paved shoulders has been demonstrated and reported by the Highway Research Board. Positive statements on the benefit of shoulder paving are found in Highway Research Board Special Report 22 and the WASHO Road Test, Part 2: Test Data, Analysis, Findings (published 1955).

Perhaps it is needless to say that the durability and adequacy of the shoulder pavement will depend on the kind of support that it has. A subcommittee of the flexible pavement committee has made a report at this meeting. The subcommittee found, through a survey of the state highway departments, that there is a tendency toward the employment of foundation layers extending from ditch line to ditch line. This survey was conducted on primary highways only. The report is much too long and detailed for presentation here. However, there are certain interesting aspects that will be briefly mentioned.

With respect to the base course width on primary two-lane highways, 18 out of the 43 states reporting use base courses extending the full width of section, or from ditch line to ditch line. Most of the remainder, or 17 states, widen the base course beyond the width of the traffic lane by amounts ranging from ¼ to 1½ ft. The report also shows that 27 out of the 40 reporting states use full-width subbases. In a table listing the shoulder widths for primary two-lane highways it is indicated that 43 states use from 8- to 10-ft shoulders, 29 states using these widths only. Twenty-five states reported the use of a bituminous surface course on the shoulders. Nineteen of these states place this course, the thickness of which varies from ½ to 3 in., on the full-width of shoulder. The report also shows that 13 states of the 25 reporting use a bituminous surface treatment on the material in place, while 9 use the same type and thickness of surfacing on the shoulder as they use on the traffic lanes.

It was stated that shoulder pavement for heavy-duty highways should consist of hot-mix asphaltic concrete or penetration macadam, and that for secondary roads the shoulder pavement should consist of surface treatment or mixed-in-place surface courses. There are adequate specifications covering these types of pavement and it is needless to repeat them here. It appears that the money spent for paving shoulders is a good investment and it is usually returned many-fold through savings in maintenance costs.

# Highway Shoulders as They Affect Rigid Pavement Design

EARL C. SUTHERLAND, Highway Engineer
Bureau of Public Roads

● THE structural design or performance of a rigid pavement is not directly affected by the shoulders. Where the subgrade or subbase is of an impervious character, however, water which leaks through the joints and cracks accumulates on the subgrade or subbase. This water is sometimes forced out between the pavement edge and shoulder thus breaking the seal, at points, between the pavement edge and shoulder. When this develops, shoulder maintenance is required near the edges of the pavement to prevent excessive amounts of water from leaking through these breaks to the supporting medium.

When rigid pavements are placed on an impervious supporting medium it is desirable that the shoulders be constructed so that they can be properly maintained without unduly marring their appearance, and the shoulder material should be of a character that it will not tend to shrink away from the pavement for some distance adjacent to the edge. If turf is to be used on the shoulders it might be desirable to leave approximately a 2-ft bare strip adjacent to the pavement edge to make proper maintenance of this area more feasible.

The control of pumping is an important consideration in the design of rigid pavements, and the design and maintenance of the shoulders are important in this matter. The subject of shoulder design is, however, being discussed by a representative of the Committee on Maintenance of Concrete Pavement as Related to the Pumping Action of Slabs so it will not be discussed further.

# Highway Shoulders as Related to the Pumping Problem

W. T. SPENCER, Soils Engineer of Materials and Tests
State Highway Commission of Indiana

● PUMPING of rigid pavements cannot occur unless there is water under the pavement. In most cases the major portion of this water originates on the surface and drains between the shoulders and edge of pavement to the surface of the subgrade or subbase. When this condition exists in combination with a repetition of heavy axle loads and certain textured subgrades or subbases pumping is likely to develop.

The Committee on Maintenance of Concrete Pavements as Related to the Pumping Action of Slabs was created by the Highway Research Board in 1942 for the purpose of studying pumping, how to prevent it and to determine the best means of maintaining pavements after pumping has started. Early studies by this committee showed that pumping could be prevented by using granular subbases. As axle loads and frequencies increased an action similar to pumping began to develop on some dense graded granular subbases.

The effect of pumping of rigid pavements constructed on a fine-grained soil subgrade is well known. The effect of the similar action that occurs on the surface of a dense granular subbase, which could be termed "erosion," "jetting," "blowing" or possibly "pumping," is not so well known at present. Although Indiana has only a few localized areas where erosion of the granular subbase has caused severe stressing, it is conceivable that cavities could develop in sufficient magnitude to affect materially the life or performance of the pavement. Experiences indicate that the most severe erosion of the subbase occurs during abnormally wet cycles.

Investigations in Indiana show that most of the water that makes either pumping or erosion possible originates on the surface of the pavement, or, in some cases, on poorly drained shoulder areas. It is admitted along the edge of pavement to the surface of the subgrade or the surface of the subbase course. In general, the major portion of the admitted water can be attributed to the failure of the shoulder material to make sufficient contact with the pavement edge to maintain a water-tight seal. This leakage may be attributed to shrinkage, if the shoulder is constructed of high volume change, fine-grained soils; to possible frost movements of the shoulder material; to cavities in the shoulder, adjacent to the edge of pavement (usually caused by debris from the grading operations); and possibly to placement of porous, uncompacted granular materials against the edges of pavement. The latter item may vary widely when granular subbases are used since it depends on the amount and location of excess material deposited at form side during fine grading operations.

The quality of the material to be used in shoulder construction can be specified to obtain the best material economically available. On one project in Indiana the shoulder soil was selected on the basis of a maximum plasticity index and a maximum volume change, based on the field moisture equivalent. If a higher quality shoulder is required than can be obtained from the better soils on the project then the shoulder should be constructed with granular materials or paved.

Good maintenance that will insure good surface drainage, and the use of good shoulder materials, well placed, is necessary if surface waters are to be properly controlled along the edge of pavement. There are indications that the construction of edge gutters, dowelled to the edge of the slab, materially assist in preventing surface waters from draining to the surface of the subgrades or subbases.

The Pumping Committee has long recognized the value of shoulder treatment and the importance of good shoulder maintenance. At the last annual meeting of the Highway Research Board this committee sponsored a panel discussion on shoulder maintenance. The committee also recognizes that if water is allowed to reach the subgrade or subbase, and the pavement deflections are of sufficient magnitude, it will be necessary to provide properly drained subbase courses to prevent pumping or erosion.

The committee would like to interest state highway departments in the construction of drained experimental granular subbases. Drainage within the pavement area would be accomplished by extending the subbase beyond the edges of pavements for distances of 2, 4, 6, and 8 ft and all the way through the shoulders. The type of shoulder material used would be a part of this study.

Good shoulders, well maintained, make a substantial contribution toward controlling pumping of fine-grained soil subgrades or blowing of granular subbases.

# Geometric Design of Highway Shoulders

D. W. Loutzenheiser, Chief, Urban Highway Branch
Bureau of Public Roads

● THE geometric aspects of highway shoulder design are those that the driver sees and feels as his vehicle operates either on the adjacent through traffic lane or the shoulder itself. Any discussion of these aspects overlaps other topics on this symposium, but to some extent this is necessary to emphasize the features that are strictly geometric.

It is the aim of the designer to provide a shoulder of such character and extent as to insure the efficiency, safety, and mobility of vehicle operations on the highway, both when all traffic flows smoothly and when an emergency condition arises. There are several geometric features involved; namely, the shoulder width, continuity, distinctiveness as compared with pavement and outer areas, direction and amount of cross slope, inclusion of curbs and drainage inlets, outer edge rounding, and the slopes beyond. On some highways there are other outer features such as sidewalks, guideposts or guardrails, walls or rock faces, and structure piers or abutments. Also the effect of a stopped vehicle on the shoulder is of concern.

In some form or another current design practices and standards are reasonably well crystallized as to "desirable" geometric features of shoulders. The shoulder should be continuous, with a usable width of 8 to 12 ft. It should be reasonably stable for occasional use in all types of weather and should obviously appear so to invite use in emergencies. It should have contrast in color and texture from that of the adjacent through traffic lane, but be sufficiently smooth to be free of hazard when a vehicle traveling at or near highway speed pulls over on it in an emergency. The cross slope should be sufficient to provide adequate pavement drainage, but not enough to discourage full width use by timid drivers coming to a stop; accepted values in the range of ¼- to 1-in. per ft accomplish this. Vertical elements such as steep curbs, rails and walls should be well set back; sloping curbs at the inner edge should be flat enough both in fact and appearance that drivers will mount them when necessary.

To a large extent these current geometric design conclusions were arrived at by experience and judgment rather than by studies and reports of detail research. Preferably, all of the desirable features should be included on all highways insofar as the desired traffic operation is concerned, but in view of the costs involved distinctions regularly are made for some types of highways and for some terrain and adjacent land development conditions. The shoulder element of width is reduced considerably on low order highways and even on major highways in rough terrain, and the elements of stability and contrast may be omitted altogether on low order highways. Since such conclusions regarding the warranted extent and character of shoulder improvement are items of engineering judgment they remain somewhat debatable. Research data that demonstrate the actual value of shoulders as compared with their cost increment would be highly useful to reach such conclusions. Such research largely falls under the subjects of other panelists but is the basis for solution of general geometric design problems concerning width and continuity of shoulders. The basic question is, "Under what traffic volumes and operating conditions are non-continuous and partial width shoulders adequate?" This question applies to all types of highways.

Most highway departments concur in conclusions that continuous, stable, and wide shoulders are proper parts of expressways, both rural and urban, and rural major highways. But, on sections of these where construction or right-of-way costs are extremely high, circumstances seem to force consideration of other alternatives, the traffic operational effects and accident rates of which are little known. One alternate is the construction of a continuous but partial width (some 4 to 7 ft) shoulder along expensive fills or as part of long viaducts. Another alternate is the virtual elimination of a continuous shoulder and instead provision of emergency parking bays at intervals. Or, there may be a combination of the two — a shoulder that is continuous but only of partial width, with full width bays at intervals. Will such arrangements suffice for the volume and speeds of traffic operating on expressways? Can traffic flow continue with safety when some vehicle makes an emergency stop? If traffic operations are satisfactory with such arrangements, what are minimum dimensions for partial shoulder, the bay length and tapers, or the spacing between bays? A few examples of such treatment are now constructed and research studies should be started on them.

A stabilized shoulder 8 to 12 ft wide and continuous along an expressway is needed to prevent blocking of all lanes when a vehicle must stop on the roadway. Some engineers now report concern about use of this smooth and reasonably wide area as an additional traffic lane during periods of peak flow on heavily traveled routes, thus nullifying it as an emergency area. As a result they are asking how to design the shoulder area to be smooth enough for use in an emergency but yet of a type or pattern to discourage use as an extra lane. They are considering, and trying to a limited extent, transverse scoring, added planks or corrugations, or roughened surfaces of some sort. Here is a new field for research, as yet wide open. Is there sufficient demonstration of such malpractice in lane operation to make it of concern on expressways generally? Or, does it occur only in special cases with high traffic overload? If it is a general problem, then what are some three-dimensional forms of stable shoulder surfacing that will at least discourage, if not prevent, use of the shoulder as a lane and at the same time not impair drainage functions? Obviously, experimentation is needed.

This problem is a part of the broader one of how to make the stabilized shoulder truly contrast with the travel lane, both day and night, good weather and bad, and still be within reason on maintenance costs. The known contrasts of light vs dark surfaces, or either vs a turf shoulder area, are not feasible or acceptable generally. A drainage arrangement with flat curbs or shallow or rolled gutter sections on the inside of shoulder are means for this distinction. A distinctive shoulder pavement stripe may be developed. Chip courses on shoulder surface may be possible of development in a more permanently contrasting form than so far used. And, effectively stabilized turf surfaces have promise in certain climatic conditions. No doubt a number of acceptable answers will evolve, but as yet there are more questions than answers on these features. Experimentation and study along these lines should be accelerated.

On divided highways the advantage of a left or median shoulder is being recognized in some areas. With two through traffic lanes in each direction the left shoulder offers advantages of safety space, edge delineation and maintenance operations. On 6- and 8-lane facilities it may be of much greater importance as emergency stopping area. During periods of peak flow a stalling vehicle in the left lane or lanes has little possibility of being able to reach the normal shoulder on the right. This opens a new field of questions so far unanswered, in this case probably involving extra width in the median design. Are left shoulders functional parts of the cross-section? Should they be only a part or all of the width used on right shoulders? What are suitable curb and drainage arrangements? Should they be carried through underpasses?

Problems also arise on means of distinction along continuous stabilized shoulders at the ends of acceleration and deceleration lanes. Questions of shoulder width also involve the size and placement of principal direction and destination signs with letters legible to high-speed traffic.

The above types of studies require data on nearly all phases of engineering shown in this symposium. Traffic studies giving data on accidents, volumes, speeds, placement, and general driver behavior are essential. Particularly lacking are studies on vehicle breakdowns, frequency and extent of use of shoulders, and resultant effects on traffic operation and capacity. Drainage, soil and surfacing design also are involved. Maintenance and financing aspects also enter heavily. A combined approach appears to be the only way in which answers to these geometric problems can be determined.

In an effort to break down the large field of geometric design research into correlated pieces that might be studied, the committee has prepared and the Highway Research Board has distributed a series of research problem statements, one of which is on the geometric design of highway shoulders (No. 13 in Special Report 12, HRB). The committee is endeavoring to bring into a research report stage any useful studies and to assist any individuals or groups that may display an interest in doing related research on any phase of geometric design. Thus far the only research noted on shoulders is that organized and reported by other HRB committees.

# Relationship of Accident Rate to Highway Shoulder Width

ERNEST T. PERKINS, Assistant Chief Engineer
Connecticut State Highway Department

● IN any discussion of the value of highway shoulders, their width always becomes a factor. The width requirement may be dependent on the presence of obstructions at the outer edge of the shoulder, such as guardrails and guide posts.

There is available, in the form of new tabulating punch cards, a summary of accident data for each control section of the state-maintained highway system in Connecticut. These punch cards include data on length of section, annual average daily traffic volume and annual vehicle miles; number of accidents, fatal accidents, fatalities and injuries, and amount of property damage; pavement, shoulder and median width and type, highway type and system; and miscellaneous items. With such information on punch cards, it is possible to compile many different tabulations in an attempt to show what relationship, if any, exists between these different factors. Since the data for four years (1951-1954) were available and since most of Connecticut's highways have paved shoulders, it was felt that there was a sufficient sample to establish the relationship of accident rate to shoulder width.

The next problem was to sort the punch cards prior to making tabulation listings, and it was done in the following manner: (1) the rural and urban sections; (2) by highway type such as two-lane, four-lane contiguous, four-lane divided with no control of access, four-lane expressways with full control of access, etc.; (3) by pavement surface width; (4) by shoulder type (grass and paved); and (5) by shoulder width. Separation by pavement surface type was not found to be significant. The great bulk of two-lane ce-

TABLE 1

ACCIDENT, MILEAGE AND TRAFFIC DATA AND ACCIDENT RATES BY VARIOUS PAVEMENT AND SHOULDER WIDTHS ON TWO-LANE CONNECTICUT HIGHWAYS (WITHOUT CONTROL OF ACCESS) FOR FOUR YEARS 1951-1954

| Pavement surface width (ft) | Item | Paved shoulder width (feet) | | | | | | | | | | | Total or weighted average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| 14 | No. of accidents | 1 | 0 | 4 | 39 | 122 | 144 | 196 | 34 | 22 | | | 562 |
| | Vehicle-miles[a] | 0.002 | 0.011 | 0.023 | 0 181 | 0 706 | 0 734 | 0.593 | 0.129 | 0 075 | 0 | 0 | 2.454 |
| | Avg daily traffic | 200 | 700 | 400 | 500 | 1100 | 1500 | 1900 | 1200 | 1100 | | | 1200 |
| | Accident rate[b] | 500 | 0 | 170 | 220 | 170 | 200 | 330 | 260 | 290 | | | 230 |
| 16 | No of accidents | 11 | 2 | 17 | 43 | 116 | 66 | 55 | 138 | | 6 | | 454 |
| | Vehicle-miles[a] | 0 009 | 0 023 | 0.074 | 0 232 | 0 396 | 0 216 | 0.183 | 0.501 | 0 | 0 034 | 0 | 1 668 |
| | Avg daily traffic | 400 | 600 | 500 | 700 | 1200 | 1200 | 1300 | 3500 | | 2100 | | 1200 |
| | Accident rate[b] | 1200 | 90 | 230 | 190 | 290 | 310 | 300 | 280 | | 180 | | 270 |
| 18 | No of accidents | 13 | 23 | 43 | 254 | 410 | 455 | 127 | 52 | | | | 1377 |
| | Vehicle-miles[a] | 0 022 | 0 097 | 0.166 | 1.009 | 1 456 | 1 818 | 0.438 | 0.253 | 0 | 0 | 0 | 5 259 |
| | Avg daily traffic | 400 | 600 | 600 | 1100 | 1500 | 2000 | 2300 | 4000 | | | | 1500 |
| | Accident rate[b] | 590 | 240 | 260 | 250 | 280 | 250 | 290 | 210 | | | | 260 |
| 20 | No. of accidents | 34 | 86 | 196 | 969 | 2321 | 3362 | 438 | 437 | 140 | 35 | | 8018 |
| | Vehicle-miles[a] | 0.141 | 0 328 | 0 977 | 3.024 | 9.446 | 12 434 | 1 754 | 1 239 | 0 612 | 0.211 | 0 | 30.166 |
| | Avg daily traffic | 900 | 800 | 1000 | 1500 | 2500 | 4000 | 3300 | 5700 | 4600 | 5300 | | 2700 |
| | Accident rate[b] | 240 | 260 | 200 | 320 | 250 | 270 | 250 | 350 | 230 | 170 | | 270 |
| 22 | No. of accidents | 31 | 257 | 753 | 1536 | 834 | 194 | 187 | 144 | 670 | 85 | 142 | 4833 |
| | Vehicle-miles[a] | 0.155 | 1.034 | 2.944 | 5 927 | 2.725 | 0 901 | 0 489 | 0 523 | 2 462 | 0.449 | 0 510 | 18.119 |
| | Avg daily traffic | 800 | 1400 | 1200 | 1500 | 1600 | 3500 | 3200 | 2400 | 3800 | 6600 | 4500 | 1700 |
| | Accident rate[b] | 200 | 250 | 260 | 260 | 310 | 220 | 380 | 280 | 270 | 190 | 280 | 260 |
| 24 | No of accidents | 31 | 107 | 617 | 397 | 172 | | | 52 | 51 | | 1 | 1428 |
| | Vehicle-miles[a] | 0 138 | 0.368 | 2 283 | 0.999 | 0 872 | 0 | 0 | 0.173 | 0.263 | 0 | 0.042 | 5.138 |
| | Avg daily traffic | 1100 | 1300 | 2100 | 3300 | 2300 | | | 5900 | 5100 | | 4500 | 2300 |
| | Accident rate[b] | 220 | 290 | 270 | 400 | 200 | | | 300 | 190 | | 20 | 280 |
| Total or weighted average | No. of accidents | 121 | 475 | 1630 | 3238 | 3975 | 4221 | 1003 | 857 | 883 | 126 | 143 | 16672 |
| | Vehicle-miles[a] | 0.467 | 1 861 | 6.467 | 11 372 | 15.601 | 16.103 | 3.457 | 2.818 | 3.412 | 0 694 | 0 552 | 62.804 |
| | Avg daily traffic | 800 | 1100 | 1300 | 1400 | 2000 | 3300 | 2600 | 3600 | 3800 | 5600 | 4500 | 2000 |
| | Accident rate[b] | 260 | 260 | 250 | 280 | 250 | 260 | 290 | 300 | 260 | 180 | 260 | 270 |

[a] hundred millions
[b] per hundred million vehicle-miles

ment concrete pavements are in the 20-ft pavement surface width group with shoulder widths of from 4 to 9 ft. The great majority of the other groups are made up of various black-top pavements. It is significant to note that all shoulders except grass shoulders are paved in Connecticut, and that the mileage of grass shoulders is small.

After running off a tabulation listing of all four years, it was found that sufficient samples for a variety of shoulder widths existed only in the rural, two-lane highway grouping. The size of the sample available for various combinations of pavement and shoulder widths is shown in Table 1. The first two values in each block of the table are the total number of accidents and the total number of vehicle-miles, respectively. The accident rate per hundred million vehicle-miles has been computed and is shown as the fourth value in each block. The average daily traffic volume during the four-year period is also shown. It can be seen that this average volume generally increases with both the pavement and shoulder width, which is perhaps a reflection of design standards being related to the traffic volume over the past years.

TABLE 2

ACCIDENTS, MILEAGE AND TRAFFIC DATA AND ACCIDENT RATES BY TOTAL SURFACE WIDTH ON TWO-LANE CONNECTICUT HIGHWAYS (WITHOUT CONTROL OF ACCESS) FOR FOUR YEARS 1951 THROUGH 1954

| Total surface width (feet) | Total number of accidents | Total vehicle-miles (hundred millions) | Average daily traffic volume | Accidents per hundred million vehicle-miles |
|---|---|---|---|---|
| 14 | 1 | 0 002 | 200 | 500 |
| 16 | 11 | 0 020 | 500 | 550 |
| 18 | 19 | 0 068 | 400 | 280 |
| 20 | 113 | 0 493 | 600 | 230 |
| 22 | 325 | 1 587 | 900 | 200 |
| 24 | 998 | 4 288 | 1,200 | 230 |
| 26 | 2,501 | 8 601 | 1,400 | 290 |
| 28 | 5,018 | 19 786 | 2,000 | 250 |
| 30 | 4,880 | 17 172 | 3,100 | 280 |
| 32 | 856 | 3 780 | 3,100 | 230 |
| 34 | 630 | 1 762 | 4,600 | 360 |
| 36 | 284 | 1 135 | 3,300 | 250 |
| 38 | 757 | 2 846 | 4,000 | 270 |
| 40 | 136 | 0 712 | 6,000 | 190 |
| 42 | 142 | 0 510 | 4,500 | 280 |
| 44 | 1 | 0 042 | 4,500 | 20 |
| Total or weighted average | 16,672 | 62 804 | 2,000 | 270 |

Table 1 shows that there is no definite relationship of accident rates to shoulder widths. The accident rates vary (in the neighborhood of 270) and do not in any case follow a consistent trend. The same is true of the relationship of the accident rate to the pavement width.

To determine if some other relationship exists, Table 2 was prepared to show the relationship of the accident rate to the total surface width (pavement plus shoulders). The values in Table 2 are a summary of values in Table 1 but arranged in different order. Again, no significant trend or continuous relationship exists among those values which have a substantial amount of data.

It can be seen that while the average daily traffic volumes have a general relationship to the pavement, shoulder, and total surface widths, there is no relationship with the accident rate. Of course that rate is already related to the traffic volume.

In conclusion, this data shows no significant relationship between accident rate and shoulder width. Accident rates may be dependent on other factors, such as side friction, alignment, pavement condition or crown, or other factors not available in these records. More data on 8-, 9-, and 10-ft shoulders is necessary to find a trend. Further breakdown of the data only reduces the size of samples to the point of no significance. The records show that side friction is an important factor, since a definite relationship between accident rate and control of access has been established. Perhaps human behavior on highways overshadows all design factors.

It appears from this data that further analysis by type of accident would be necessary in an effort to establish optimum shoulder width solely from the standpoint of accidents. Shoulders may be partially justified by increased roadway capacity and mental ease for the driver, but those considerations have not been treated in these inconclusive statistics.

# Highway Shoulders Construction Practices

C. H. SHEPARD, Soils Engineer, Bureau of Construction
Ohio Department of Highways

●DURING the last two decades, Ohio has gone through a wide variety of shoulder practices. Twenty years ago it was the practice to use a 4-in. thickness of granular material at the pavement edge. The granular material was not stabilized or sealed and was at times unstable and trapped water. Then during a period of many years, it was general practice to provide soil berms with grass to the pavement edges on heavily traveled primary roads as well as lightly traveled secondary roads. This policy beautified the shoulders, but it created hazardous shoulders of low wet weather stability. Heavy vehicles frequently use the shoulder on heavy duty roads, resulting in high maintenance costs and some pavement failure. The lack of suitable shoulders encourages heavy vehicles to make emergency stops on the through traffic lanes, causing considerable delay and confusion as well as serious traffic hazards.

Now the policy for new construction provides stabilized shoulders along the outside pavement edge of all divided pavement highways, and along each edge of all two-lane pavements with more than 200 heavy commercial vehicles per day. Seeded earth shoulders are still generally used on low traffic roads. Figure 1 shows a standard typical section using earth shoulders. Features intended to facilitate rapid runoff of surface water (of primary importance for good shoulder maintenance) are the shoulder finished 1 in. below the pavement edge, shoulder slope of 1 in. per ft, and deep side ditches with a minimum depth of 18 in. below the outside edge of the shoulder.

## Stabilized Shoulders

The present standard for stabilized shoulders (Figure 2) consists of a 4-ft width of stabilized crushed aggregate, 6-in. compacted depth, finished flush with the pavement surface, with a slope of $^3/_4$ in. per ft. Materials for this course are crushed limestone, crushed slag, or crushed gravel. If gravel is used, specifications require that the portion retained on a No. 4 sieve shall contain not less than 40 percent fractured pieces. Specifications require a well graded material with a 2 in. top size, with 0 to 15 percent passing the No. 200 sieve, and a plasticity index of not more than 6. In addition, the physical characteristics of the material must be such that it will compact to the satisfaction of the engineer.

Figure 3 shows the shoulder detail for a flexible pavement project with a stabilized crushed aggregate shoulder (Ohio Project 36(1955) now under construction). The 4-ft wide stabilized shoulder has 6 in. compacted thickness and a slope of 1 in. per ft. The subbase is extended through the shoulder to the ditch on a slope of $^3/_{16}$ in. per ft to provide drainage.

Figure 4 shows the shoulder detail for Project 184(1953), a four-lane divided highway on a new location 9 miles long. Throughout the project, this shoulder treatment was used on the median sides as well as on the outside edges. Excellent drainage provided by longitudinal pipe underdrains minimizes problems during wet weather construction and insures adequate drainage. The shoulders on this project are in excellent condition after one year of service, with practically no shoulder maintenance necessary.

Other types of stabilized shoulders have been used in Ohio. Calcium chloride and sodium chloride have often been used successfully in stabilized aggregate shoulders. Ohio Project 205(1955), now under contract, specifies aggregate shoulder material stabilized with portland cement where the pavement grade is between 4 and 6 percent. Erosion of shoulders at the pavement edge has been a problem on other projects with similar grades, and the cement stabilized shoulders are to resist erosion. Ten percent cement by volume will be used. The shoulders will be inspected periodically after construction. The dimensions of the cement stabilized shoulders are 4 ft wide and 6 in. deep. The aggregate and cement may be plant-mixed or mixed-in-place and will be compacted and cured in a manner similar to that specified for soil-cement base construction.

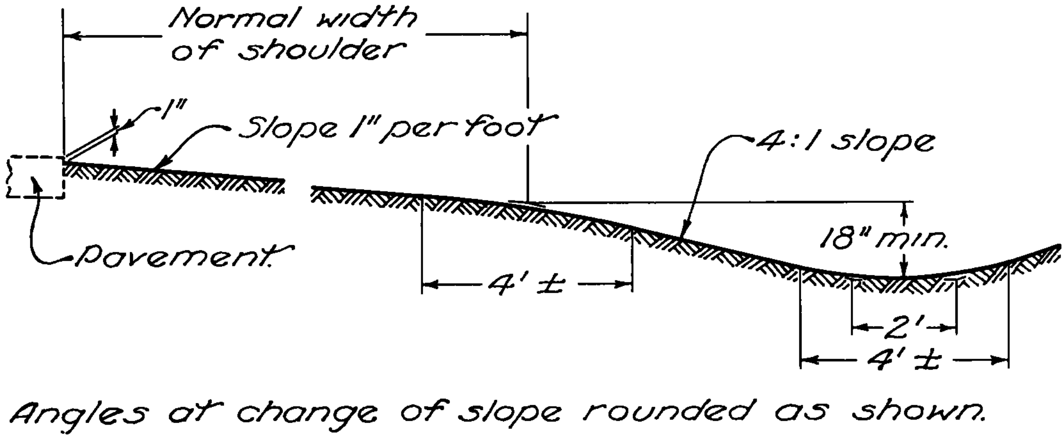


Figure 1. Standard section using earth shoulder.

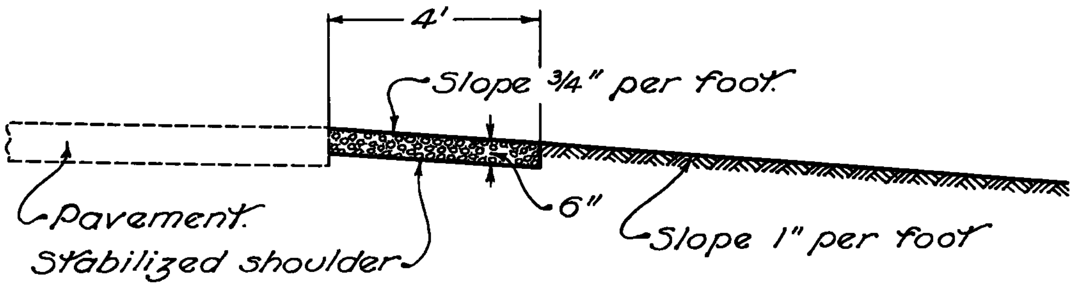


Figure 2. Standard section using stabilized shoulder.

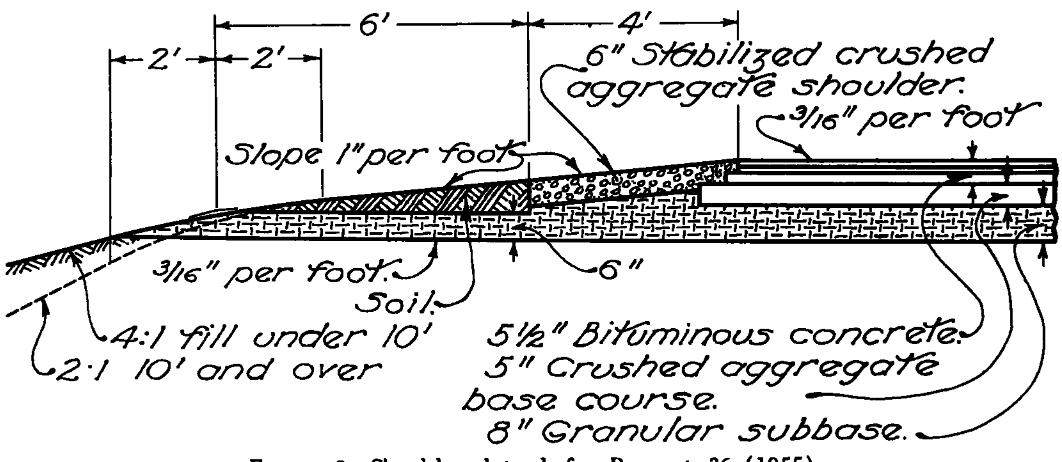


Figure 3. Shoulder detail for Project 36 (1955).

## Construction Methods

Shaping the subgrade for the standard stabilized shoulder course is usually done with a motor grader, often with a special blade of proper dimensions for the purpose. Figure 5 shows a trench for the stabilized shoulder being cut. The subgrade for the stabilized shoulder is rolled until the compaction is not less than the specification requirement, which varies from 98 to 102 percent of Standard AASHO Method T-99 depending on the soil being compacted. The higher percentages of compaction are required for the lighter weight soils. A trench roller is usually used for rolling the subgrade, although other types of rollers are permitted provided specified compaction is obtained.

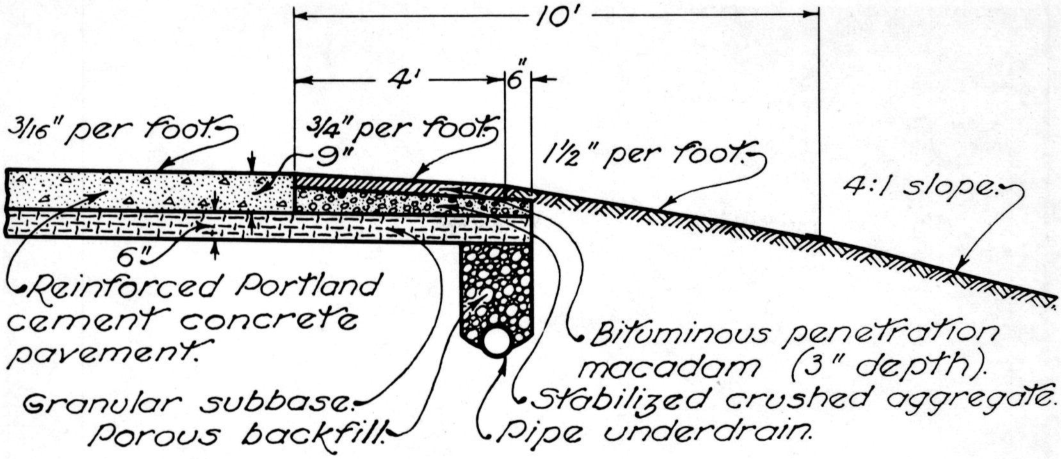


Figure 4. Shoulder detail for Project 184 (1953).

Check tests for subgrade density are made by either the sand or cylinder density method. A template is used to check conformity to plan lines.

After the subgrade is shaped and compacted, the crushed aggregate is spread upon the subgrade in layers not to exceed 6 in. compacted thickness. Usually the crushed aggregate is spread in one course with a mechanical spreader, as shown in Figure 6. A rear view of the spreading operation is shown in Figure 7, which also shows a power broom towed behind the spreader, here being used to keep the pavement free from loose aggregate.

For initial compaction of the stabilized shoulder material, specifications permit the use of any suitable equipment approved by the engineer. For final compaction of the surface of the stabilized shoulder, the use of approved pneumatic tired equipment is required (Figure 6). Moisture-density principles are used in compaction control. When ordered by the engineer, water is applied to aid in compaction and prevent segregation. The material is compacted to the density established as satisfactory by field density tests. The sand method is used for compaction control, and compaction is not considered satisfactory until the density in the compacted stabilized shoulder is as high or higher than the density at optimum moisture as determined by Standard AASHO Method T-99 using that fraction of the material which passes the ¾-in. sieve.

The number of density and moisture checks required for control during construction is not great where the work is proceeding smoothly and uniform materials are being compacted. If adequate densities are being obtained and proper moisture content is being maintained, the job of inspection is principally one of determining the number of passes of the roller which will achieve the desired result and seeing that this number is actually made. Under such conditions, only one or two density checks per day are sufficient.

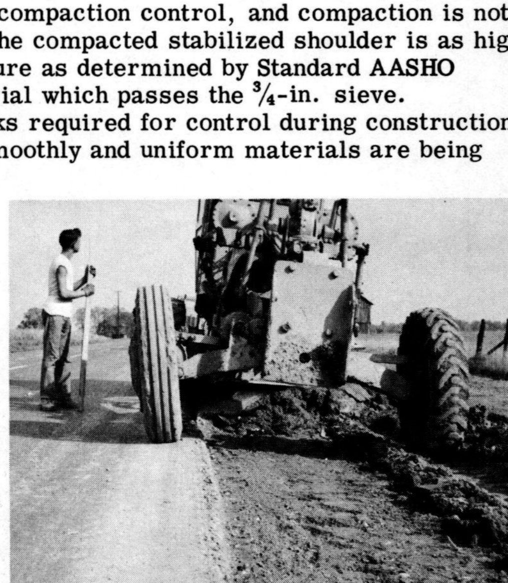

Figure 5. Subgrade for stabilized shoulder being prepared with motor grader.

## Construction Problems

Effective compaction control procedures and continual inspection during construction are necessary to insure adequate compaction of stabilized shoulders and the subgrades. Side ditches and shoulders must be properly shaped at all times during construction to provide proper runoff during rains and to prevent

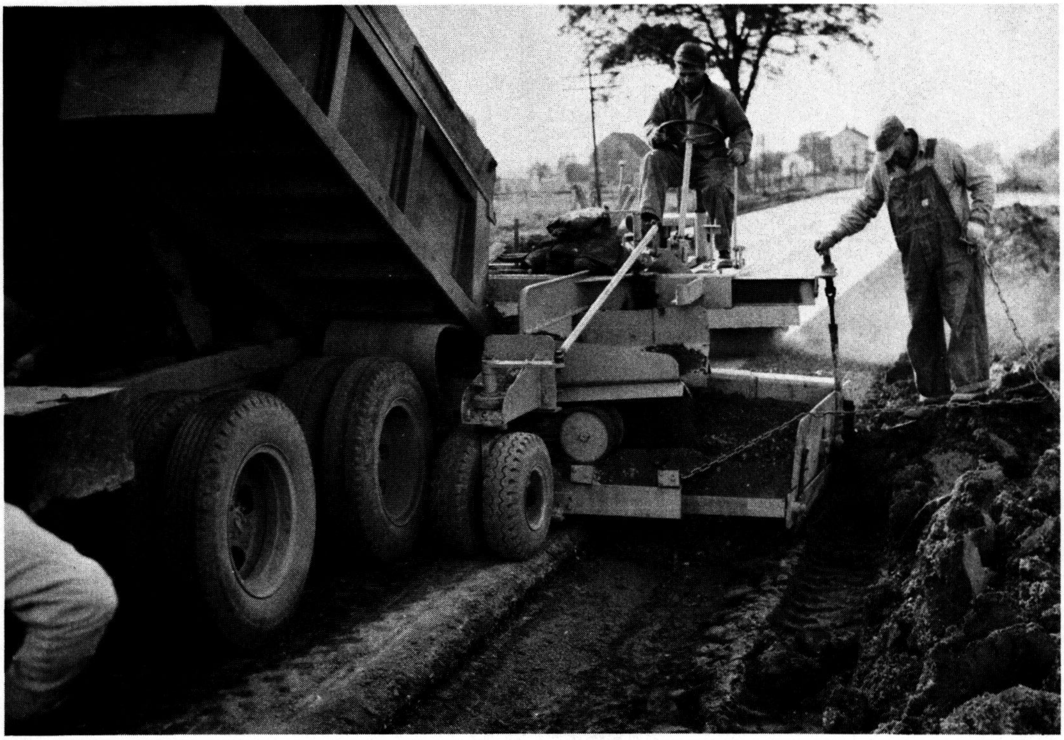

Figure 6. Stabilized crushed aggregate shoulder material being placed with mechanical spreader.

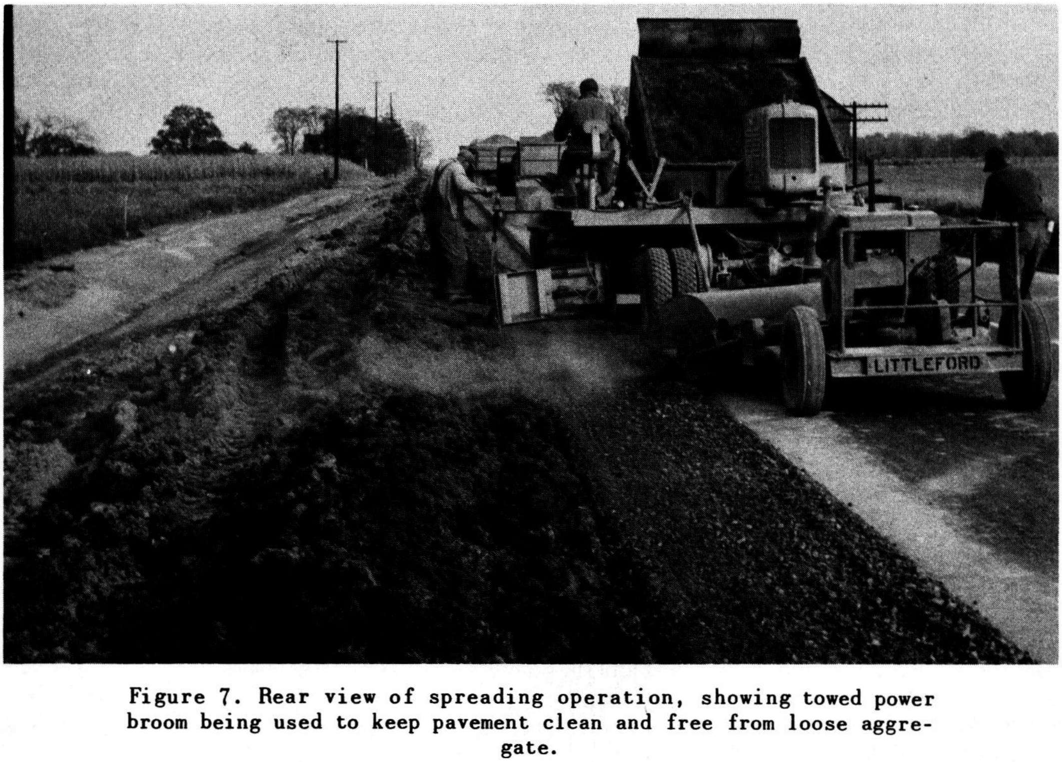


Figure 7. Rear view of spreading operation, showing towed power broom being used to keep pavement clean and free from loose aggregate.

ponding of water on the roadway. Construction trenches through the shoulders are necessary to provide for proper drainage of surface water from trenched pavement and shoulder sections. There seems to be a general tendency for contractors to neglect cutting drainage trenches through the shoulders during construction, and constant attention by the engineer is usually necessary to insure that these trenches are established and maintained where needed.


Figure 8. Pneumatic tired roller being used to compact stabilized crushed aggregate shoulder.

To improve practices for the construction of flexible pavements, it has been proposed to keep all heavy construction equipment and trucks hauling materials off of the finished subgrade, subbase and base courses during construction, and to require all equipment not needed in the construction of the pavement to use the shoulders. It is anticipated that such requirements will create problems in shoulder construction. Heavy traffic on the shoulders during pavement construction will interfere with maintaining construction trenches across the shoulders and will create rutting of the shoulders, making it difficult to keep the shoulders properly shaped to maintain adequate drainage of surface water during construction.

On heavily traveled primary roads, there is an unquestionable need for stable shoulders with some type of paved surface to provide surface drainage. Maintenance forces, as facilities permit, are now engaged in a program of applying bituminous surface treatment to shoulders which have been previously maintained for several years as stabilized aggregate shoulders. For new construction on primary roads, where granular stabilized shoulders with no binding surface are provided, shoulder problems are being passed on to maintenance forces. To meet future needs on primary roads, it is indicated that stabilized shoulders, provided during construction with some type of bituminous surface, will be necessary.

# Maintenance Costs of Highway Shoulders

S. E. RIDGE, Highway Engineer
Bureau of Public Roads

●TO the maintenance engineer, the shoulders of a highway are similar to the eaves of a house. One of their prime purposes is to keep surface moisture from entering the base, subbase, and subgrade and destroying the surface support. The shoulder must have the ability to carry the water deposited on it and the adjacent pavement over the shoulder area into the ditch where it can have little or no effect on the stability of the surface support, and it must have this ability under all conditions. The shoulder surface must be impermeable.

The shoulder should also be built upon a base that will allow the subsurface water to move freely from beneath the pavement. The shoulder base should not act as a dam and trap water beneath the roadway surface.

This ability to shed surface water and carry subsurface water to the ditch must be present under all climatological conditions. The shoulder design should be such that surface thawing after a deep frost penetration occurs evenly over the surface and shoulder areas and such that thawing does not penetrate more rapidly under the surface areas and form a pocket in which moisture can accumulate. It is also important to the proper functioning of the shoulder that the ditch design be such that snow can be completely removed from the shoulder. Otherwise, snow melting on the pavement will be held on the shoulder and some will seep through into the base.

It is quite evident, therefore, that shoulder maintenance costs alone cannot be used to evaluate the over-all maintenance economy of different types and designs of shoulders. The effect of the shoulder type and design on surface maintenance costs must also be considered.

Another element that has an important effect on shoulder maintenance costs is the width of the adjacent surface. Shoulder maintenance costs are much higher on roads with narrow lane widths. A recent study of shoulder maintenance costs indicates that at traffic volumes of 3000 VPD, the annual cost of maintaining gravel shoulders on highway sections with 22-ft surfaces (two 11-ft lanes) is $44. 00 per mile less than the cost of maintaining the same type shoulders on sections with 20-ft surfaces (two 10-ft lanes). The effect would, of course, be much greater adjacent to narrower lanes and much greater at higher traffic volumes.

Another requisite of shoulders, insofar as the maintenance engineer is concerned, is the stability of the shoulder. Even on wide roads, vehicles will accidentally or through disability move off the pavement onto the shoulder. The shoulder should be able to support the vehicles without rutting or other damage under all weather conditions. If it cannot, pavement edge ruts soon develop. These ruts hold water which soon seeps into the subgrade and causes failure of the pavement. Obviously the ruts must also be repaired and this requires maintenance expenditures.

The engineer designing the shoulders of the new high speed, high traffic highways should keep in mind the fact that such shoulders are subjected to an entirely different type of traffic than a surface. If the pavement is sufficiently wide, the traffic on these shoulders will be infrequent. A large portion of that traffic, however, will be of a very damaging type — high speed vehicles which for one reason or another have accidentally left the surface. On leaving the surface, the driver of the vehicle reacts in one or both of two ways: he either applies his brakes suddenly or he attempts to regain the pavement by changing drastically the direction of the vehicle. Either of these two actions produces a tearing effect on the shoulder surface. This, combined with the fact that the normal traffic on the shoulder is very light, makes it very difficult to maintain anything but the most durable shoulder surfacing. The design of shoulder surfacing should be made with these facts in mind for, on this type of highway, shoulder maintenance is a most difficult, costly, and dangerous operation — dangerous both to the maintenance forces and to the traveling public. Safety often costs two to three times the cost of the actual maintenance.

The shoulder texture should be different from the texture of the roadway surface.

The driver should know both by sight and sound when he leaves the pavement surface or else he will use the shoulder as a riding surface and shoulder maintenance cost will rise.

In summary, from the maintenance cost viewpoint, the shoulder surfaces should be stable and impermeable. They should be tough enough to withstand the tearing effect of high-speed traffic. They should not accumulate dirt and debris. They should contrast with the roadway surface and they should be built upon a base that will allow moisture to drain. The maintenance engineer would also like to have the roadway surface built wide enough to minimize the accidental use of the shoulder or the deliberate use of the shoulder as the traveled way. The evaluation of the maintenance economy of different surface types should be based not only on the cost of maintaining the shoulder but also on the effect that the shoulder type has on the maintenance cost of the roadway surface. The evaluation should also take into account the possibility that the reported costs do not represent full maintenance. On the narrow older roads carrying high traffic volumes, it is often impractical to do the blading necessary to maintain a smooth surface on untreated gravel or soil shoulders. The reported costs are, therefore, only a partial indication of maintenance economy.

# Design of Shoulders to Provide Safer Winter Travel

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New Hampshire Department of Public Works and Highways

●IN order to discuss shoulder design changes which will provide safer winter travel it appears necessary to include certain adjacent areas which may or may not be considered shoulders. Consideration of the following factors in the design and construction of highway shoulders and adjacent areas will contribute materially to safer winter driving and lighten the burden of the maintenance forces. Regardless of the width or surface type of a shoulder there should be some feature which definitely separates it from the pavement. One way in which this can be accomplished is by increasing the crown of the shoulder from three to four times that of the pavement; in addition to defining the shoulder this permits the free flow of water away from the pavement. Water on the pavement, whether from rain or melting snow creates serious problems during the winter months for the motorist and the maintenance men. On a frozen pavement a very small amount of water in the path of motor vehicles becomes a thin sheet of ice for a considerable area.

The shoulders on the high side of superelevated curves should be constructed with a slight crown from the edge of the pavement for 3 or 4 ft and the remainder sloped in the opposite direction from the superelevation. This prevents water from flowing onto and across the pavement from melting snow windrows or any other source.

Grassed areas in back of curbs should slope down at least one inch to the foot from the top of the curb and for a sufficient distance to provide an adequate gutter for the area drained.

Median strips for divided highways should always be depressed at least one inch to the foot whether they are between the curbs of 30 in. cement concrete or 30 ft grassed areas.

Channelization islands to direct traffic in a desired path of necessity are placed directly on the pavement with no possibility of a gutter surrounding them; consequently, they drain water onto the pavement. They should be depressed back of the curbs whenever possible. The grassed areas in back of curbs at highway interchanges should also be depressed. Traffic circles should be similarly depressed in back of the curbs to conduct water to drainage receptacles.

As soon as the public and the engineers have become accustomed to seeing these designs they will accept them as readily as they accepted the change from raised to depressed median strips. If desired, low growing shrubs can be planted to camouflage these changes in cross-section. When determining the section to be used for grassed areas, consideration should be given to the rapid rate at which shallow grassed gutters become raised and eliminated from natural causes, as well as to the expense of reconstructing these gutters.

The shoulder and adjacent area at side road, street, and other entrances should be constructed so that water cannot flow onto the pavement of the main highway.

Highway signs or similar obstacles should be placed on the slopes where they will not interfere with the economical, mechanical maintenance of the shoulders.

# Role of Highway Shoulders in Traffic Operation

A. TARAGIN, Highway Engineer, Highway Transport Research Branch
Bureau of Public Roads

● HIGHWAY shoulders are an integral part of a road structure. Since a highway is designed and constructed to accommodate traffic, it is very important to evaluate the effect of the shoulders on traffic operation. A Highway Research Board committee organized in 1947 undertook to evaluate this effect.

Because of the broad functions of highway shoulders the committee felt that the research should be divided into the following main categories:

1. Effect of shoulder width and type on traffic when the shoulder is not occupied by parked vehicles or other objects
2. Effect of shoulder width and type on traffic when the shoulder is occupied by parked vehicles or other obstructions such as parapet walls, bridge piers and abutments, utility poles and guardrails.
3. Extent of shoulder use by parked vehicles.
4. Relation between shoulder width and type and motor vehicle accidents.

The following is a brief statement as to the extent of research work already completed and what needs to be done on each of the foregoing items:

1. From extensive studies in 15 states it was found that speeds and lateral positions of moving vehicles are not affected by the width of shoulder, provided the shoulder is clear and at least 6 ft wide. There is no substantial effect if the shoulder is at least 4 ft wide. Bituminous-treated shoulders, 4 ft or more in width, adjacent to two-lane concrete roads 20 ft or less in width, increase the effective surface width approximately 2 ft. It is believed that research on this phase of the problem is quite complete and no further work is indicated for the time being.

2. From studies of driver behavior on sections of highway with and without vehicles or other objects on the shoulder, it was found that for traffic not to be influenced substantially, a clear distance of 4 ft is needed between the pavement edge and the parked vehicle or other obstructions such as parapet walls and bridge piers.

It should be borne in mind that the capacity of a highway is reduced by inadequate shoulders. For shoulders less than 6 ft wide, the capacity is affected inversely to a higher degree as the shoulder width becomes narrower. Furthermore, without a place of refuge outside the traffic lanes, one disabled vehicle can reduce the capacity of a highway by more than the capacity of one lane.

3. Perhaps one of the simpler problems to solve (for which there are as yet very little data available) is the extent to which shoulders on rural highways are used by parked vehicles. Since a vehicle parked too close to the pavement edge causes a lateral shift in the position of vehicles traveling in the lane adjacent to the shoulder, the role of the shoulder becomes very important especially on narrow pavements where an indiscriminately parked vehicle can cause hazardous conditions in addition to the reduction in highway capacity.

One preliminary study in an eastern state showed that there is one emergency stop for each 7,500 vehicle-miles of travel and one stop (for any purpose) for each 300 vehicle-miles of travel. The observation for the emergency stops was at a location where there were no shoulders and stops were possible only on the roadway.

Information of this type is needed to determine the frequency of parked vehicles per mile of highway at various traffic volumes and on different types of highways. How is the frequency of parking related to trip length and to distance from urban areas? Do turnouts on a highway decrease the frequency of shoulder use? Do drivers take advantage of wider and better stabilized shoulders to a greater extent than they do narrow and unpaved shoulders? Can the parked vehicle be ultimately related to accident causation? These are some of the questions that need to be answered before a really clear evaluation can be made of the role of shoulders on traffic operations.

4. Intensified research has been conducted in the past two years to determine the relation between highway shoulders and motor vehicle accidents. Several states have

developed some very interesting and even challenging results. One study indicates that with gravel shoulders property damage accidents vary inversely with shoulder width. Earlier studies produced almost opposite results. Additional research on this phase of the problem is definitely needed and it is being undertaken in two or three states.

From this brief statement it is clear that although highway shoulders play an important role in traffic operation, there is still much to learn.

# Highway Shoulders as Viewed by the Soil Engineer

OLAF L. STOKSTAD, Michigan State Highway Department

● THE soil engineer considers the highway shoulder as auxiliary to the adjacent traffic lane. Primarily it is that part of the highway cross-section into which a driver and his vehicle may safely escape the flow of traffic. In addition the shoulder structure also supplies support to the outside pavement edge. The soil engineer, therefore, considers the shoulder as having length, width, and depth, and he also considers the necessity of a service life consistent with that of the traffic lane pavement. To function as an auxiliary to the traffic lane, the shoulder must be surfaced to permit safe deceleration, and it must be built to carry the axle loads permitted in the traffic lane. The technique of obtaining these objectives at least cost varies with the location, type, and importance of the highway and also with locally available construction materials.

In designing to satisfy requirements of strength and safety, there are certain elements of the Michigan shoulder structure which serve a dual purpose. For instance, climatic conditions in Michigan dictate a minimum subbase thickness of 12 in. over clay subgrade soils. Good subgrade drainage requires that the subbase be built of free-draining granular material and also that it be extended through the shoulder. The subbase thus becomes a part of the shoulder structure where it serves the dual purpose of providing a drainage medium for the traffic lane and load bearing strength for the shoulder (Figure 1).

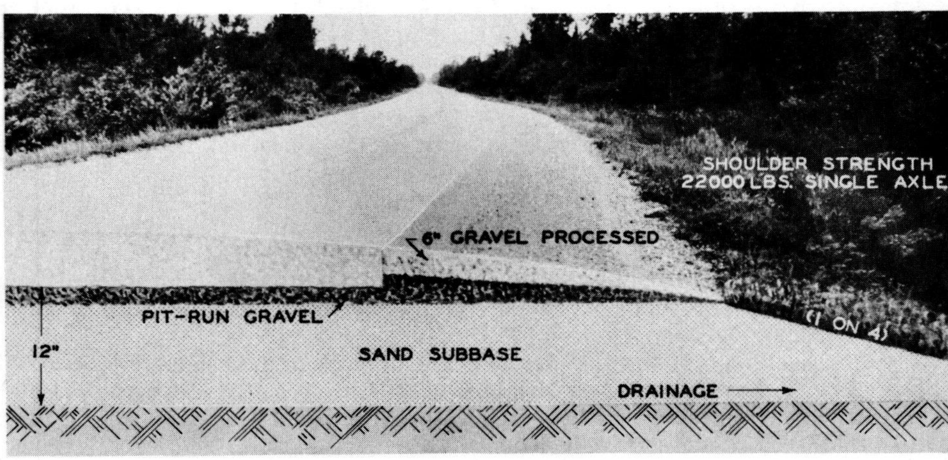


Figure 1.

Some items of shoulder design conflict in their requirements. Good topsoils for vigorous turf development, for instance, are notoriously poor load bearing soils during periods of wet weather. This consideration, plus the destructive effect of traffic on grass, serves to limit the use of turf shoulders to lower traffic roads. The modern trend, especially on the more important industrial routes, is toward an emphasis on shoulder strength and on a wear resisting shoulder surface.

The nature of shoulder traffic does not require the same surfacing or thickness design as is required by the traffic lanes. Reduced traffic abrasion permits the use of materials ranging from turf and gravel to bituminous seals and mats. Also, the repetition of heavy axle loads is low on highway shoulders as compared to that of traffic lanes. Actually the character of shoulder traffic is more nearly that considered normal for airport pavements. Strength design criteria developed for flexible airport pavements may, also be applied to the design of shoulders.

It is recognized that every locality will have special conditions governing the details of shoulder construction. Whatever these may be there is one objective recommended for all areas; namely, that shoulders be built sufficiently strong to permit a low cost surfacing (such as a bituminous seal) to carry the locally normal traffic throughout the year without special seasonal restrictions.

# General Discussion

WILBUR H. SIMONSON, Chief, Roadside Section
Bureau of Public Roads

● CHAIRMAN Shelburne, in opening this Symposium, described a shoulder as including three main functions: (1) to accommodate stopped vehicles; (2) to be used for emergency stops; and (3) for lateral support of base and surface courses. Many types of shoulder have been evolved over the years and each type has its place in the construction of a highway system.

The design of each type of stabilized or paved shoulder involves complex questions requiring decisions as to proper pitch, adequate drainage, and careful selection and mixture of the soil and material to be used for the surface of the finished shoulder.

This panel discussion has been constructive and timely in an effort to arrive at "areas of agreement" among highway engineers on some of these complex factors, and to attempt to isolate "points of difference" among highway engineers on such questions as:

1. What is the purpose cf a well-designed shoulder?
2. How may a shoulder best be designed, constructed, and maintained to fit these purposes?
3. What are the relative advantages and disadvantages of the several types of shoulder design and shoulder materials suitable for different regional conditions of climate, soil, and traffic?

Chairman Shelburne should be commended for organizing this Symposium at this particular time to seek the best solution of highway shoulder problems and I feel certain that his hope will be realized, namely that this Symposium will promote a closer relationship between members of the committee so that the work of the committee may be integrated to the best extent in our effort to solve many of the perplexing problems confronting us.

The "highlights" of this panel discussion indicate that there are several "areas of agreement" which emphasize these features of highway shoulders:

1. Need for definite demarcation of stabilized shoulders from the pavement, i. e., the texture of the shoulder should be different from the texture of the roadway surface (traveled way).
2. Need for increased pitch of shoulder to three or four times that of the pavement, i. e., a one-fourth inch crown of pavement and a three-fourth inch per foot to one inch per foot pitch of shoulder.
3. Need for provision of positive drainage, both surface drainage and underdrainage.

Drainage is a most vital factor in shoulder stabilization but practices among the states vary widely. Test projects have shown that there is a close relationship between the pavement, the base, and the subbase. In the design of stabilized shoulders, not only the pitch of the surface is important, but also the cross slope of the subgrade.

All committees should be interested in this problem of positive drainage so that an adequate pitch or cross slope of the subgrade can be developed for each classified condition.

As Shepard pointed out, stabilized shoulders in Ohio are designed to facilitate rapid runoff of surface water, found to be important in shoulder maintenance. The ¾-in. per ft pitch provides more positive shoulder drainage. This compensates the design to offset the rough-textured surfaces of shoulders impeding surface runoff of water.

The detail of shoulder design indicated in Figure 3 for Ohio Project 36 (1955) shows the subbase extended through the shoulder to the ditch on a slope of $^{3}/_{16}$-in. per ft to provide more positive underdrainage. Newest shoulder designs with a paved transition strip and a pipe underdrain — positively providing for both surface drainage and underdrainage — are shown in Figure 4. Note the parabolic form of the design of shoulder surface with ¾ in. per ft pitch at edge of pavement (paved transition width) and the 1½ in. per ft pitch at the outer edge of shoulder (stabilized width) or junction with the 4:1 slope (3 in. per ft). Shepard reported that these shoulders on this project were in excellent condition after one year of service, with practically no maintenance necessary.

These policy changes, based on 20 years of experience with various construction practices in Ohio, are certainly timely and worthy of study.

Cooperative research between the several committees and departments is needed on unresolved "points of difference" among highway engineers. There is a lack of definite information that should be obtainable by research to resolve such differences.

As pointed out by Farrell there is need for a precise definition of costs truly chargeable to shoulders in order to provide the basis to compare the cost of shoulders with total highway cost, and resulting benefits of adequate shoulders in dollars and cents. As Brant stated we need answers to such questions as: (1) maximum pitch of shoulder permissible (to effect more positive surface drainage and at the same time provide for safety of traffic), (2) definition of degree of shoulder-rutting acceptable on stabilized turf shoulders, and (3) width of stabilized shoulder desirable.

Research data that demonstrate the actual value of shoulders as compared with their cost increment would be useful to reach conclusions regarding the extent and character of shoulder improvement warranted.

I should like to emphasize the need for more research into the psychological aspects of design. As described by Loutzenheiser, the geometric aspects of shoulder design are those that the driver "sees" or "feels" as he operates his vehicle either on the adjacent through traffic lane or on the shoulder itself. When we provide a stabilized shoulder 8 ft to 12 ft wide, however, that appears like a traffic lane, drivers tend to use the shoulder as an additional lane thus nullifying it for emergency stops. To counteract this hazard on the part of drivers, we need to do everything possible to make the appearance and use of the shoulder different from a traffic lane.

I should like to invite attention to the need for study of some of the devices we can use to discourage drivers from using the shoulder as a traffic lane: (1) increase the pitch of shoulder to several times that of the crown of pavement; (2) construct a rough-texture surface of a different color to contrast with the surface of the smooth traffic lane; and (3) construct a paved transition strip (3 to 6 ft wide) between edge of pavement and outer shoulder edge, so that the shoulder appears too narrow to be used as a traffic lane.

Further research into the psychological aspects of drivers "seeing" and "feeling" would be useful to designers conscious of the need to alert drivers, both by sight and by sound, when their vehicles are off the pavement surface. We should keep our minds open for study and experimentation, and try to adapt shoulder design to local conditions of climate and soil and the requirements of traffic.

Industrial research has shown that green is the most restful color. The "green" of roadside vegetation is likewise "restful" and psychologically beneficial to "relaxed" driving. Although there are places too dry to grow a roadside cover of "green," there are places in most states where grasses grow well and remain green.

Research is needed to determine the kinds of grasses that thrive best in each state. The results of this research would then serve as the basis for recommended check-lists of grasses best adapted and suitable for each region. Such lists of grasses would be helpful to each state.

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