SHOULDER STRUCTURAL DESIGN AND CONSTRUCTION CONSIDERATIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SHOULDER MAINTENANCE CONSIDERATIONS

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

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

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

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

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