

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.

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

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

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

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

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

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

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

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

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