R-684

OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

October 4, 1968

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To: R. L. Greenman
Testing and Research Engineer

From: L. T. Oehler

Subject: Feasibility of Portland Cement Concrete Shoulder Construction. Research Project 68 F-101. Research Report No. R-684.

The following information has been prepared in response to your telephone request of September 12, 1968 for presentation to the next meeting of the Pavement Selection Committee.

In the late 1950's, shoulder design consisted of prime and double seal, over a 6-in. compacted aggregate base course. This produced approximately 1/2 in. of wearing surface which proved to be inadequate. The current design was adopted in October 1960 and consists of 6 in. of select base material, with 170 lb per sq yd (roughly 1-1/2 in.) of plant-mix bituminous aggregate. The cost of these shoulders is about $1.85 per sq yd, in large quantities, based on recent average unit contract prices.

There have been numerous complaints of longitudinal cracking in the shoulder near the pavement edge, caused by frost action. Research Laboratory studies have indicated that the cracking generally occurs during the first year because of moisture present in the base at the time of construction. Although the cracks remain in subsequent years, they have not as yet presented a significant maintenance problem. Maintenance expenditures seem to be primarily required due to deterioration of the outside edges of the shoulder. This appears to result from shear failure in the granular base, and occurs when lateral constraint of the base course is no longer present. Once started, these failures are progressive.

There are several possible remedies for the shoulder problems that exist and the main question to be answered is how much additional initial expenditure is required and justified to reduce future shoulder maintenance to a reasonable minimum.

One solution that has been suggested is the use of portland cement concrete shoulders. The state of Illinois has an experimental installation of concrete and bituminous shoulders constructed during the summer of 1966 on Interstate 80, east of Joliet. The following information on the Illinois project was furnished by John E. Burke, Engineer of Research

and Development, Illinois Division of Highways:

The project included 15, 434 sq yds of non-reinforced portland cement concrete and 18,657 sq yds of bituminous aggregate mixture stabilized shoulders. Unit prices bid by the contractor were $3.41 per sq yd for portland cement concrete and $3.20 per sq yd for bituminous aggregate. Both types of shoulders are 10 ft wide and vary in thickness from 8 in. at the pavement edge (same as slab thickness) to 6 in. at the outside edge of the shoulder.

The non-reinforced portland cement concrete shoulder is tied to the continuously reinforced concrete pavement with 1/2-in. diam deformed bars, 30 in. long, spaced at 30-in. centers. Dummy groove transverse joints were spaced at 20-ft centers and rumble strips 6 ft long were spaced at 60-ft intervals. Concrete was carried to the site in agitator trucks and placed with a slip-form paver. Hand floats and burlap drags were used to finish the surface. The longitudinal joint between the shoulder and the pavement was sealed with a liquid asphalt sealant.

The bituminous aggregate shoulders were constructed in two layers. The specifications required a density of not less than 85 percent of theoretical maximum density for the bottom layer and not less than 90 percent for the top layer. The asphalt content of the top layer was 0.5 percent greater than for the bottom layer. A liquid asphalt sealant was used to seal the longitudinal joint between the bituminous shoulder and the pavement.

Research Laboratory personnel, visiting the site on September 19, 1968, found both the bituminous and concrete shoulders to be in excellent condition (Fig. 1). Figure 2 shows the narrow concrete shoulder on the median side of the roadway. Rumble strips can be seen on both the outside and median side concrete shoulders.

A design incompatibility between the continuously reinforced concrete pavement and the non-reinforced shoulder has caused rather open cracks in the continuously reinforced pavement at approximately every other shoulder joint. A typical example is shown in Figure 3. The continuously reinforced pavement expands and contracts, with this movement being absorbed in fine, transverse cracks, varying in spacing from one to perhaps 10 or 12 feet apart. The concrete shoulder absorbs contraction and expansion at joints spaced at 20-ft intervals, and yet the pavement and shoulder are tied together with 1/2-in. diam tie bars. As a result, the continuously reinforced pavement develops a larger crack adjacent to every joint (20 ft) or every other joint (40 ft) in the concrete

shoulder. This crack is open much wider than it normally would have been, and is a source for infiltration of water, maintenance chemicals and dirt. If not sealed, the cracks will result in corrosion of the continuous reinforcement.

In Michigan design practice, where a continuously reinforced and a jointed pavement are adjacent and tied together, we have recommended (and installation has been made) a circular compressible doughnut around the tie bar to permit some absorbing of the small relative longitudinal displacement of these two pavements.

In general, the concrete shoulders are excellent in appearance. The painted, reflectorized edge line and rumble strip should provide adequate delineation to keep motorists from using the shoulder as a traffic lane. The rumble strip would seem to be a valuable safety device as well, since a drowsy driver would be warned by the intermittent noise as soon as his car wandered onto the shoulder. Poured seals should be adequate to seal the transverse joints if slab length is not more than 20 ft. Commutative cracking could cause problems on continuously reinforced pavements but might not be as serious on standard jointed pavements.

Based on recent average unit contract prices, we would estimate that non-reinforced concrete shoulders built in Michigan would now cost $4.25 to $4.50 per sq yd in large quantities, and could easily exceed twice that amount on smaller jobs.

We feel that current problems with shoulders are not severe and do not warrant the expenditure of funds required for concrete installations, with the exception of one special application— namely, the inside shoulder on cloverleaf ramps. These ramp shoulders are now constructed with concrete base course and bituminous cap because of the tendency of traffic to ride on the inside shoulder. The bituminous cap evidently is applied to give color contrast, but the contrast decreases with age. It would seem reasonable to apply the concrete shoulder full depth in one operation with rumble strips and edge lines for delineation. The cost would probably be about the same as the present concrete base course and the bituminous cap could be eliminated.

We believe that current shoulder problems can be corrected by the use of a bituminous stabilized base. It appears to be possible to provide an improved bituminous shoulder at a cost of around $2.00 per sq yd. A research proposal is being prepared recommending the testing of new bituminous shoulder designs to improve performance at minimum

increase in cost.

In summary, full-depth concrete shoulders are specifically not recommended except for cloverleaf ramps. Redesign of bituminous shoulders is recommended with the incorporation of black base. A study proposal will be submitted by the Research Laboratory in the near future for Departmental review.

TESTING AND RESEARCH DIVISION

L. Ray T. Oglesby

Director - Research Laboratory

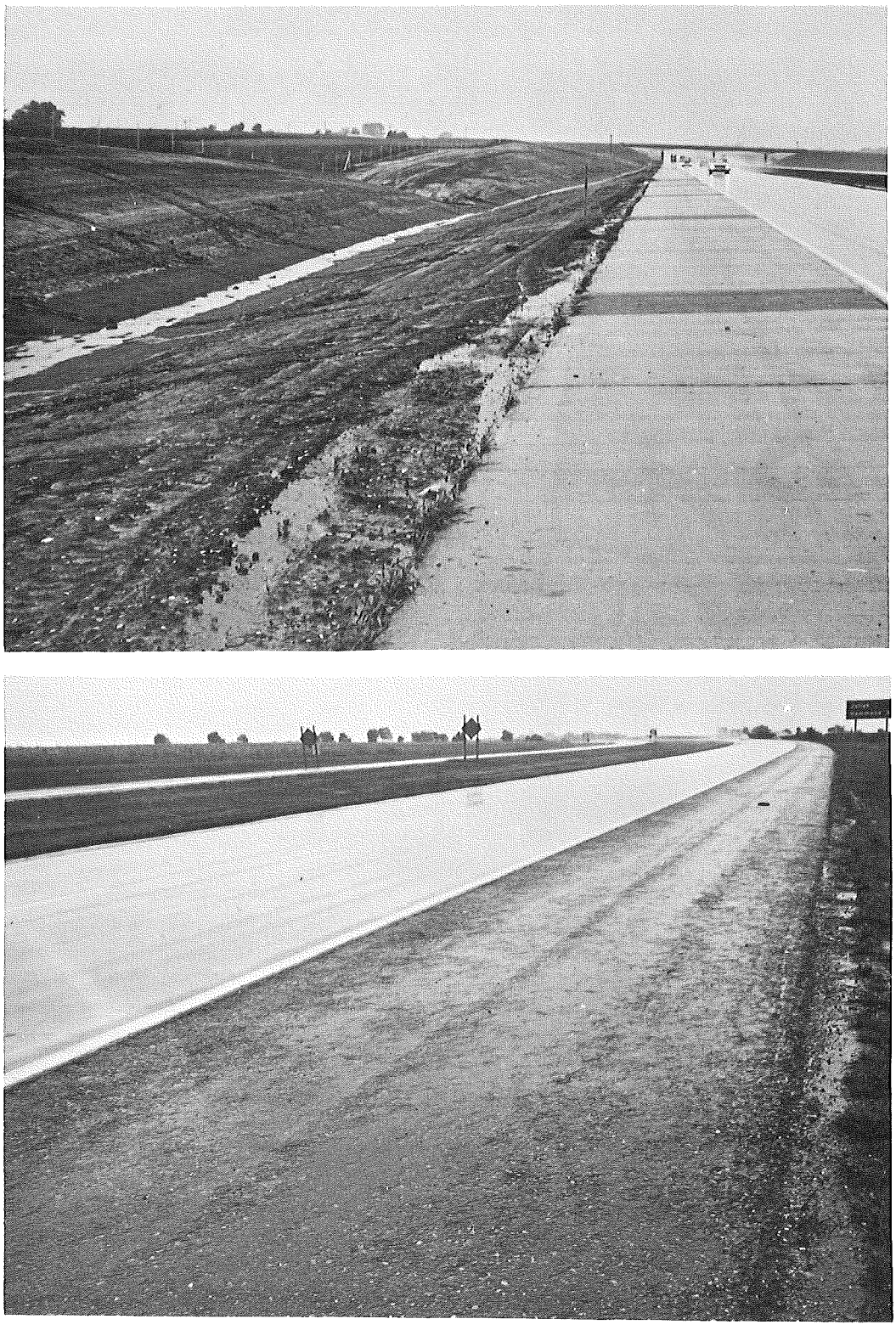

Figure 1. Illinois experimental shoulder installation: non-reinforced portland cement concrete (above) and bituminous aggregate (below).

Figure 2 (above). Portland cement concrete shoulder on median side of roadway. Note edge line and rumble strip.

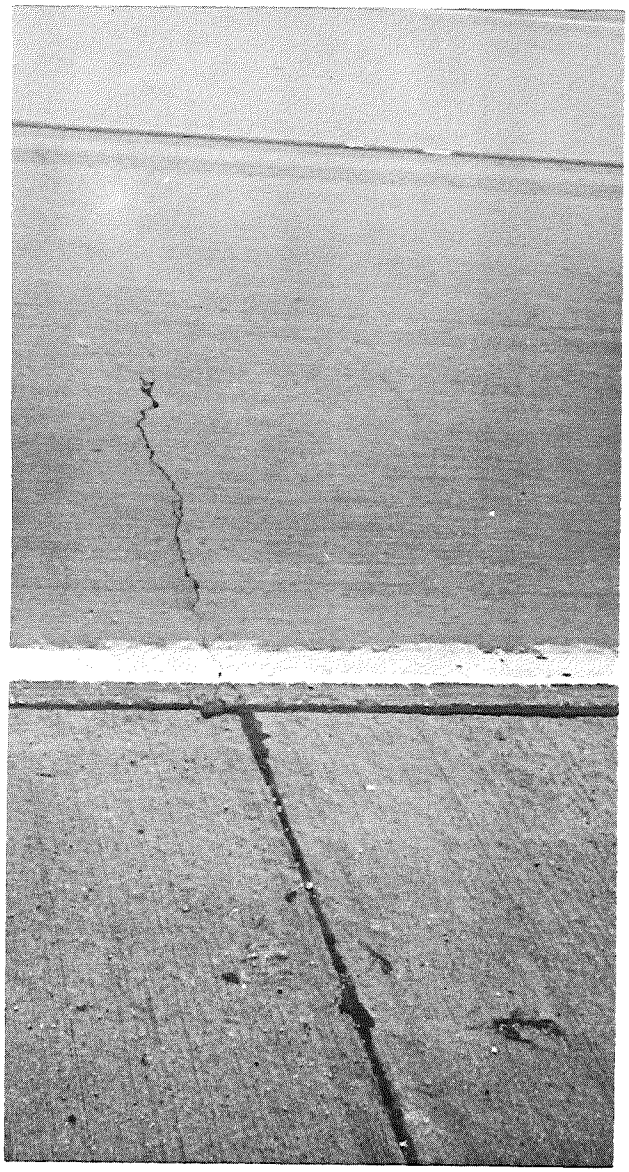

Figure 3 (right). Commutative cracking in continuously reinforced concrete pavement at shoulder joint.