An Investigation of Lean Concrete Mixes as Base Courses for Bituminous Surfaces
[Dec. 1952]

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TO: D. V. Terrell
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Early in 1951 when we prepared an initial report dealing with lean concrete mixes as base courses for bituminous pavements, I expressed the opinion that there would be many looking forward with interest to reports of performance on the field portion of the project - U.S. 60 in Montgomery County. Attached is a second report which will benefit those who maintained their interest in the performance of this pavement.

You will recall that the field test consisted of widening the major portion of existing concrete from Mt. Sterling to the Clark County Line, and also that there were four revisions to improve grade and line where lean concrete base was placed full width. The lean mix, which was based on tests made in the laboratory, contained 3.5 sacks of cement per cubic yard of concrete. Some sections of the lean base were jointed, and others were left unjointed - except, of course, at the center.

By means of several photographs in the report Mr. Sawyer has illustrated some of the important features of the pavement as it appears after two years of service, and through layout sketches in the appendix he has recorded all the cracks in the full-width revisions. It is interesting to note that in all the revisions fewer than half the original cracks and joints in the concrete base have come through as cracks in the bituminous surface.

Still more important is the fact that the greater the number of cracks or joints in the concrete prior to surfacing with bituminous mix the fewer the number of cracks in the bituminous surface after two years.
of service. In other words, where restraint in the concrete base was relieved by cracks or joints prior to surfacing cracks did not form in the surface. This general relationship, and the fact that there were no surface cracks at all where the full-width lean base was jointed at 30-foot intervals, leaves no doubt that bases of this type should be placed with transverse joints.

Conditions at the time a core was taken from the pavement did not make extensive coring feasible, so no attempt was made to get several cores and evaluate the present strength of the concrete. This will be attempted in the future, but for the present it is not considered an important omission since there is no evidence whatever of structural failure in the lean base. Of course, there are evidences of some distress in the pavement overlying the old 1924 concrete, but they have no bearing on the test.

Despite the fact that the bituminous surface has had quite an open texture from the time it was placed in 1950, the pavement is generally good. Certainly that portion overlying the lean concrete is performing well enough to create a great deal of confidence in construction with a lean-mix base.

Respectfully submitted,

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Copies to: Research Committee Members
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During the summer of 1950, the Kentucky Department of Highways placed a lean concrete mix for base construction and widening in Montgomery County. This project was a 4.415 mile section of U.S. 60 on the Winchester-Mt. Sterling Road, and was designed as SP 87-117. Four major revisions - three alignment and one grade - were completed on the project thus requiring full-width base replacement of sections of the old pavement with the lean concrete mix.

For the most part, the widening consisted of two feet of additional new base on each side of the old slab, thereby increasing the pavement width to 22 feet.

Weakened plane contraction joints were placed coincident with the joints in the existing slab (at intervals of 30 feet) in the widened edges on the south side, and at the same intervals in the full-width slabs between Stas. 190/00 and 196/00. Joints, other than construction joints,
were eliminated entirely on the widened edges on the north side and in the three remaining full-width sections. Expansion joints were not included in the project.

The concrete mix used in the base construction (6-8-6 inch section) was designed, after extensive laboratory tests, with the following requirements:

- Cement Factor: 3.5 Sacks per cubic yard
- Maximum Free Water: 9.75 gallons per sack
- Ratio of Fine Aggregate to Total Aggregate: 34 to 38 percent by weight
- Entrained Air: 3 to 6 percent

The materials used were air-entraining portland cement, Ohio River sand, and No. 36 crushed limestone.

Results of laboratory tests and initial field observations during and immediately following construction were contained in Report No. 1 by S. T. Collier, dated January, 1951. This second report is a record of general performance characteristics of the pavement after two years of service.

Performance of the concrete base must be judged almost entirely from the condition of the bituminous surface. Items of particular interest are: the relation between cracks in the concrete base at the time of construction and cracks that have developed in the bituminous surface since that time; relative effects of joints versus no joints on the performance of the surface; the condition of the pavement underlain by lean concrete as opposed to pavement placed on the old concrete built in 1924; and the effects of widening strips on performance characteristics. In addition, the overall condition of the pavement is obviously of interest.
Full-Width Revisions

On December 12, 1952, a crack survey of the pavement with full-width lean concrete base revealed that there were 31 surface cracks in three of the four major revisions. The fourth, which is a grade revision containing weakened plane joints at 30-foot intervals, was void of any surface cracks or other deteriorative features. A layout showing the locations of all cracks and joints in the full-width revisions is contained in Fig. 8 at the back of this report. Dark lines in the layout represent cracks in the concrete base just prior to the time it was surfaced in 1950, while red lines represent those cracks in the bituminous surface which were evident at the time of the 1952 survey.

The general location and occurrence of these cracks are summarized in Table 1. Each crack listed was limited to a single traffic lane, and two cracks were recorded when the flaw was continuous across the pavement. In Table 1 and on the layout, it can be seen that there was a tendency toward a greater number of surface cracks over revisions containing the fewer number of cracks or joints in the concrete base. This could be dependent somewhat on conditions at the time of construction; however, the last two revisions provide overwhelming evidence that the surface performance is better when the restraint in the underlying concrete base is relieved by cracking or jointing at fairly frequent intervals prior to the placement of the surface.

Distribution of the surface cracks with respect to features in the underlying lean concrete base were as follows:
39 percent occurred over cracks that existed in the concrete when the bituminous surface was placed;

26 percent occurred over joints constructed in the concrete; and

35 percent could not be associated with any feature in the underlying base.

It should be noted again that all the joints over which cracks occurred were random construction joints placed at the end of a days run. No cracks have occurred over the pavement deliberately jointed at 30-foot intervals.

Table 1
Location and Occurrence of Cracks in the Bituminous Surface Over Full-Width Revisions

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<tbody>
<tr>
<td>Sta. 1134/77 to Sta. 1244/1</td>
<td>15</td>
<td>7</td>
<td>8</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Sta. 1344/12 to Sta. 1414/87</td>
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<td>18</td>
<td>7</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
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<td>7</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Sta. 1894/6 to Sta. 1964/56</td>
<td>0</td>
<td>3</td>
<td>25*</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31</strong></td>
<td><strong>49</strong></td>
<td><strong>47</strong></td>
<td><strong>8</strong></td>
<td><strong>12</strong></td>
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* Contraction Joints. Those listed above are construction joints.

A single crack is limited to one traffic lane, and those which are continuous across the full-width of surface are listed as two cracks.
Fig. 1. Close examination of this photograph shows transparent or indicated cracks as evidenced by the dark streaks appearing in the center of the picture and extending upward. These lines are thought to result from cracks in the underlying pavement and are visible because of a slight excess of bitumen being extruded upward through expansion and contraction of the base.
Fig. 2. Core taken from the lean concrete base at Station 15268. The surface portion of this sample is in very good condition, however, close examination reveals that a small amount of the stone used was crushed by the roller during the paving operation. Note the slight deficiency in bond. Had the finishing operation on the concrete surface been coarser, a greater bonding area would have been available and possibly a better bond would have resulted.
Fig. 3. Crack in the north lane at Station 232/30 (near West City limit of Mt. Sterling) over the old pavement and extending to the edge above the widening strip. Note evidence of raveling in the right foreground.

Fig. 4. Crack at Station 231/69 directly over a contraction joint in the old slab. The crack was not open across the entire surface at this time, but it is expected to open under cooler temperatures.
Fig. 5. Prominent crack in surface above old concrete base at Station 231/00.
the relationship between cracks in the new concrete base and overlying surface previously discussed, this observation on the portions overlying old concrete is pertinent. No attempt was made to correlate surface cracks with base cracks where the base was old concrete, because there was no record made of cracks in the old concrete when construction was under way in 1950.

Performance of the surface over old concrete generally improved as the distance from Mt. Sterling increased. Probably this reflects the condition of the underlying base before it was resurfaced, and also the general distribution of traffic over the project at present. Traffic counts in 1950 showed the annual daily flow to be 4000 vehicles near the city limit, and 2330 vehicles at the Montgomery - Clark County line. Probably a similar relationship in use of the road has existed for a period of several years.

Widening Lanes

The entire length of the widening strips was not thoroughly inspected because of limitation in time. However, there was sufficient information obtained to show that no more than 5 percent of the overall length of the bituminous pavement over the widening strips has become separated from the main section by longitudinal cracks. Generally, the performance of these widening lanes is satisfactory. No transverse cracking in the surface was found, while longitudinal cracks occurred intermittently in each of the widening lanes. The south side, with weakened-plane contraction joints coincident with joints in the existing slab,
Fig. 6. Core taken from lean concrete base at the beginning of the first full-width revision, Station 113/77. Note that the crack on the surface of the bituminous course was slightly offset from the underlying construction joints.
Fig. 7. View of finished surface over the full-width revision between Station 148+50 and Station 155+07. Fig. 3 in original report shows the corresponding revision under construction.
apparently contained as many feet of linear cracks as the widening strip on the north side.

General Observations

The general condition and appearance of the entire project is considered relatively good at this time, despite the fact that the surface obviously had a high percent of voids at the time it was placed. Nevertheless, recent observations of the surface provide no basis for estimating that this bituminous mix would be better than average in resisting surface deterioration.

The value of base construction with a lean concrete mix is, of course, not fully established by the project at this early date and with its limitation to relatively moderate traffic. However, substantially good performance at this time indicates a great deal of merit in this type base construction and surface.
Fig. 1b - Layout of Full Math Revision (Sta. 134 + 12 to Sta. 141 + 57) Showing the Location of Cracks and Joints.
Fig. 2C - Layout of Pull Mills Revision (Sta. 146 to Sta. 155) Showing the Location of Cracks and Joints.