MEMORANDUM.

TO: A. O. Neiser
Assistant State Highway Engineer

SUBJECT: A Modified Class I Surface Mixture, Hopkins County, US 41-A, Resurfacing

The 1956 Standard Specifications for Class I, Type B surface mix will permit an aggregate gradation in which percentage of material finer than the No. 100 screen is zero. The maximum limit passing this screen size is 10 percent. The Specification requirement for the No. 200 sieve is 0 to 5 percent passing. The complete gradation limits are plotted in dashed lines on page 4 of the attached memorandum report by R. L. Florence.

It is possible to obtain a satisfactory aggregate gradation for a surface mix using the present specification, but such a mix is not necessarily required by the specification. In an effort to determine specification limits for adequate Class I, Type B surfaces, several approaches have been taken; one has been described in this report.

Under the present specification some deficiencies in stability and in durability have been observed. It appears that in the majority of these cases the difficulty can be traced to aggregate gradation deficiencies and attendant bitumen content requirements. Bituminous concrete mixtures with small percentages of aggregate passing the No. 100 sieve, of necessity, have high void contents and are very susceptible to raveling due to weathering. An increase in bitumen content, to lower the void content and improve the durability, has the resulting effect of reducing stability. This would be evidenced by rutting of the surface course.
The problem has been most serious in Class I, Type B surface mixes made with natural sand. The natural sand is deficient in aggregate sizes passing the No. 100 sieve. On the other hand, certain limestone aggregates available in Kentucky are susceptible to polishing and have been found to cause dangerous slipperiness unless blended with polish-resistant silicous, natural-sand aggregates. In an effort to control the skid-resistant properties of Type B surfaces, durability and stability have been sacrificed.

In areas of the state where limestone fine aggregates are readily available, it has been the practice for the last two years to permit blending of the fine aggregates for surface mixes. The blend, by weight, could consist of 60 percent Natural Class I sand and 40 percent manufactured limestone Class I sand. Because the fine sizes were usually available in the manufactured limestone Class I sand, it has been possible to obtain significant percentages of material passing the 100 and 200 sieves. These mixes have somewhat higher asphalt contents, higher stability, and considerably lower void contents.

The Class I, Type B surface for the three flexible pavement sections on I-64 in Clark and Montgomery Counties was modified by change order to obtain improved stability and durability as mentioned above. The resultant aggregate composition on these projects was:

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Percent of Total Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 9 limestone</td>
<td>40</td>
</tr>
<tr>
<td>Class I sand</td>
<td></td>
</tr>
<tr>
<td>Natural</td>
<td>40</td>
</tr>
<tr>
<td>Mfg. limestone</td>
<td>20</td>
</tr>
</tbody>
</table>

The coarse aggregate was reduced somewhat, and the overall gradation was changed appreciably. This surface has a very good appearance.

In an effort to define the ideal final mix gradation for high-type surfacing, the Hopkins County project was placed last season. Through a change order which involved no extra cost to the Department, Dixie Pavers agreed to produce the modified mix shown in Fig. 2, page 4 of Mr. Florence's report. The plant and paving crew of the Dixie Pavers were most co-operative in this experimental
project. The gradation for this mixture was developed through the cooperation of the Asphalt Institute, and the Materials, Construction, and Research Divisions of the Department of Highways.

I am of the opinion that the best method of securing an acceptable Class I surface mix is through a final mix gradation specification. We must not overlook the need for a skid-resistant mix which, it appears, can be obtained with 30 to 40 percent natural sand in the final mix -- this, of course, is subject to confirmation.

The modified gradation gives an excellent mix, but it may be somewhat difficult to obtain enough of the fine fractions unless efficient dust collectors and return systems are used or unless provisions are made for replacing this aggregate in the mixture. Separate mineral-filler-size aggregates may be required in some areas of the state.

Respectfully submitted,

W. B. Drake
Director of Research

WBD:dl
Enc.
cc: Research Committee Members
    Bureau of Public Roads (3)
Commonwealth of Kentucky
Department of Highways

A MODIFIED CLASS I SURFACE MIXTURE

by

R. L. Florence
Research Engineer Associate

Highway Materials Research Laboratory
Lexington, Kentucky
January, 1962
January 23, 1962

MEMORANDUM

TO: W. B. Drake
    Director of Research

FROM: R. L. Florence
    Research Engineer Associate

SUBJECT: A Modified Class I Surface Mixture

Since the summer of 1954, it has been the practice of the Department to require only natural sand or slag as the fine aggregate in high-type (Class I, Type B) bituminous surface mixtures. This, of course, was done in order to build skid resistance into the mixture, i.e., by use of polish-resistant fine aggregate. At first, this was specified by means of plan notes; and, during 1957, an Amendment was made to the Standard Specifications. While this has apparently reduced the slickness problem it has created problems relating to the durability and, at times, the stability of the surface course.

With 50 percent natural sand, the voids in the mixture may be as high as 10 percent. Accepted mixture design practice has established void contents of 3 to 5 percent (Marshall) as being desirable for a water-tight, durable surface. The primary reason for the high void content is apparently the lack of material finer than the No. 50 screen. The present grading specification for the surface mix has no significant requirement for the amount of material finer than the No. 50 screen in the mixture (2 to 20%). The present grading specification for Class I natural sand does not require over 5 percent finer than the No. 50 screen, and the typical river sand is noticeably deficient in this size range. Shown in Fig. 1 is a typical grading for Class I, Type B surface containing approximately 50 percent natural sand and 50 percent No. 9 limestone. Note the high amount of material within the sand-size (No. 10 to No. 40), as is evidenced
Fig. 1. Typical Grading of Class I, Type B Surface Containing No. 9 Limestone and Class I Natural Sand.
by the hump in the curve, and the small amount of material finer than the No. 50 screen. This, of course, causes a bulking of the aggregate and a consequent loss of density and stability in the asphaltic mixture.

To correct or alleviate this condition, the following Modified, Class I surface composition has been proposed:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 in.</td>
<td>100</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>80-100</td>
</tr>
<tr>
<td>No. 4</td>
<td>55-75</td>
</tr>
<tr>
<td>No. 8</td>
<td>35-50</td>
</tr>
<tr>
<td>No. 16</td>
<td>25-38</td>
</tr>
<tr>
<td>No. 50</td>
<td>11-21</td>
</tr>
<tr>
<td>No. 100</td>
<td>6-14</td>
</tr>
<tr>
<td>No. 200</td>
<td>3-7</td>
</tr>
</tbody>
</table>

Bitumen Content 4.5 - 8.0%

The modified surface grading limit is the same as the Class I, Type B except that the fraction finer than the No. 16 screen has been increased while the fraction coarser than the No. 16 has been left essentially unchanged (Fig. 2).

In order to evaluate the modified composition requirements described above, a 6.2-mile section of US 41A near Madisonville was resurfaced with the new mixture in late September, 1961. A change order, prepared for the project, specified the following material requirements:

A minimum of 30 percent by weight of the aggregate blend was to consist of Class I natural sand complying with the quality and gradation requirements of Article 7.3.0. The remainder of the aggregate was to consist of crushed limestone complying with the quality requirements of Article 7.4.0. The gradation requirements of limestone aggregate used in the preparation of the mix were to be waived in order to achieve the desired blended-aggregate gradations.
Fig. 2. Class I, Type B and Class I, Modified Surface Grading Limits.
The modified surface was produced at the Dixie Pavers' Plant located at the Hopkinsville Stone Company's quarry in Hopkinsville. All of the limestone aggregate used in the modified mixture was produced at the quarry. Natural sand used on the project came from the Bedford-Nugent Sand Company in Henderson. A preliminary Marshall mix design performed by the Materials Division on materials sampled from the plant gave the following results:

Aggregate Blend:

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>No. 9 Limestone</td>
</tr>
<tr>
<td>10%</td>
<td>No. 11 Limestone</td>
</tr>
<tr>
<td>30%</td>
<td>Class I Natural Sand</td>
</tr>
<tr>
<td>26%</td>
<td>Class I Limestone Sand</td>
</tr>
<tr>
<td>4%</td>
<td>Mineral Filler (Limestone)</td>
</tr>
</tbody>
</table>

Optimum Asphalt ...... 5.5% (PAC-5)
Stability ............. 1630 lbs.
Unit Weight ............ 149.1 lbs/cu.ft.
% Voids, Mix ......... 3.5
% Voids, Aggregate .... 16.6
% Voids, Filled with Bitumen ....... 81.0

These data show a large improvement in density over the typical Class I, Type B surface made from equal parts of No. 9 limestone and Class I natural sand.

Production of the modified surfacing material began September 28, 1961. The plant was a Hetherington-Berner, batch plant equipped with a dust collector and dust storage bin (Fig. 3). Collected dust or mineral filler could be weighed from the bin and introduced into the mix in any desired quantity.

Several sizes of limestone aggregate were blended with the natural sand in order to establish the sizes and proportions that would best meet the gradation sought. The requirement of at least 30 percent natural sand restricted the proportions of coarse and fine aggregate to a fairly narrow range. Excepting the limestone dust, the aggregates used met the standard gradation requirements or came very close thereto (Table 1). Changes in portions of aggregate at the cold feed took a fairly long time to become effective in the mix because of the storage capacity of the hoppers (Fig. 4).
Fig. 3. Hetherington-Berner Batch Plant. Note the dust storage bin.
Fig. 4. Four aggregates were combined by pre-blending No. 9 and No. 11 limestone in one hopper.


<table>
<thead>
<tr>
<th>Spec. Gravity</th>
<th>Percentage Passing Sieve Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate</td>
<td>No. 1/2</td>
</tr>
<tr>
<td>Blended No. 9 &amp; 11</td>
<td>2.70</td>
</tr>
<tr>
<td>No. 9</td>
<td>2.70</td>
</tr>
<tr>
<td>(Cone Crusher)</td>
<td>*Coarse Ls. Sand</td>
</tr>
<tr>
<td>*Ls. Concrete Run</td>
<td>2.71</td>
</tr>
<tr>
<td>*Ls. Sand</td>
<td>2.71</td>
</tr>
<tr>
<td>Fine Ls. Sand</td>
<td>2.71</td>
</tr>
<tr>
<td>Class I Natural Sand</td>
<td>2.65</td>
</tr>
<tr>
<td>Ls. Dust</td>
<td>2.71</td>
</tr>
</tbody>
</table>

The aggregate blends used in each day's production were as follows:

**Thursday, September 28**

45% - Blended Limestone (3 parts No. 9 and 1 part No. 11)  
30% - Class I Natural Sand  
17% - Concrete Sand (Limestone)  
8% - Limestone Dust (from collector)

*Note:* The limestone concrete sand was a fine sand having a portion of the -16 material removed. It was found that the dust collector could not supply sufficient -100 material, consequently, dust collected from the manufacture of the limestone concrete sand was added. This source of additional dust was used throughout the remainder of the project.

**Friday, September 29**

The aggregate blend and the proportions remained approximately the same except that a fine limestone sand was substituted for the limestone concrete sand. It was thought that this would help supply the needed filler sizes.

**Monday, October 2**

A coarse crusher-run limestone sand was substituted for the fine limestone sand. This was done in order to eliminate the necessity of blending No. 9 and No. 11 stone. The crusher-run material contained a higher percentage of dust; and so the amount of dust added was reduced from 8 to 6 percent. The proportions of aggregate were as follows:

45% - No. 9  
30% - Class I Natural Sand  
19% - Coarse Limestone Sand  
6% - Dust

*Note:* The fine aggregates were wetted by a week-end rain and did not feed from the cold storage bins as well as during the previous week.
The proportions and sizes of aggregates remained essentially the same during the remainder of the project. On Thursday, October 5, it was noted that the No. 9 stone particles tended to be elongated, and this was attributed to production by a cone crusher. The proportions of aggregate were checked frequently at the cold feed. The proportion of natural sand varied between 27 and 33 percent. It was noted that the mixture tended to be finer in the early morning due to some overloading of the screens when filling the bins. Marshall specimens, prepared from the first two days' production indicated that the density and stability values determined by the preliminary Marshall design were being met; consequently, no adjustment in the designed asphalt content (5.5 percent) was considered necessary. The asphalt cement was a PAC-5 from the Lion Oil Company.

Gradations and extractions were run in the morning and afternoon of each day. Samples of the mixture were taken daily for laboratory testing. Gradations and extractions were run in laboratory and at the plant, and these data are shown in Table 2. Results obtained from laboratory testing of reheated mixtures are shown in Table 3.

The temperature of the mixture was maintained between 300 and 325°F. The haul-distance was approximately 50 miles.

Two sections of US 41A, totaling 6.2 miles, in Hopkins County, were resurfaced with the modified material. The existing pavement was portland cement concrete and varied between 18 to 20 feet in width. The general condition of the existing pavement was poor. Blowups at the joints had occurred at intervals of approximately 150 to 200 feet throughout the length of the project. Prior to resurfacing, however, the blowups had been removed and patched with an asphalt mixture.

The first section resurfaced extended 4.6 miles eastwardly from the Hopkins-Webster County line to within the Corporate Limit of Nebo. This section of pavement had been resurfaced previously with 1-1/2 inches of bituminous concrete except for 0.2 mile at the West Corporate Limit of Nebo (Figs. 5 and 6). The pavement narrowed from 20 to 18 feet at Nebo. The second section extended 1.60 miles west from the end of the US 41 - US 41A connection road. The existing pavement was 18 feet wide and had some bituminous patches.

No difficulty was encountered in laying or handling the material. Due to the rough condition of the pavement, a great deal of the modified material was used for patching and leveling (1,712 tons).
<table>
<thead>
<tr>
<th>Date Sampled</th>
<th>Asphalt (Extr.)</th>
<th>AM 9-28-61</th>
<th>%</th>
<th>1/2</th>
<th>3/8</th>
<th>4</th>
<th>8</th>
<th>16</th>
<th>50</th>
<th>100</th>
<th>200</th>
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</thead>
<tbody>
<tr>
<td>AM 9-28-61</td>
<td>5.6</td>
<td>100</td>
<td>94.3</td>
<td>61.8</td>
<td>40.7</td>
<td>31.5</td>
<td>12.2</td>
<td>6.4</td>
<td>4.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM 9-28-61</td>
<td>5.5</td>
<td>100</td>
<td>95.6</td>
<td>63.5</td>
<td>42.5</td>
<td>33.5</td>
<td>12.7</td>
<td>6.9</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM 9-29-61</td>
<td>5.8</td>
<td>100</td>
<td>91.4</td>
<td>63.3</td>
<td>41.4</td>
<td>32.1</td>
<td>12.5</td>
<td>6.7</td>
<td>4.2</td>
<td></td>
<td></td>
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<tr>
<td>PM 9-29-61</td>
<td>5.6</td>
<td>100</td>
<td>91.8</td>
<td>61.8</td>
<td>41.1</td>
<td>33.9</td>
<td>13.9</td>
<td>7.8</td>
<td>5.1</td>
<td></td>
<td></td>
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<tr>
<td>AM 10-2-61</td>
<td>5.8</td>
<td>100</td>
<td>90.0</td>
<td>65.0</td>
<td>43.6</td>
<td>31.5</td>
<td>11.9</td>
<td>6.8</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM 10-2-61</td>
<td>5.5</td>
<td>100</td>
<td>90.5</td>
<td>68.6</td>
<td>43.4</td>
<td>34.4</td>
<td>16.6</td>
<td>9.4</td>
<td>5.8</td>
<td></td>
<td></td>
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<tr>
<td>AM 10-3-61</td>
<td>5.5</td>
<td>100</td>
<td>90.1</td>
<td>66.5</td>
<td>47.3</td>
<td>37.1</td>
<td>13.7</td>
<td>7.2</td>
<td>4.3</td>
<td></td>
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<tr>
<td>PM 10-3-61</td>
<td>5.4</td>
<td>100</td>
<td>94.2</td>
<td>70.8</td>
<td>47.3</td>
<td>33.4</td>
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<tr>
<td>AM 10-4-61</td>
<td>5.5</td>
<td>100</td>
<td>92.7</td>
<td>65.0</td>
<td>41.6</td>
<td>32.4</td>
<td>13.8</td>
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<tr>
<td>PM 10-4-61</td>
<td>5.4</td>
<td>100</td>
<td>88.9</td>
<td>64.1</td>
<td>45.0</td>
<td>34.7</td>
<td>13.4</td>
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<td>3.4</td>
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</tr>
<tr>
<td>AM 10-5-61</td>
<td>6</td>
<td>100</td>
<td>96.8</td>
<td>65.2</td>
<td>40.8</td>
<td>33.9</td>
<td>11.6</td>
<td>6.0</td>
<td>3.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AM 10-6-61</td>
<td>5.6</td>
<td>100</td>
<td>90.4</td>
<td>69.3</td>
<td>45.3</td>
<td>35.9</td>
<td>15.1</td>
<td>8.3</td>
<td>4.8</td>
<td></td>
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<tr>
<td>PM 10-6-61</td>
<td>5.4</td>
<td>100</td>
<td>89.8</td>
<td>69.6</td>
<td>45.0</td>
<td>34.2</td>
<td>15.0</td>
<td>8.2</td>
<td>5.0</td>
<td></td>
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</tr>
</tbody>
</table>

Tests Performed at Plant

Tests Performed in Laboratory
Table 3. Marshall Test Results for Sampled Mixtures.

<table>
<thead>
<tr>
<th>Date Sampted</th>
<th>Stability lbs.</th>
<th>Flow 0.01 in.</th>
<th>Unit Weight lb/cu.ft.</th>
<th>Total Mix</th>
<th>Comp. Aggr.</th>
<th>Bitumen</th>
<th>Filled with</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-28-61</td>
<td>1900</td>
<td>11.6</td>
<td>146.2</td>
<td>5.5</td>
<td>17.9</td>
<td>69.4</td>
<td></td>
</tr>
<tr>
<td>9-29-61</td>
<td>2260</td>
<td>14.0</td>
<td>150.0</td>
<td>2.3</td>
<td>16.3</td>
<td>86.3</td>
<td></td>
</tr>
<tr>
<td>10-2-61</td>
<td>2100</td>
<td>12.0</td>
<td>149.5</td>
<td>2.6</td>
<td>17.2</td>
<td>84.9</td>
<td></td>
</tr>
<tr>
<td>10-3-61</td>
<td>2550</td>
<td>13.0</td>
<td>148.6</td>
<td>3.0</td>
<td>17.2</td>
<td>82.7</td>
<td></td>
</tr>
<tr>
<td>Avg.</td>
<td>2202</td>
<td>12.7</td>
<td>148.6</td>
<td>3.4</td>
<td>17.5</td>
<td>80.8</td>
<td></td>
</tr>
</tbody>
</table>

Note: Samples taken on 10-4-61 and 10-5-61 damaged by over-heating in the laboratory.
Fig. 5. Section of US 41A with Asphalitic Concrete Overlay.

Fig. 6. Section of US 41A within Corporate Limits of Nebo. Note the patches where blowups have been repaired.
Leveling was done by tacking the existing surface and spreading the mixture with a grader. No tack was used between the leveling course and the machine-laid surface course (Fig. 7). The locations of each day's paving is shown in Fig. 8. The total tonnage of modified material was 6,253 tons.

The following general observations were made during the manufacture and laying of the modified material. Although it was not required in the change order, the modified material was produced with specification-size and near-specification-size aggregates -- except for the limestone dust. However, using standard gradation aggregates, a minimum of three aggregates and dust or filler appear to be necessary to produce the desired gradation when natural sand is required. Although it seems that the gradation can be produced with either standard-size or non-standard-size materials, the gradation of the aggregates must be known and must be fairly constant in order to exercise the proper control of production.

Although a minimum of 30 percent natural sand was specified for the project, it was difficult to maintain this percentage with the aggregates used on this project. It appears that 30 percent river sand is about the maximum amount that can be used without going outside of the specification limit on the No. 8 and the No. 16 sieve sizes.

The low void content of the modified material (3 percent by Marshall) is in line with accepted design criteria, and the material should prove to be very durable. However, low void contents necessitate a closer control of the asphalt content and gradation. Whereas Marshall design tests on the materials can be used to establish a job-mix formula for a project, field control to insure close adherence to the job-mix formula is essential. While this is important with any bituminous mixture, it is even more essential in the case of dense-graded mixtures. Slight excesses of asphalt and filler could easily produce a "zero voids" condition and result in bleeding and loss of stability.

An inspection of the surface was made last January 24, and it was found that transverse cracks in the concrete had reflected through the new surface course. These cracks are apparently due to contraction of the concrete inasmuch as they extend completely across the pavement. The only other damage observed was some marks made by tire chains.
Fig. 7. Appearance After One Pass of Paver. Note the extensive grader-laid leveling course.
<table>
<thead>
<tr>
<th>Date</th>
<th>Section</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2</td>
<td>September 28</td>
<td>545+65</td>
</tr>
<tr>
<td>October 3</td>
<td>October 2</td>
<td>495+50</td>
</tr>
<tr>
<td>October 3</td>
<td>October 4</td>
<td>456+30</td>
</tr>
<tr>
<td>October 4</td>
<td>October 4</td>
<td>385+40</td>
</tr>
<tr>
<td>October 5</td>
<td>362+67</td>
<td>349+52</td>
</tr>
<tr>
<td>October 5</td>
<td>East Nebo City Limit</td>
<td>336+27</td>
</tr>
</tbody>
</table>

Fig. 8. Diagram Locating Sections Suraced each Day.