MEMO TO: W. B. Drake
Assistant State Highway Engineer

FROM: Jas. H. Havens
Director of Research

SUBJECT: Manufactured (Crushed), Limestone, Fine Aggregate for Portland Cement Concrete; proposed Special Provision; Ref.: memo, Director of Research to Engineer of Specifications, Aug. 8, 1962

We have been pursuing studies on limestone, fine aggregate for concrete since 1958; and I am offering herein a brief, historical account of some of the previous actions which relate significantly to the problem and to the development of an appropriate specification.

Some time in 1957 or 1958 an informal meeting was held in Mr. Bray's office - at which time, Mr. W. O. Snyder and Mr. Sam Nally, representing the Kentucky Crushed Stone Association, discussed the matter and requested that the Department undertake studies to establish quality requirements and a specification. It was recognized by all present that portland cement concrete containing limestone sand would not be suitable for paving inasmuch as it would be particularly susceptible to polishing and to slipperiness. It was also understood by all that limestone sand should be a quality product and that the term should not in any way allude to limestone screenings such as material which had long been held in disfavor by the Department. Subsequently, and upon Mr. Snyder's invitation, I prepared a written discussion on the qualities sought in concrete sands and of the problems encountered in producing crushed stone sands. Much of the information was based upon my review of the literature. Mr. J. E. Gray, Engineering Director, National Crushed Stone Association succeeded me on the program and affirmed his belief in the significant issues which I had discussed.
They were:

1. Particle Shape - sub-angular to rounded particles; to minimize water requirement of concrete.

2. Gradation - ideal grading sought; also to minimize water requirement and to enhance finishing characteristics of concrete.

3. Deleterious Substances - minimizing shale and other objectionable materials by producing the sand from quality coarse aggregate.

During 1959, we made some rather extensive studies of the effect of shape and gradation (Fineness Modulus) on the water requirements of mixes. We also attempted to develop tests which would detect shales and clays in coarse and fine aggregates (Glycerine Boiling-Test and Sand-Equivalent Test). None of the tests for shale and clays proved to be sufficiently reliable or discriminating. However, a dry-bulking test developed by the National Crushed Stone Association and recommended by J. E. Gray did prove to be adequately discriminating with respect to particle shape and particle texture. The data, of course, are summarized in our report.


Under the date of April 11, 1961 we transmitted a draft of a proposed Special Specification for "Manufactured (Crushed), Limestone, Fine Aggregate for Portland Cement Concrete" for consideration by the Specification Committee. The proposed draft was reviewed by the Committee July 26, 1962 and certain revisions were ordered - one of which was the addition of the sand-equivalency test (80%). The revised draft was transmitted August 8, 1962.

An audience was granted the Manufactured Sand Committee of the Kentucky Crushed Stone Association January 17, 1963, in Mr. Neiser's office, at which time, they requested reconsideration of the gradation; and, by letter, January 18, 1963 (W. D. Milne), they requested that the requirements on the #8, #16, #30, and #50 screens be opened up. Mr. Weidemer, proprietor of the Hopkinsville Stone Company, commented off the record that the gradation was tight but that he could produce it.

On February 13, 1963, Mr. Drake forwarded our 1960 (Feb.; by G. R. Laughlin) report to Mr. J. E. Gray (National Crushed Stone Assn.) for his review and comments. We had discussed the matter with Mr. Gray from time-to-time at occasional meetings. Mr. Gray's replies of March 11 and 13, 1963, offered his concurrence in all viewpoints except gradation requirements. Whereas, we preferred a fineness modulus ranging between 2.40 and 2.80 - in addition to which, the sample-to-sample variance was to be limited to + 0.20; Mr. Gray interpreted this tolerance to permit extremes ranging from 2.20 to 3.00. He further
favored the gradation of ASTM C-33 (Fineness Modulus: 2.15 - 3.38), but with a narrower limit on fineness modulus (2.40 to 2.95). Mr. Gray also thought that 2.5 percent was too restrictive for the amount of material passing the 200 sieve (he preferred 5 percent). Much of the ensuing discussion with Mr. Gray was concerned with fineness modulus. I feel that Mr. Gray was attempting to reconcile the practical aspects of sand production with the technical aspects of quality concrete; and, although we should give every consideration to the producers' points of view, I feel that our foremost objective is to delineate the requirements which in our judgement, are essential to the production of quality concrete. This has been our guiding thought throughout our investigations. The new draft of the proposed Special Provision now being submitted (attached hereto) reflects a continuation of this conservative attitude.

You will note that the references to "Standard Specifications..." are indexed according to proposed revision of the book of standards.

I believe the Specifications Committee should review this draft and record whatever action is taken. In the event that further revisions are desired, we will proceed with them upon receipt of further instructions.

JHH:1ga
Attachment: Proposed Special Provision Manufactured (Crushed), Limestone, Fine Aggregate For Portland Cement Concrete

c: Specifications Committee
   Harold G. Mays
This Special Provision covers the material requirements for manufactured (crushed), limestone, fine aggregate for use in portland cement concrete. This Special Provision shall be applicable to individual projects only when indicated on the plans or in the proposal; and when so indicated, it shall supersede all conflicting provisions of the Department's Standard Specifications...

A. DESCRIPTION

Manufactured (crushed), limestone, fine aggregate for use in structural concrete, concrete base courses for pavements, or as may otherwise be designated, shall be manufactured by crushing and sizing aggregate-quality limestones and dolomites. Manufactured (crushed), limestone, fine aggregate shall not be used in concrete surface courses for pavements or bridge decks unless specifically authorized by the Engineer.

B. GENERAL REQUIREMENTS

Manufactured (crushed), limestone, fine aggregate shall consist of hard, strong, durable, sub-angular particles and shall be manufactured by crushing coarse aggregate meeting the general requirements of Article 612.1.0 and the specific requirements of Article 612.2.4. The size of the coarse aggregate from which the sand is manufactured shall be such that 100 percent will pass the 4-inch sieve and not
A minimum sand-equivalent value of 80 percent shall be required (AASHO T 176).

The shape of the particles shall be so controlled, by crushing and milling, that when the fine aggregate is subjected to the dry-bulking test, as hereinafter described, the volumes of voids shall not exceed 52 percent.

1. Method of Test. This test procedure describes the method of determining the dry-bulking characteristics of size-fractions of fine aggregate.

a. Apparatus.

(1) Balance - a balance having a capacity of 1500 grams and a sensitivity of 0.1 gram.

(2) Drying Pans - at least 1500-gram capacity, suitable for drying samples.

(3) Cylindrical Cup - a rigid, cylindrical cup having an inside diameter of 2-7/8 inches and a height of 5-1/2 inches.

(4) Funnel - a truncated, hollow, metal cone, having an over-all height of 4 inches and an inside diameter of 5-1/2 inches for the large opening and 1 inch for the small opening.

(5) Sieves - (ASTM Designation E 11) of the following sizes are required: No. 4, No. 8, No. 16, No. 30 and No. 50.

(6) Steel Straight Edge - 1-inch x 6-inch x 1/16-inch.

b. Samples.

(1) Fine Aggregate. The sample of fine aggregate shall be washed thoroughly, dried to constant weight at 105° to 110° C. (221° to 230°F.), and separated into the following sizes:
<table>
<thead>
<tr>
<th>Passing</th>
<th>Retained</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 4</td>
<td>No. 8</td>
</tr>
<tr>
<td>No. 8</td>
<td>No. 16</td>
</tr>
<tr>
<td>No. 16</td>
<td>No. 30</td>
</tr>
<tr>
<td>No. 30</td>
<td>No. 50</td>
</tr>
</tbody>
</table>

Approximately 1500 grams of each of the above sizes shall be required for test.

(2) Coarse Aggregate. A sample of the parent coarse aggregate shall be required for the determination of bulk specific gravity (oven-dry basis). This sample shall consist of 500 grams of material which passes the 1-1/2-inch sieve and is retained on the 3/4-inch sieve and shall be representative of the parent rock used in the manufacture of the fine aggregate.

c. Procedure.

(1) The apparatus shall be assembled, as illustrated in the accompanying diagram.

(2) Each of the 4 sizes of fine aggregate to be tested shall be poured into the funnel while a stiff piece of metal is held against the bottom aperture. The funnel shall be filled until the sand is heaped between 1 and 2 inches above its top level; care shall be taken not to overflow the funnel or to spill material into the cylinder below. The piece of metal used to close the bottom of the funnel shall be quickly withdrawn in a horizontal movement and the sand permitted to flow freely into the cylinder until it overflows. Then, the flow of sand into the cylinder shall be cut off, and any sand remaining in the funnel shall be allowed to flow into a shallow pan.

(3) The cylinder shall then be carefully struck off with the straight edge, level with the top of the cylinder. This is ac-
Diagram of Apparatus for Determining the Dry-Bulking Characteristics of Fine Aggregate.
accomplished by holding the straight edge in both hands, edge down; starting at one side, striking off the sand above the plane of the cylinder. The straight edge is then placed along a diameter of the cylinder and the sand struck off again. This is then repeated in the opposite direction.

Extreme care shall be taken during the striking-off operation to avoid any downward pressure on the sand or any jarring of the cylinder.

(4) After carefully removing any sand that may be adhering to the outside of the cylinder, the weight of the contents shall be determined to the nearest 0.1 gram.

(5) The sand shall then be recombined with the excess from the cone, thoroughly mixed, and two additional determinations made. An average of three determinations having a maximum variation of 4 grams shall constitute a test.

(6) Tests shall be performed separately on each size.

2. Calculations. The percent voids in each size shall be determined by the following formula:

\[
\text{Percent voids} = 100 \left(1 - \frac{W}{V}G\right)
\]

\(W\) = weight of sand in the cylinder
\(V\) = volume of cylinder in cubic centimeters
\(G\) = bulk specific gravity (oven dry) of the coarse aggregate as determined by the applicable portions of ASTM Designation C-127-42.

3. Report. The arithmetical average of the percent void so determined for each of the 4 size-fractions; that is, the sum of the percentages divided by 4, shall be reported.
D. GRADATION

Manufactured (crushed), limestone, fine aggregate shall be well graded from coarse to fine and when tested by means of standard laboratory sieves shall conform to the following gradation requirements:

<table>
<thead>
<tr>
<th>Passing</th>
<th>Percent by Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 in.</td>
<td>100</td>
</tr>
<tr>
<td>No. 4</td>
<td>95-100</td>
</tr>
<tr>
<td>No. 8</td>
<td>85-95</td>
</tr>
<tr>
<td>No. 16</td>
<td>65-80</td>
</tr>
<tr>
<td>No. 30</td>
<td>40-55</td>
</tr>
<tr>
<td>No. 50</td>
<td>20-30</td>
</tr>
<tr>
<td>No. 100</td>
<td>5-10</td>
</tr>
<tr>
<td>No. 200</td>
<td>0-5</td>
</tr>
</tbody>
</table>

Note: For air-entrained concrete, the maximum percentage of material passing the No. 200 sieve shall not exceed 2-1/2 percent.

The fineness modulus of the resultant fine aggregate shall not be less than 2.30 nor more than 2.90. Fine aggregate which varies more than .20, plus or minus, from the fineness modulus of the representative sample of that source shall be rejected.

Note: The fineness modulus shall be determined by adding the cumulative percentages, by weight, of the portions retained on the 3/8 inch, No. 4, No. 8, No. 16, No. 30, No. 50, and No. 100 sieves and dividing the sum by 100.