COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT
June 12, 1959

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
MATERIALS RESEARCH LABORATORY
132 GRAHAM AVENUE
LEXINGTON 29, KENTUCKY

Ward J. Oates
COMMISSIONER OF HIGHWAYS

B.3.9

MEMO TO: A. O. Neiser
Assistant State Highway Engineer

SUBJECT: Density of Dense-Graded Aggregate Base;
Ref., Your Memo 5-15-59

Density requirements for crushed graded aggregate base courses are necessary to obtain the desired performance, i.e. to develop shearing strength and to eliminate subsequent consolidation. The load transmission of a particular base material is thereby indirectly dependent upon density.

Listed below are some of the factors that affect the density of dense-graded aggregate base constructed from crushed limestone.

1. Specific Gravity and Porosity of Solid Stone. The specific gravity used is termed "bulk specific gravity (SSD basis)" by ASTM and is the saturated surface dry weight divided by the bulk volume of the stone particles. Limestones that will meet Kentucky stone base requirements will normally have less than 1% of water absorption which would be less than 3% of the solid volume of the stone. By Kentucky density requirements, it is more difficult to obtain density on the porous stones with water absorption of over 1%. However, I do not believe that this has been a major factor in our recent compaction problems.

2. Stone Gradation. A long gradation range and a minimum of 5% passing the No. 200 sieve (1-inch top size) is most essential. The fines are needed to fill the voids and act as a binder in the aggregate.

3. Moisture Content at Time of Compaction. The aggregate gradation is compactable if it is at or near optimum moisture content. This moisture content, for best results, appears to be slightly higher than that necessary for saturation at 85% solid volume of the stone. It is best, therefore, to mix and place the

stone a little on the wet side; and, it has been noted that upon drying, the stone will shrink somewhat and obtain a greater density. It is possible that the water necessary for compaction, particularly that adhering to the fine particles will hold the stone apart. This effect is predominate in the bulking of wet sands.

The Department has placed dense-graded aggregate with and without moisture control additive (calcium chloride). The Research Division has reported densities on projects of each type. Fayette County RS 34-304, Southland Drive in Lexington, was the first dense-graded limestone base placed in Kentucky. One-half of one percent calcium chloride was used and the DGA was placed over a single course of waterbound macadam. The following year, the Phil-Pine Grove road, Casey County F 505, was constructed using DGA without moisture control additives. On this project, the DGA was placed over existing TBM. Average densities on the Fayette County project were 8.6 lbs. per cu. ft. greater than on the Casey County project. The Fayette County DGA, while placed under the same specifications, did have a greater percentage of fines. The percentage of voids on the Fayette County project averaged 9.9% while the Casey County section averaged 15.1%. Both of the above projects were wetted and mixed in place.

It has been reported by A. M. Johnson, J. A. Knight, and F. O. Slate that maximum density granular soils and base materials could be obtained with less compactive effort when moisture control chemicals are used (HRB Bibliography 24).

4. Compactive Effort and Depth of Layers. These items include the concentration of the compactive load, type of compaction, and the number of repetitions of the load.

In a paper presented at the 1959 Kentucky Highway Conference and published in the April issue of American Highways, Mr. John J. Laing of the Bureau of Public Roads emphasized the basic principles of compaction. Mr. Laing's paper, "Compaction of Asphaltic Concrete", also discussed compaction of granular base courses and equipment requirements. He mentioned that base course layers were normally placed in thicknesses of 3 to 5 in., but that maximum thicknesses of 8 to 10 in. have been reported. In Fig. 2, which deals with the pressure distribution through a compactable layer, he shows that 0.9 of the tire contact pressure is distributed to a depth of 4 in., while the pressure is reduced to 0.5 at a depth of 8 in. At 13 in. the effective pressure is only 0.3 of the contact pressure at the surface. Mr. Laing concludes from his discussion, quote: "It would seem preferable to develop an "end result" specification where density or other finished characteristics in addition to profile and crown tolerances would be specified".

Compactive effort is dependent upon three factors: (1) roller contact pressure, (2) depth of layer, and (3) number of repetitions or passes or roller. These three items are independent and can be varied within reasonable ranges to obtain desired densities. The depth of layer can not be increased appreciably without increasing the contact pressure of the roller.

5. Subgrade Support or Reactance. It was mentioned in item 3 above that the DGA on Fayette RS 34-304 was placed over a course of WBM, while the Casey County project was placed over TBM. The WBM undoubtedly provided a better reactance for compaction than the TBM. Some of the density variables can be attributed to this reactance; but, of course, other factors were involved there also.

A dense, dry subgrade should provide ample reactance for plant-mixed DGA. Wet or soft subgrades can affect the densities obtained.

6. Method of Test. The method of test for density (rubber balloon) of DGA is primarily a soils or fine aggregate test. At the time the turnpike insulation course was being constructed, it was decided that more than one method of density test would be investigated. The general consultant's materials engineer made density comparison tests at various locations using calibrated sand, paraffin coated chunks, and the rubber balloon. On the average it was found that the density results were higher when tested with the rubber balloon than by the sand method, but the paraffin coated samples that were used for reference varied from location to location. The average difference in density was in the order of 2 lbs. per cu. ft. It was decided, however, to use the rubber balloon in calculating the volume of the hole because of the convenience it afforded and because the variations in density test comparisons were only minor. The turnpike insulation was placed in 6-in. compacted layers. Various compaction equipment was used for the different contracts.

On June 8, 1959, I visited the Hardin County section of Interstate I-65. Plant-mix DGA base was being compacted in a 6-in. layer. Pneumatic rollers and Jackson-type vibrators were being employed. Some water was being added during the shaping and compaction operation. Some difficulty was encountered in obtaining the 85% solid density before a satisfactory compaction procedure was decided upon. It was also noted by the project engineer that density could not be obtained if the subgrade was wet and did not provide the necessary reactance. Density tests were being conducted after the base had cured to about 3% moisture. It appeared that the compaction procedures (initial rolling with pneumatic followed by Jackson vibro-tampers) were producing the required densities.

I am of the opinion that the density requirements of 85% solid volume as calculated from the bulk specific gravity of the stone is realistic and practical. It is somewhat severe for certain stones but should go a long way toward the elimination of rutting in flexible base courses.

I believe that consideration should be given to a modified sand density test such as Tennessee uses, particularly if the top size of DGA is increased over the present 1 in. The rubber balloon-type test would not be suitable for the coarser aggregates.

I prefer an end result specification for DGA and believe that the choice of thicknesses of layer and type of roller should be left to the contractor. Density can be affected by either item.

Respectfully submitted,

W. B. Drake

W. B. Drake
Associate Director of Research

WBD:dl
Encs.