



COMMONWEALTH OF KENTUCKY  
DEPARTMENT OF HIGHWAYS  
FRANKFORT  
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Ward J. Oates  
COMMISSIONER OF HIGHWAYS

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

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MEMO TO: D. V. Terrell  
Director of Research

The attached reports, "Development of Dense-Graded Aggregate Base" and "Discussion of Manufactured Sand", were prepared for and presented to the Kentucky Crushed Stone Convention in Louisville on April 4, 1959.

The subjects are, of course, still under study by the Division. The two papers are being distributed to the Research Committee as a matter of record.

Respectfully submitted,

A handwritten signature in cursive script that reads "W. B. Drake".

W. B. Drake  
Associate Director of Research

WBD:d1  
Enc.

cc: Research Committee Member  
Bureau of Public Roads

Commonwealth of Kentucky  
Department of Highways

DENSE GRADED AGGREGATE BASE DEVELOPMENT

by

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Associate Director of Research

(Prepared for Presentation at the Kentucky Crushed  
Stone Association Convention, April 4, 1959, Louis-  
ville, Kentucky)

Highway Materials Research Laboratory  
Lexington, Kentucky

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## DENSE GRADED AGGREGATE BASE DEVELOPMENT

During the years immediately following World War II, the Kentucky Department of Highways undertook a revitalized construction program. Beginning with 1946 through 1950, several miles of high-type flexible pavement were constructed using waterbound macadam base. The riding quality on some of the new pavements was questionable and, it was thought, did not compare with waterbound-type construction placed some years earlier.

The Research Division's report, "Measurements of Surface Irregularities and Riding Qualities of High-Type Bituminous Pavements," December, 1952, pointed out: "...It appears that the highway industry has gone through a transition from conditions where; hand labor could be applied rather freely to base construction; standards of workmanship, in general, were high; and speed or progress of work was not exaggerated even though it was emphasized. Now we have entered a time when hand labor must be kept to an absolute minimum, standards of workmanship have deteriorated and speed is emphasized almost to the exclusion of everything else". The report further pointed out that the cause of poor riding qualities lies in the section and grade-finish of the base course. As a result of the study, some tests were conducted using a patrol grader for spreading a leveling course of bituminous concrete. The results were promising, and it was further proposed that a granular base course that could be leveled or shaped with a patrol grader might be feasible.

The Research Division proposed a project with such a base course material in 1951. The project selected for trial was Fayette

County, RS 34-304, presently noted as Southland Drive in Lexington.

The pavement on this project consisted of:

1" Insulation Course (50% No. 5 & No. 10)

4" WBM - Size No. 1 & No. 10

4" DGA - 2-2" Courses with  $\text{CaCl}_2$

1-1/2" Class I, Type A Binder

1-1/4" Class I, Type B Surface

The WBM course was placed in the conventional manner and precise levels were taken of the profile and cross-section.

The dense-graded aggregate base courses were mixed and wet in place. The aggregate was supplied in two gradings and mixed with calcium chloride and water on the road. Patrol graders were used for mixing, spreading and leveling. Precise levels and roughness measurements were taken on the base components and the finished surface.

The report on the above project noted: "The surface contour that can be obtained by blade spreading is considerably superior to the contour of waterbound macadam placed in what is now the customary way." Because of the experience gained and the apparent advantages in lower construction costs noted in the report, the Department let to contract several different types of dense-graded aggregate base courses during the following year. All of these projects contained calcium chloride as a moisture control aid.

State route 54 in Grayson County was constructed using 2 inches of dense-graded aggregate base beneath a 4-inch WBM base. The DGA base set up very hard and there was a tendency for the coarse WBM

stone to roll on top of the DGA and not key into it. This is the only WBM base placed over DGA base; although, there are some projects on which DGA has been used as insulation.

In an effort to determine the merits of dense-graded aggregate base without a moisture control additive, the Division of Design selected the Phil-Pine Grove Road in Casey County for such a test. This was in the initial treatment program of 1953 and the design called for 3 inches of DGA and 1-1/2 inch of Class C-1 roadmix surface. It was concluded that the base could be constructed without additives but that protection against damage from traffic was necessary. Densities obtained were considerably lower than on the Fayette County project.

Laboratory studies to evaluate the bonding properties of limestone dust and the effect of calcium chloride on the strengths developed were made in 1953 and 1954. It was shown that strengths developed were dependent upon the quantity of the dust fraction (-No. 200 sieve) and, further, that the moisture content at time of compaction was important. It was pointed out that the calcium chloride was a moisture control additive and did not in itself add any strength to the stone. It was concluded also that calcium chloride through moisture control aided compaction, eliminated segregation, and prevented loss of density upon curing.

The first projects having appreciable tonnages of dense-graded aggregate were the turnpike surfacings. A 6-inch course of this base was used for insulation under the concrete slab. The base was placed to 85% or greater of solid volume density. The gradation used was essentially the same as our present specifications.

In December, 1954, a group of Kentucky Department of Highway Engineers visited a base construction project near Nashville, Tennessee, which was producing and placing an average of 2,000 tons of DGA base per day. The maximum day's run was 2,900 tons in 12 hours. The limestone was quarried and crushed through a 2-inch screen with a jaw-type crusher. The stone was separated into two bins at the No. 4 screen. Two hammer mills were available for controlling the grading in the fine bin. On the date of inspection, only one hammer mill was being used. The stone was wet and there was very little loss of fines in dust.

The grading used on the project was as follows:

<u>Sieve Designation</u>	<u>Percent Passing</u>
2-inch	100
1-inch	75-90
1/2-inch	60-75
No. 4	45-60
No. 40	15-30
No. 200	5 to 2/3 amount passing No. 40 sieve

Eight pounds of calcium chloride per cubic yard of compacted base was added at the plant.

The Tennessee gradation was coarser than any used in Kentucky. The 2-inch top size was not as easily worked or shaped with a blade, but a minimum of blade work was required on the plant-mix operation. After observing the work in Tennessee, and other projects in North Carolina, it was decided to provide two coarser gradings of the dense-

graded aggregate to be used in plant-mix base construction. The Type A, 3-inch top size; Type B, 2-inch top size and Type C, 1-inch top size were incorporated in the 1956 Standard Specifications. An attempt was made to eliminate the number of sieves in the test and to convert to the normal aggregate sieve sizes. The grading was lengthened to require 5% retainage on the 3/4-inch screen.

In 1956, the stone producers requested a hearing with the Specification Committee to discuss dense-graded aggregate. It was brought out during the session that some producers had been able to make the DGA specified in SS 58 without hammer mills or special equipment but were unable to produce the 56 Standard Type C. It was noted that the quarries that had been able to produce crusher-run DGA had been crushing through a 3/4-inch screen in order to obtain the required amount of minus 200 material. Upon using the 1-inch top size, the aggregate was short in fines. It was proposed by some of those present that the percentage of aggregate passing the No. 200 sieve be dropped to 3%, if it was necessary to maintain the 5% retained on the 3/4-inch screen. The Department decided to revert to the SS 58 grading and to maintain the fine portion at 5 to 15% passing the No. 200 and to allow from 70 to 100% passing the 3/4-inch screen. In making the amendment to the 1956 Standard Specification, Types A, B & C were deleted; and the grading from old SS 58 was substituted. Only one type is now available to the designer.

The first full-depth plant-mix dense-graded aggregate base for flexible pavements in Kentucky was on a reconstruction job on US 31E south of Hodgenville. The DGA base was placed in 3 courses, 2 without calcium, about 5 or 6 inches thick, and 1 course with calcium chloride.

There have been several producers question the loss of fines in stockpiles. Problems along this line may have developed. Some of the biggest tonnage projects have been worked from stockpiled aggregate. A portion of the stone used on the turnpike for insulation was crushed one year and used the next. There have been some rather elaborate methods for elimination of stockpile segregation. One producer built his stockpile over a conveyor installed in a large diameter metal pipe, and satisfactory results were obtained.

There seems to have been a tendency to place DGA base in thicker layers. Some of the problems that have developed in obtaining the desired densities may be attributed to construction of too thick layers. Granted, some types of construction equipment do the job better than others, but there is still the possibility that we are trying to compact layers that are too thick.

One of the most important factors in the performance of flexible base is its susceptibility to subgrade intrusion. As early as 1954, reports of the depth of subgrade infiltration into waterbound macadam base were prepared by the Research Division. Clay in a granular base upon becoming wet will lubricate the aggregate and cause loss of stability. Rutting or pavement failure will normally occur if the clay infiltration is significant.

There are two conditions by which clay can be forced up into the voids in the base course. One is through the action of rollers or compactors at the construction stage. Excess water for water-bonding can soften the subgrade making it quite easy for the rollers to force subgrade into the base. The second condition is for traffic to provide the action necessary to pump the subgrade into the base. In both



instances, it is necessary that voids be available or the density be low enough to permit the soil to enter.

During the summer of 1958, the Research Division opened several flexible pavements to observe the condition of the layered components. Only sections showing some form of rutting were selected to be opened. Most of the pavements were constructed over WBM base courses. The WBM was found to be susceptible to clay intrusions; and, in the majority of the WBM base courses examined, the infiltration was fairly uniform throughout a particular layer of WBM. In some instances, one layer would be impregnated; and, in other cases, two or even three courses would contain the clay from the subgrade. In one instance, infiltration was most pronounced in the wheel tracks; and indicated that the traffic had caused the clay to be forced into the base. One dense-graded aggregate base was opened to see if any clay could be observed in the aggregate. No clay was observed even though there was some minor surface rutting.

Dense-graded aggregate base should serve as a much better insulation against subgrade infiltration than the WBM base. On the average, there would be less than 1/2 the volume of voids subject to be filled.