M. W. TINDER
COMMISSIONER OF HIGHWAYS

COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

December 13, 1954

ADDRESS REPLY TO

ATTENTION: B.3.6.

MEMO TO: L. E. Gregg
Assistant Director of Research

SUBJECT: Inspection of Full Depth Modified Dense-Graded Aggregate Base, Plant Mixed (Tennessee Project)

On December 1, 1954, a group of engineers of the Kentucky Department of Highways made an inspection of a construction project near Nashville, Tennessee. Those who made the trip were:

J. A. Bitterman, Director of Materials
S. T. Collier, Assistant Director of Design
W. B. Drake, Research Engineer
J. S. Hill, Assistant Director of Construction
M. F. Johnson, Director of Design
C. B. Owens, Director of Construction
H. H. Sandusky, District Engineer
O. F. Threlkeld, Assistant Director of Materials
C. T. Warwick, Assistant Director of Construction

A group of engineers from the Tennessee Department of Highways met the above group at the project and conducted the inspection trip. Those present from Tennessee were:

Ed Burchette, State Materials Engineer
G. R. Champion, Division Construction Engineer
J. J. Conroy, Soils Engineer
D. M. Daugherty, Resident Engineer
H. D. Long, State Construction Engineer
R. S. Patton, State Design Engineer

The project (designated as I-001-5(27) was located about 20 miles southeast of Nashville in Rutherford County, and extended south from the city limit of Smyrna to Stones River Bridge - a distance of 8.816 miles. It involved the construction of two additional lanes which will make this section of U.S. 41 and U.S. 70 (south) a four-lane divided highway.

Design requirements for the pavement were: 14 inches of dense graded aggregate base, 250 pounds of binder per square yard, and 125 pounds of sand asphalt surface per square yard, for an overall depth of approximately 17-3/4 inches.

Alternate-type bids were taken, the rigid alternate being a 9-inch uniform plain cement-concrete pavement. There were three combinations of flexible-type pavement alternates.

MATERIALS

The base was constructed from crushed limestone having a specific gravity of 2.69. The grading requirement of the stone was as follows:

Sieve Designation	Percentage Passing
2-inch	100
1-inch	75 - 90
1/2-inch	60 - 75
No. 4	45 - 60
No. 40	15 - 30
No. 200	(not less than 5 percent nor more than 2/3 the percentage passing the No. 40 sieve)

Calcium chloride was applied at the rate of 8 pounds of flake per cubic yard. Stone weighed 2800 pounds per cubic yard, making a ratio of approximately 5.7 pounds of calcium chloride per ton of stone.

CONSTRUCTION

Limestone was quarried and then crushed through a 2-inch screen with a jaw-type crusher (See Fig. 1). The stone was separated into two bins at the No. 4 screen (See Fig. 2). Two hammer mills were available for controlling the grading in the fine bin. On the date of the inspection only one hammer mill was being used. Since the stone was wet, there was very little loss of fines in dust. All of the stone that was originally put through the jaw crusher was ultimately run through the pug mill and placed on the road.

The gradation requirement was met with stone from the two bins mixed in near-equal proportions. With this combination, about 11 to 12 percent of the material was retained on the 1-inch screen and approximately 6 percent passed the No. 200 screen.

The two bins fed stone onto a belt already containing the required amount of calcium chloride (See Fig. 3). The belt discharged this material through water from a double spray bar into a continuous-type pugmill. From 4 to 6 percent of water was added in this way at the pugmill (See Fig. 4).

The average output of the aggregate plant was 2000 tons per day and the record day was 2900 tons in 12 hours.

Wet-mixed stone was delivered to the job in heavy tandem-axle trucks and spread from a hopper mounted on a bulldozer (See Fig. 5). The distribution appeared to be reasonably uniform, but the bulldozer left tread marks in the loose stone.

Plans called for placement of the 14-inch base in 4 lifts, each having a compacted depth of 3-1/2 inches. A loose spread of 5 to 6 inches

Fig. 1 - Primary crusher in operation. This unit produced 2000 to 2900 tons of stone per day through a 2-in. screen. Quarry trucks dumped material into a hopper (not shown) just above the crusher.

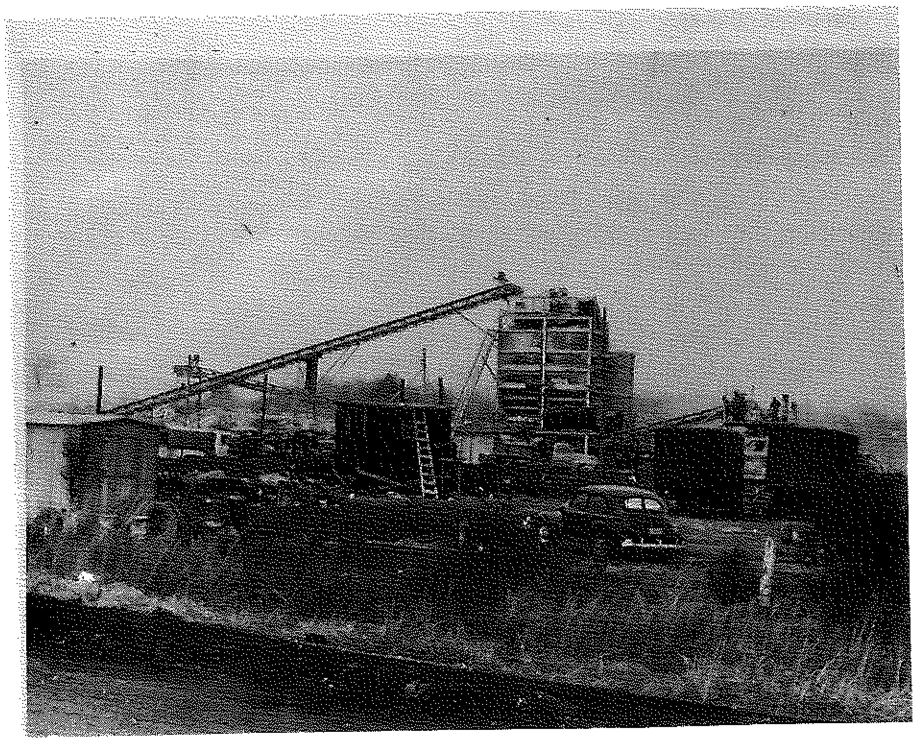

Fig. 2 - General view of aggregate plant. The primary crusher is located (behind the shed to the left) at the lower end of the long conveyor. From this conveyor stone of 2-in. maximum size is fed onto the screen at the top of the bins. The left bin contains minus No. 4 stone; the right bin contains minus 2-in. and plus No. 4 stone. Oversize stone, and also the surplus of plus No. 4 material is fed through one of two hammer mills (out of sight in this illustration) situated at the rear of the bins. Another conveyor returns material from the hammer mills to the long conveyor. The two bins supply (by another conveyor belt) the pugmill at the right.

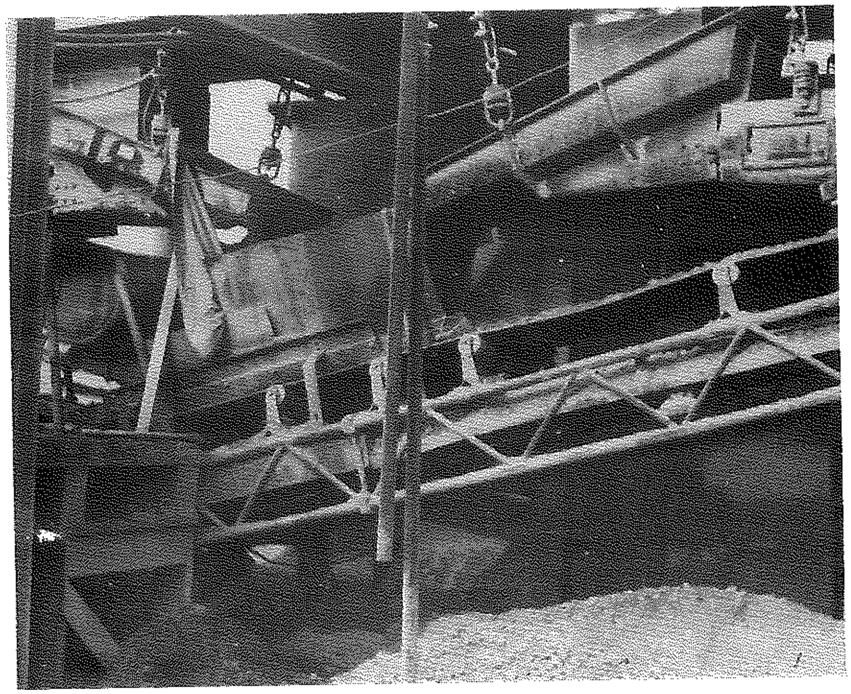

Fig. 3 - Near view of bin feeds. The vibrator on the left feeds minus No. 4 stone, and the one on the right feeds plus No. 4 material. A cut-away oil drum (immediately under the vibrator on the left) supplies calcium chloride to the conveyor belt just before it passes under the stone feed. The flow of calcium chloride is regulated manually and is periodically checked against stone tonnage output.

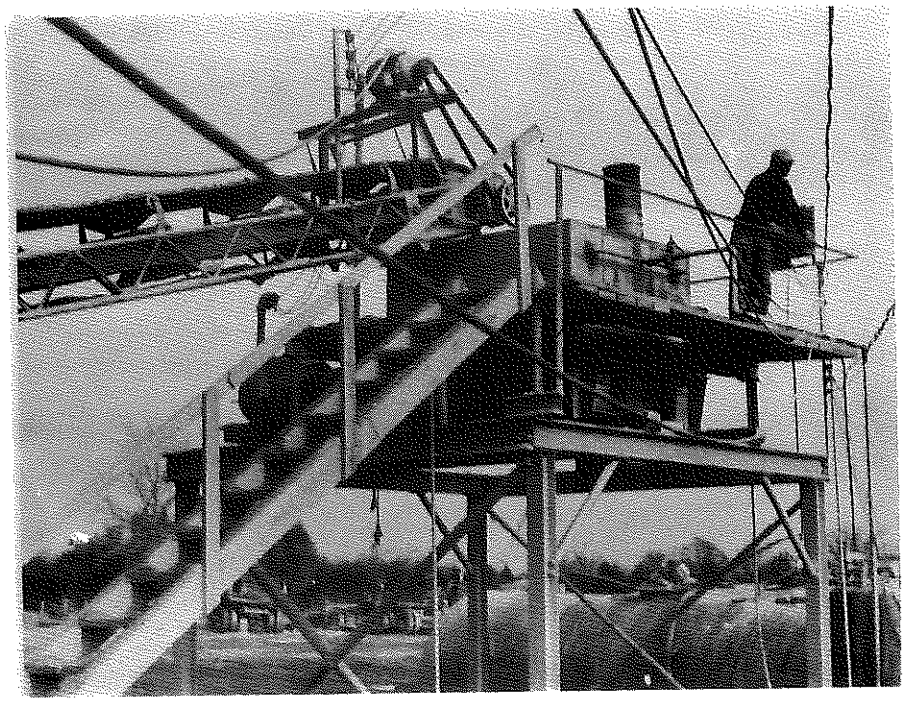

Fig. 4 - General view of the continuous-type pugmill. Water is sprayed into the mill through the two pipes shown entering the box. The workman on the platform controls the conveyor and operates the pugmill.

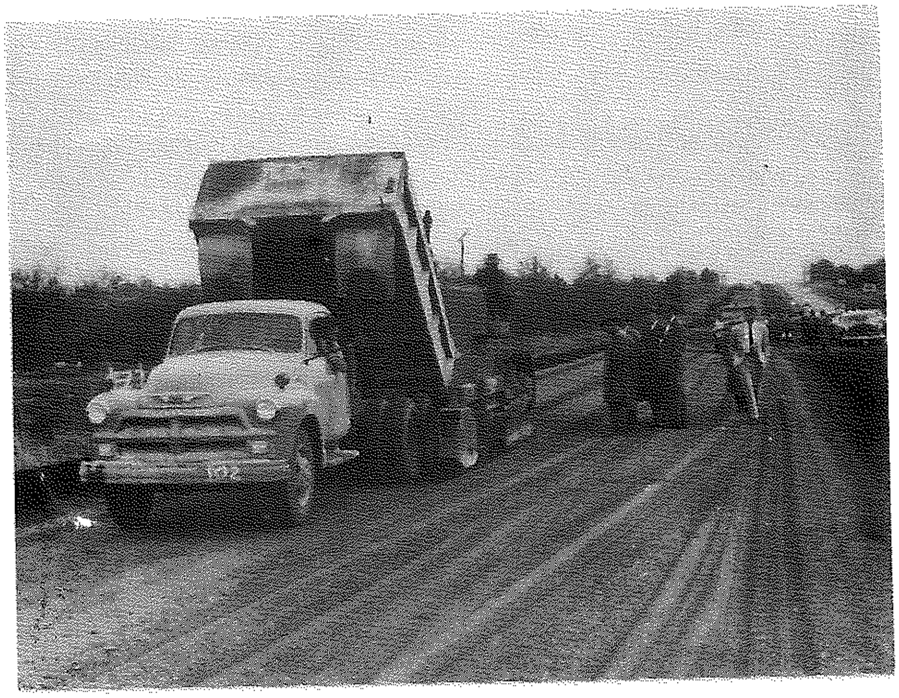

Fig. 5 - Stone spreading operation. Stone was distributed from a hopper mounted on a bulldozer. A loose lift of 5 to 6 inches was required to produce the 3-1/2-in. compacted layer. Very little segregation of stone was encountered with this type of spreading (See Figs. 7 and 8).

was required for the desired thickness after compaction. For experimental purposes the 14-inch base was placed in two 7-inch lifts for a short distance in one section.

Immediately following application of stone, the base was shaped to the required cross-section and grade with a patrol grader. Grade stakes, set to the elevation of the finished base, were placed at 50-foot intervals on each side of the roadway. A light wobble-wheel-type pneumatic roller was used with the patrol grader. (See Fig. 6) Irregularities caused by partial compaction with the bulldozer and grader were eliminated by shaping operations of the grader and initial rolling.

During most of the project primary compaction of the base was accomplished with a 25,000 pound, vibrating-type, pneumatic, singled-tired roller. A three-wheeled, 10-ton roller was used for the final pass over the base.

The vibrating-type, steel-wheel roller shown in Fig. 9 was being demonstrated at the time of the present inspection. This roller replaced the heavier pneumatic roller on a portion of the last lift.

Of primary concern was the effect of the grader on the plus 1-inch stone. However, there was very little evidence that stone was being pulled from the mix by the blade(See Fig. 7). The texture of the completed base is shown in Fig. 8, and it can be seen that the larger stone particles prominent in Fig. 7 had satisfactorily "tied down" during the rolling operation.

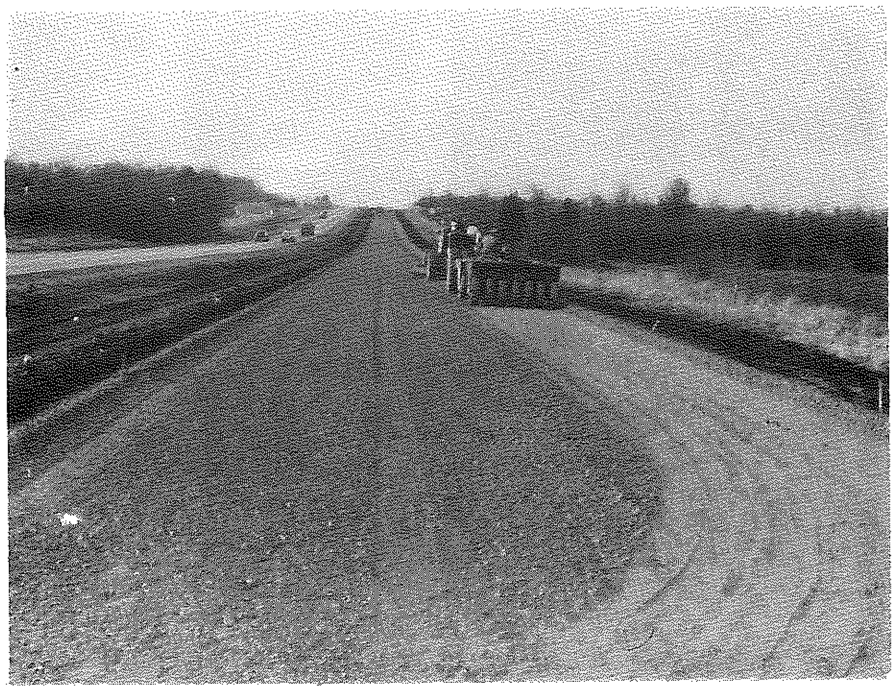

Fig. 6 - Shaping and rolling operations. A patrol grader was used to shape the stone to final grade, which was controlled by blue tops at intervals of 50 ft. on both sides of the road. In the shaping operation, a light pneumatic roller was used simultaneously with the grader in the manner depicted here.

Fig. 7 - Close-up view of base prior to compaction and just after the patrol grader had passed. Note the small amount of segregated stone present.

Fig. 8 - Near view of texture of finished base, which appeared firm and stable under the weight of construction equipment.

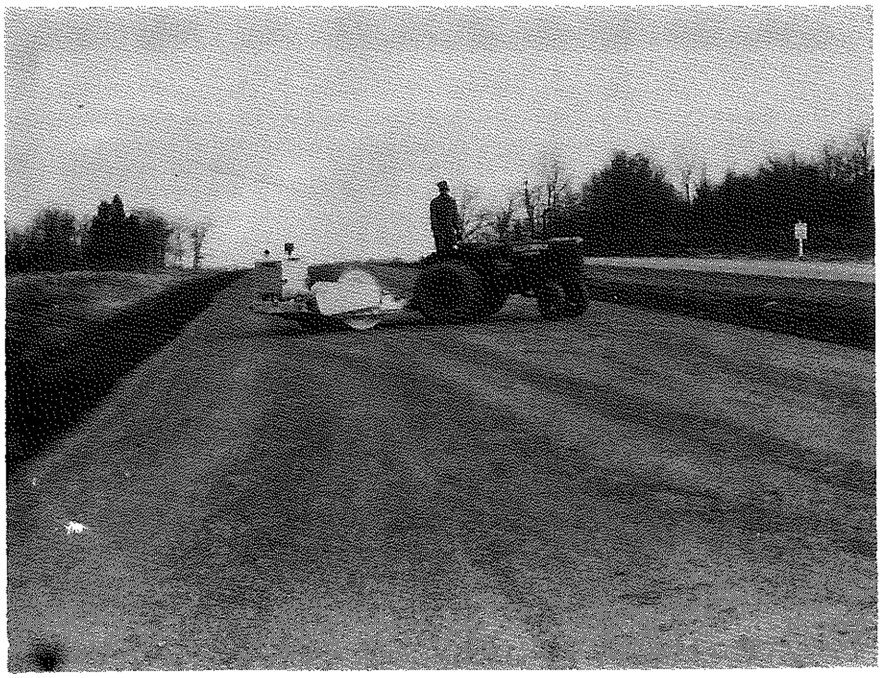

Fig. 9 - Vibrating-type roller used for final compaction This machine (drum dimensions: 5 ft. wide and 3-1/2 ft. in diameter) weighed 7200 lb. and was pulled by the tractor shown in the illustration. The roller was being demonstrated on this project and was used for only 3 days on the top lift. A 25,000-lb. vibrating type pneumatic roller was used during most of the project. However, both types were considered satisfactory.

TEST RESULTS

As construction progressed, openings were made in the various lifts, and compaction characteristics were analysed by field density tests. Densities varied from 135 to 161.8 pounds per cubic foot, the average being 146.2 pounds per cubic foot. Field density values were compared with the theoretical solid density of the limestone. This figure (assuming the absence of voids) was 167.9 pounds per cubic foot. Thus field densities were 80.4 to 96.4 percent of the solid density value, the average being 87.1. Data from these tests are summarized in Table 1.

Two density tests were performed in the section consisting of two 7-in. compacted layers. These tests showed values of 144.1 and 144.3 pounds per cubic foot. At these test locations, the percentages of solid volume were 85.8 and 85.9 percent.

With the exception of samples taken at stations 557+50 and 577+50, all test samples of the base had been compacted with the 25,000-pound vibrating-type pneumatic roller. The two former locations were compacted with the vibrating-type steel-wheel roller. Density values of samples taken at these locations were 135.4 and 140.5 pounds per cubic foot, so the percentages of solid density were 80.7 and 83.7 percent respectively.

Tests were made at two points (Stations 602+50 and 623+00) where the base had been compacted with the heavy pneumatic roller on the same day that the steel-wheel roller was operating. Density values of samples from these two locations were 149.6 and 150.6 pounds per cubic foot. The percentages of solid density for these two locations were 89.1 and 89.7 percent, respectively. Thus, in this limited way it was indicated that better densities were obtained with the heavy pneumatic roller than with the vibrating steel-wheel roller, and that densities of base placed in two 7-inch lifts were equal to those obtained when the material was placed in four 3-1/2-inch lifts.

Compaction characteristics of the various lifts have been summarized as follows:

Lift	Thickness	Average Density	Average Percent Solid Density
1st	3-1/2"	150.2	89.5
2nd	3-1/2"	144.4	86.1
3rd	3-1/2"	142.3	84.8
4th	3-1/2"	143.8	85.6
2nd	7"	144.2	85.9

The inspecting group was particularly impressed with the riding quality of the completed base. However, none of the pavement was completed so that ultimate riding qualities could be judged. The binder and surface courses are not scheduled to be placed until an early date during the next construction season.

Respectfully submitted,

W. B. Drake

W. B. Drake
Research Engineer

WBD:ddc
copies to: Research Committee
Mack Galbreath (3)

Table 1 - Field Density Test Results

Date	Station	Lift	Percent Moisture	Field Density Lbs. Per Cu. Ft.	Percent Solid Density
9-27-54	301+50	2	3.3	156.4	93.2
9-27-54	319+00	2	2.8	147.0	87.6
9-29-54	417+60	1	3.9	145.3	86.5
10-1-54	408+00	2	3.4	146.6	87.3
10-1-54	346+00	2	4.1	154.6	92.1
10-5-54	428+00	1	3.3	153.4	91.4
10-7-54	507+00	1	2.4	143.2	85.3
10-9-54	451+00	1	1.9	158.6	94.5
10-9-54	557+00	1	2.3	143.3	85.3
10-16-54	590+00	1	2.7	144.6	86.1
10-16-54	645+00	1	2.1	143.9	85.7
10-20-54	682+00	1	1.1	158.6	94.4
10-20-54	735+00	1	1.8	161.8	96.4
10-23-54	456+00	2	2.0	139.5	83.1
10-23-54	501+00	2	1.7	135.0	80.4
10-27-54	559+00	2	2.0	148.0	88.1
10-27-54	608+00	2	1.5	145.2	86.5
11-1-54	677+00	2	3.9	141.1	84.0
11-9-54	729+50	2 (7")	2.2	144.1	85.8
11-9-54	742+50	2 (7")	2.5	144.3	85.9
11-11-54	700+00	3	2.4	142.6	84.9
11-11-54	650+00	3	1.7	136.3	81.2
11-13-54	600+00	3	3.6	150.0	89.3
11-13-54	550+00	3	2.5	138.1	82.3
11-23-54	500+00	3	3.8	143.6	85.5
11-23-54	450+00	3	3.4	144.1	85.8
11-29-54	557+50	4*	2.9	135.4	80.7
11-29-54	577+50	4*	2.6	140.5	83.7
11-29-54	602+50	4	3.4	149.6	89.1
11-29-54	623+00	4	5.2	150.6	89.7
Average			2.7	146.2	87.1

* Compacted with vibrating-type steel wheel roller.