Service Record Study of Bituminous Concrete and Sand Asphalt Pavements in North Carolina

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● THIS is the second performance report on observed behavior of several test sections of specially designed high-type bituminous-concrete paving mixtures. All mixtures have been used as an overlay over old portland cement concrete pavement.

During construction of the project, samples were taken from each truck load for laboratory analysis. Subsequent samples have been taken every year from the area covered by each truckload.

The important factors in this report are the following: (1) Proper design and field control of the mixture, (2) behavior of three types of commercial aggregates under severe service conditions, (3) tack coats, (4) the effect of traffic on density of the pavement after three years of service, and (5) reflection cracking as related to design.

The data should be helpful in determining satisfactory design and control methods for future asphalt-pavement construction for heavy-duty highways.

DESIGN PROCEDURE

Among the chief factors considered in designing a high-type bituminous-concrete pavement is stability. Stability may be defined as resistance to deformation. The laboratory has found a close association between density of the graded aggregate and stability. Regardless of the type of aggregate, the grading that produces the highest aggregate density will produce a bituminous mixture having a higher stability than can be obtained with less-dense gradings of the same aggregate. The first problem, then, is to determine the blend of available aggregates that will produce maximum density (minimum void content).

In selecting the formula for the test sections the following items were taken into consideration: stability, density, percent of voids for total mix, and percent of voids filled with asphalt (Table 5). All mixtures selected contained between 3 and 5 percent voids in the total mix and had from 70 to 78 percent of the voids in the aggregate filled with asphalt. Only AP-3 asphalt (85-100 penetration) was used in these mixes. Several other grades of asphalts were used as tack coats.

Three types of coarse aggregate were used—crushed granite, crushed siliceous gravel (about 50 percent crushed particles), and uncrushed gravel. The uncrushed gravel was the same coarse aggregate used in the bituminous-concrete resurfacing where the rapid and serious failures took place on US 301 as described in the original report. All sections are 1,000 ft in length. (See Table 1 for job mix formulas.)

At the time these test sections were constructed, it was felt that a direct relationship existed between the density and stability of any bituminous mixture. This relationship had been noticed during the analysis of routine reports made on previously designed mixtures.

Since the test sections were constructed, a detailed comprehensive laboratory study has been made in an effort to determine the true relationship between density of bituminous mixtures and stability (Figures 1 and 2). Results of this investigation were reported in the February 1956, issue of the ASTM Bulletin. The Unconfined Compression Test, A.S.T.M. D 1074-52T, was used to make this study. The double-end plunger method of compaction was used in forming the test specimens.

It has been shown that the stability of a bituminous concrete mixture increases with an increase in density up to the point where additional compactive effort would fracture the aggregate. In roadway construction, it may be assumed that unless the mixture on the road receives compaction comparable to that obtained in the laboratory, full benefit is not being derived from the materials in use. Sufficient compactive effort should be applied on the road to produce a finished mixture with a void content within the range permitted by the design procedure.

CONSTRUCTION PROCEDURE ON SECTIONS 1, 2, AND 3

Two grades of asphalt were placed separately on these experimental test sections as a tack between the surface course material and the underlying old cement-concrete pavement. Cutback asphalt, Grade RC-2, at the rate of 0.117 gal per sq yd was applied to the western lane of the pavement and hot bitumen, Grade AP-3 (85-100 pen.) at the rate of 0.063 gal per sq yd was applied to the eastern side. Identical construction methods were employed throughout the surfacing operations, and one-way traffic was maintained on the east shoulder of the road while paving operations were in progress.

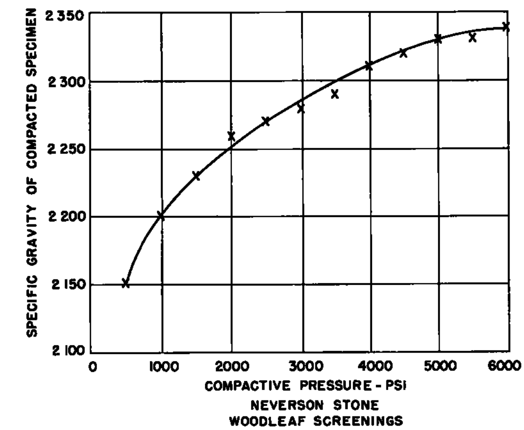

Figure 1.

Each section has a special mix design based on the type of coarse aggregate used. Other materials used in the three designs, such as fine aggregate, mineral filler, and the asphaltic cement, are similar throughout and are from the same source. The rate of application was 150 lb per sq yd.

CONSTRUCTION PROCEDURE ON SECTIONS 4, 5, AND 6

In these three cases, a tack coat of AP-3 (85-100 pen.) asphalt was applied to the western side of the road, at a temperature of 415 F and at the rate of 0.063 gal per sq yd. On the eastern half-width the tack coat consisted of RC-2 and was applied at the rate of 0.120 gal per sq yd. The RC-2 tack coat material was applied two days before the laying of the binder course was begun to allow for sufficient curing.

Each section has a special mix design based on the type of coarse aggregate used. Other materials used in the three designs, such as fine aggregate, mineral filler, and the asphaltic cement, are similar throughout and are from the same source. The resurfacing is composed of 150 lb per sq yd of bituminous concrete binder and 150 lb per sq yd of bituminous concrete wearing surface.

Immediately before spreading the surface-course material a tack coat of Grade AP-3 asphaltic cement, which had a temperature range from 370 to 415 F, was applied to the binder course at an average rate of 0.063 gal per sq yd.

The bituminous concrete was delivered to the paving by trucks loaded uniformly with 6 tons each at an average temperature of 290 F, maximum 390 F, minimum 255 F. The paver was operated at a speed of 18 to 22 ft per minute.

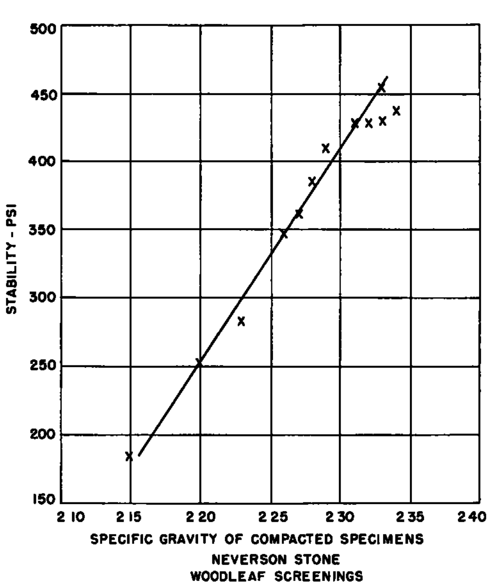

Figure 2.

SECTIONS 7, 8, AND 10

Sections 7, 8, and 10 differ radically from the other test sections in design. Section 7 consists of a standard-specification bituminous surface-treatment mat course which was substituted for the usual hot-mix binder course, and after a 12-day curing period this mat course was surfaced with a laboratory designed hot-plant-mix of bituminous-concrete surface-course material or of hot-plant-mix sand-asphalt surface-course material as prescribed for the subject section. No tack coat was used between the mat and surface courses.

Section 7 was built with a mat-course which consisted of 65 lb per sq yd of specification No. 10 crushed stone (size 1½ in. to No. 4 sieve) and 0.613 gal per sq yd of AE-3 emulsion. The same day this course was applied, 7 lb per sq yd of sand was applied as a blotter course to absorb any excess emulsion. Traffic used this section for 12 days before the surface course was applied consisting of 105 lb per sq yd of bituminous concrete mixture, the same design as the wearing surface on sections 1 and 6.

Section 8 was built with a mat-course of specification No. 10 uncrushed gravel (size 1½ in. to No. 4 sieve) and 0.645 gal per sq yd of AE-3 emulsion. The surface course consisted of 102.6 lb per sq yd of bituminous concrete mixture, the same design as the wearing surface on sections 3 and 4. The construction details of this section are the same as for section 7.

Section 10 was built with a two part mat-course. The first 500 ft consists of 64 lb per sq yd of specification No. 10 uncrushed gravel with 0.589 gal per sq yd of Grade AE-3 emulsified asphalt. The second 500 ft consists of 65 lb per sq yd of specification No. 10 crushed granite with 0.633 gal per sq yd of Grade AE-3 emulsified asphalt. On these mat courses was placed 165 lb per sq yd of hot-plant-mix sand asphalt surface course materials. The same sand was used in all hot-plant mixtures in these test sections. The asphaltic cement used in these surface course mixtures for section 10 consists of AP-5 (60-70 pen.).

OBSERVATIONS OF PERFORMANCE

Section 1: One-Course Bituminous Concrete Containing Crushed Granite Aggregate

The surface of this section is in good condition. No displacement is evident. The reflection of cracks from the underlying old cement-concrete pavement have all appeared in the bituminous concrete surface. This condition had occurred at the end of the first year of service. There is no evidence of instability.

Section 2: One-Course Bituminous Concrete Surface Containing Crushed Gravel Aggregate

Actually the angularity of these aggregates are 49 percent by crushing, 32 percent by nature, and 19 percent of rounded particles.

This section is in very good condition. There is no present evidence of instability. The reflection of cracks from the underlying old cement concrete pavement all appeared in the bituminous concrete overlay by the end of the first year.

Section 3: One-Course Bituminous Concrete Surface Containing Uncrushed Gravel Coarse Aggregate

Some shallow rippling and disturbance of the surface under traffic was evident in this section at the end of the first year. There were some local areas in this section which were characterized by a series of connected threads of asphalt running between the coarse aggregate particles in a direction roughly parallel to the movement of traffic. Such thread patterns have been seen on other roads just before actual distortion of the bituminous concrete takes place. This is construed to indicate that the volume of asphalt or of asphalt and water (total liquid content) in these areas of the pavement is greater than can be accommodated by the voids in the compacted mineral aggregate.

Two years later actual distortion of the bituminous concrete had taken place at these local areas in this section. The analysis of these samples show the specific gravity to be 2.395 which is 101.5 percent of laboratory design density, voids in the total mix to be 0.99 percent and voids filled with asphalt 92.91 percent. The percentage of extracted asphalt is 5.53 or 0.43 greater than the design for this section.

The distortion in this section where most of the distress has occurred is due partly to very poor subgrade under the underlying concrete pavement. This subgrade is characterized as the "pumper type."

Section 4: Two-Course Bituminous Concrete; Uncrushed or Rounded Gravel Coarse Aggregate in Both Binder and Wearing Course

Some displacement and indication of non-uniform asphalt composition are quite evident in the southbound lane of this section. The extracted samples show the average asphalt content in the binder to be 0.63 greater than the laboratory design and the wearing surface to be greater by 0.34.

The northbound lane in this section shows no signs of movement or displacement. The average asphalt content in binder samples is greater by 0.36 than design and the wearing surface less by 0.49 than design. Some slight evidence of raveling appears on the surface which, perhaps, indicated the lack of sufficient asphalt. This would indicate that 4.8 percent asphalt for the surface and 4.4 for the binder is about optimum.

Forty percent of the cracks in the underlying concrete pavement now appear in the surface of the bituminous overlay.

Section 5: Two-Course Bituminous Concrete, Crushed Gravel Aggregate in Both Binder and Wearing Courses, Using the Same Source and Type of Materials as Section 2

The surface of this section is in excellent condition. No displacement is in evidence due to design or construction. The average asphalt content from extracted samples of the wearing surface course is 4.86 percent and from binder samples 4.69 percent. Considering a comparison of the surface area of crushed aggregates versus uncrushed, it is suggested that 5.1 percent should be the optimum asphalt content for the wearing surface and 4.6 for the binder course.

Thirty-eight percent of the cracks in the underlying concrete pavement have appeared in the surface of the overlay.

The increase in roughness after three years services of this section is 16 in. per mi, which compares favorably with section 1 which is 14.5, however, section 1 consists of a wearing surface course only and does not have a binder. (Table 4)

Section 6: Two-Course Bituminous Concrete; Crushed Granite Coarse Aggregate in Both Wearing Surface and Binder Courses

Considerable ruts are discernible in the southbound lane on the low side of the superelevated curve. Asphalt-thread patterns, such as were described in discussing section 3, were seen in many areas of this section. Definite lateral displacement is evident. Some slight lateral displacement occurs in the northbound lane.

The southbound lane of this section was the first pavement laid on these test sections and the portion of this lane in which the greatest amount of displacement has occurred was placed somewhat thicker and with slightly higher asphalt content than designed. These could be contributing factors in this condition.

Thirty percent of the cracks in the underlying pavement now appear in the surface of the overlay pavement.

Section 7: Bituminous Concrete Wearing Course over a Surface Treatment Mat Course; Crushed Granite Coarse Aggregate in Both Courses

The appearance of this section is very good and shows no signs of displacement. Samples removed from this section showed considerable free moisture in the mat course, but whether the uncoated areas seen on the large stone particles is attributable to stripping or to the method of constructing this course is not clear.

The riding quality of this section is very good. There is an increase of only 11.7 in. of roughness per mile during this three-year period.

It seems noteworthy that only 15 percent of the cracks in the underlying concrete pavement are reflected in the bituminous surface overlay.

Section 8: Bituminous Concrete Wearing Course over a Surface Treatment Mat Course; Uncrushed Gravel Coarse Aggregates in Both Courses

The appearance of this section is very good and shows no signs of instability. The riding quality is very good. There is an increase of 10.2 in. of roughness per mile during this three-year period.

As in section 7 only, 15 percent of the cracks in the underlying concrete pavement are reflected in the bituminous surface overlay.

Section 10: Sand-Asphalt Wearing Course over a Surface Treatment Mat Course

The mat course was built in two sections: the first 500 ft consists of crushed granite aggregate and the second 500 ft uncrushed gravel.

The sand asphalt wearing course fine aggregate consists of the same material used in all hot-plant-mix sections.

The laboratory design for the wearing course set the asphalt at 7.5 percent. Road samples show that 7.9 percent was used.

One year after construction 100 percent of laboratory density was obtained.

Slight forward movement or displacement appeared in some areas of the first 500 ft of this (crushed granite) section. Otherwise, the riding quality and general physical condition are good.

Ten percent of the cracks in the underlying concrete pavement are reflected in the bituminous surface overlay. The second 500 ft of this section (uncrushed gravel) shows very little if any movement or displacement. The riding quality and general physical condition are good.

Less than 5 percent of the cracks in the underlying concrete pavement are reflected in the bituminous surface overlay.

Samples have been removed from these test sections annually and each time an attempt was made to evaluate the effectiveness of these tack coats. The values were based on the estimated degree of resistance that the bond between the overlay surfacing and the underlying cement concrete pavement offered when removing the samples.

The degree of bond is expressed in percent: excellent, 100 percent; good, 80 percent; slight, 10 percent; etc.

An over-all average of data after three years shows that for the areas where tack coat material was asphaltic cement, grade AP-3, 36 percent of the original bond was retained. The RC-2 material shows 40 percent of the original bond retained. This indicates that there is little, if any, practical difference between the effectiveness of the two types.

ROAD ROUGHNESS MEASUREMENTS

Roughometer measurements were obtained using a NCSH & PWC roughometer which is patterned after the one-wheel trailor type first built by the Bureau of Public Roads.

The roughness figures reported as units per mile are proportional to the units read from the counter, with the proportionality constant being a factor which is determined by calibration.

Surface roughness measurements were made immediately after construction of these test sections and each year thereafter (Table 4). The original measurements and those taken during the first and second years were made with a high pressure tire. During the third year the high pressure tire was changed to low pressure, which made it necessary to change the standard for evaluating road roughness measurements.

DISCUSSION

It is believed that this project will have a definite effect on future North Carolina specifications for high-type bituminous concrete. It was constructed for a two-fold purpose First, the aggregates used are typical of North Carolina commercial aggregates. The three principal types of coarse aggregates (crushed stone, crushed gravel, and uncrushed gravel) are represented on this project, and the project is considered a test of average commercial aggregates under severe service conditions. Second, it is hoped that the importance of laboratory design and field control will be established through this work.

One of the most important factors in this experiment is the correlation which was found to exist between the laboratory compactive effort for design purposes and the densities obtained from cores taken from the road which show the results of construction rolling.

Bulk specific gravity values are valid only when the pavements compared are alike with respect to specific gravity of the aggregates and mixture composition, including aggregate gradation. Comparisons based on the calculated voids in the compacted mineral aggregate, as it is found in the road surface, would perhaps be more convincing in a demonstration.

After several years of close observation and contact with both laboratory design and field practice in the placing of bituminous plant mix surfaces, it has been repeatedly confirmed that durability and stability of bituminous wearing surfaces are directly related to densities that are obtained during construction.

1. There seems to be no direct relationship between the occurrence of stripping of the asphalt films from aggregate particles and instability of the mixture. Instability occurs without evidence of extensive stripping; on the other hand, considerable stripping is often noted without evidence of instability in the bituminous surfacing. It must be concluded that on this project, there were characteristics of the mixture disposing to success or failure other than the ability of the aggregate particles to retain an asphalt coating.

2. There appears to be no direct relation between the type of coarse aggregate used (stone or gravel) per se, and pavement performance. Both satisfactory and unsatisfactory conditions are noted containing gravel and also crushed stone.

3. There does seem to be a relationship between the range of optimum bitumen contents and the type (stone or gravel) of coarse aggregate.

4. The enriched sections, as shown by sample analysis, evidently are not due to the tack coat applications, since these variations in asphalt content are far greater than the small percentage of asphalt in the tack coat, even assuming that the entire tack coat became a part of the bituminous mixture.

5. There appears to be little if any difference in the effectiveness of AP-3 or RC-2 materials when used as tack coats. There may be a slight advantage in using AP-3 (85-100 pen.) from a construction standpoint, because there would be no waiting period for evaporation which is required when using a cutback such as RC-2.

Careful planning and supervision notwithstanding, there are indications of non-uniform mixture composition within several of the individual sections. By sample analysis it is found actually to exist, and from observation it is shown that the enriched portions of the sections are not giving as good service as the sections in which the asphalt content is near the laboratory design.

ACKNOWLEDGMENT

The author wishes to acknowledge, with sincere appreciation, the help given by all those who have assisted in this experimental work. Special credit should be given to H. D. Hester for accurate records during construction and efficient field sampling, and to H. Fred Waller, Jr., Materials Engineer, for laboratory design work.

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Appendix

TABLE 1

JOB MIX FORMULAS

Passing	Retained	Uncrushed Gravel Percent	Crushed Gravel Percent	Crushed Granite Percent
		Binder Course		
1 in	3/4 in	0.82	1.24	0.00
3/4 in.	1/2 in.	23.03	17.88	23.67
1/2 in.	3/8 in	5.47	13.62	10.54
3/8 in.	No 4	17.83	18.14	14.74
No. 4	No 10	10.09	6.48	7.86
No. 10	No. 40	13.76	14.49	14.07
No. 40	No. 80	14.60	14.14	14.15
No. 200	-	3.26	3.24	3.23
Percent Bitumen	-	4.60	4.40	5.34
		100.00	100.00	100.00
		Wearing Surface		
3/4 in.	1/2 in	0.91	2.60	0.38
1/2 in	3/8 in.	4.31	18.44	9.35
3/8 in	No 4	28.11	25.04	27.47
No 4	No. 10	18.87	10.86	14.62
No 10	No. 40	14.88	14.04	15.44
No. 40	No. 80	15.60	13.32	15.37
No 80	No. 200	7.29	6.24	7.10
No. 200	-	4.93	4.36	4.47
Percent Bitumen	-	5.10	5.10	5.80
		100.00	100.00	100.00

TABLE 2

COMPARISON OF ANALYSIS OF ROAD SAMPLES WITH DESIGN MIX

	Retained on No. 10 Sieve	Passing No 10 Retained No 200	Passing No 200	Bitumen Percent
	Section No. 1 Surface			
	%	%	%	%
Mix Design	51.82	37.91	4.47	5.80
Test Results	47.44	41.28	5.54	5.74
	Section No 2 Surface			
Mix Design	56.94	33.60	4.36	5.10
Test Results	49.50	39.96	5.47	5.07
	Section No 3 Surface			
Mix Design	52.30	37.77	4.93	5.10
Test Results	55.34	35.14	4.39	5.13
	Section No. 4 Surface			
Mix Design	52.30	37.77	4.93	5.10
Test Results	52.22	37.30	5.41	5.07
	Section No. 4 Binder			
Mix Design	56.42	34.90	3.26	4.60
Test Results	57.18	34.40	3.33	5.09
	Section No. 5 Surface			
Mix Design	56.94	33.60	4.36	5.10
Test Results	47.99	42.28	4.92	4.87
	Section No. 5 Binder			
Mix Design	57.36	35.00	3.24	4.40
Test Results	60.35	31.76	3.21	4.69
	Section No 6 Surface			
Mix Design	51.82	37.91	4.47	5.80
Test Results	49.47	39.35	5.31	5.88
	Section No. 6 Binder			
Mix Design	56.81	36.62	3.23	5.34
Test Results	51.47	39.11	3.93	5.47

TABLE 3

VARIATION IN ASPHALT CONTENT FROM DESIGNED FORMULA

Section No	Asphalt Content, percent				Aggregate Type
	Design	High	Low	Ave.	
1 W.S. W. Lane	5.80	6.17	5.43	5.73	Granite
1 W.S. E. Lane	5.80	6.05	5.14	5.67	"
2 W.S W. Lane	5.10	5.35	4.78	5.02	Crushed Gravel[a]
2 W.S. E. Lane	5.10	5.38	4.78	5.10	" "
3 W.S. W. Lane	5.10	5.53	5.02	5.23	Uncrushed "
3 W.S. E. Lane	5.10	5.29	4.73	5.07	" "
4 W.S. W. Lane	5.10	5.75	5.22	5.44	" "
4 Binder W. Lane	4.60	5.53	5.11	5.23	" "
4 W.S. E. Lane	5.10	4.65	4.55	4.61	" "
4 Binder E. Lane	4.60	5.42	4.81	4.96	" "
5 W.S. W. Lane	5.10	4.87	4.40	4.68	Crushed Gravel[a]
5 Binder W. Lane	4.40	4.77	4.33	4.47	" "
5 W.S. E. Lane	5.10	5.12	4.98	5.05	" "
5 Binder E. Lane	4.40	5.31	4.50	4.92	" "
6 W.S. W. Lane	5.80	6.18	5.75	5.96	Granite
6 Binder W. Lane	5.34	6.00	5.15	5.56	"
6 W.S. E. Lane	5.80	6.15	5.50	5.80	"
6 Binder E. Lane	5.34	6.33	4.88	5.38	"

[a] 49% by crushing, 32% by nature, 19% rounded particles.

TABLE 4

ORIGINAL AND PROGRESSIVE SURFACE ROUGHNESS

Section No.	Original Roughness	First Year	Second Year	Third Year	Total Increase	Aggregate Type
1	71.9	75.5	89.3	86.4	14.5	Crushed Granite
2	64.6	66.8	77.7	80.6	16.0	Crushed Gravel
3	61.7	70.4	102.4	118.4	56.7	Rounded (uncrushed) Gravel
4	53.0	66.8	93.2	96.6	43.6	Rounded (uncrushed) Gravel
5	50.1	51.5	70.4	76.2	16.1	Crushed Gravel
6	57.3	77.1	102.4	106.8	49.5	Crushed Granite
7	67.5	65.3	69.0	79.2	11.7	Crushed Granite Mat.
8	66.1	65.4	85.0	76.3	10.2	Rounded (uncrushed) Gravel Mat.
10	50.6	51.6	66.7	80.9	30.3	Rounded (uncrushed) Gravel Crushed Granite

STANDARD FOR EVALUATING ROAD ROUGHNESS

Roughness Index (Inches per Mile)	Riding Qualities
50 - 60	Excellent
60 - 75	Good
75 - 85	Fair
Above 85	Poor

Note: Roughness measurements are shown in total accumulated inches per mile.

TABLE 5

TABULATION OF AVERAGE VOIDS, VOIDS FILLED WITH BITUMEN AND PERCENT COMPACTION VALUES

	H - F Specimens		Cores 1st Day			Cores-After 1 Yr			Cores-After 3 Yrs		
Wearing Surface Section	% Voids	% Voids Filled with Bitumen	% Voids	% Voids Filled with Bitumen	% Compaction	% Voids	% Voids Filled with Bitumen	% Compaction	% Voids	% Voids Filled with Bitumen	% Compaction
1	2 49	84 29	6 64	65 33	95 7	4 17	74 50	97 9	1 78	88 18	100 8
2	3 28	78 25	6 94	60 97	96 6	6 56	63 10	96 6	2 71	81 28	100 4
3	2 88	80 38	5 74	66 49	97 4	4 11	74 13	98 7	2 14	84 83	100 9
4	3 28	78 25	4 10	74 53	99 1	3 41	76 07	99 1	3 02	79 97	100 0
5	4 07	74 35	4 49	72 77	99 1	3 26	77 85	99 1	2 62	78 63	99 8
6	2 49	84 29	3 72	76 82	99 1	2 92	82 37	99 1	1 83	88 14	100 6
Ave					97 8			98 4			100 4
Binder Section											
4	4 44	70 65	4 10	73 48	98 7	3 33	77 06	97 5	2 82	80 76	100 2
5	2 83	78 53	5 26	65 33	93 3	4 49	70 96	93.3	4 11	72 45	98 2
6	2 47	83 40	4 90	67 95	98 3	3 31	79 50	98 7	2 31	84 64	99 7
Ave					96 8			96 5			99 4

TABLE 6

DESCRIPTION OF MINERAL AGGREGATES

A. Greystone Granite

1. Mineral Classification — Biotite Granite
2. Mineral Composition — 39% Quartz
   50% Orthoclase
   2% Plagioclase
   6% Biotite
   3% Misc. (Apatite, Magnetitie, Muscovite, Chlorite)
3. Specific Gravity 2.63
4. Absorption 0.4%
5. Los Angeles Wear 39%

B. Lilesville Gravel

1. Mineral Classification — Translucent Quartz and Quartzite Gravel
2. Mineral Composition — Practically Pure Quartz Approximately 99% Silica
3. Specific Gravity 2.64
4. Absorption 0.3%
5. Los Angeles Wear 45%

C. Vander Gravel

1. Mineral Classification — Quartz
2. Mineral Composition — 90%+ Silica and remaining impurities iron oxides
3. Specific Gravity 2.63
4. Absorption 0.6%
5. Los Angeles Wear 39%

TABLE 7

COMPARISON OF LABORATORY AND ROAD SPECIFIC GRAVITIES

Section Number	Design Sp Gr.	Roadway Sp. Gr.	Percentage of Laboratory
		First Day	
1	2.35	2.25	95.7
2	2.36	2.28	96.6
3	2.36	2.30	97.5
4	2.36	2.34	99.2
5	2.36	2.34	99.2
6	2.35	2.33	99.1
Ave.	2.36	2 31	97.9
		First Year	
1	2 35	2 30	97.9
2	2.36	2.28	96.6
3	2 36	2.33	98.7
4	2.36	2.32	98.3
5	2.36	2.34	99.2
6	2.35	2.33	99.1
Ave.	2 36	2.32	98.3
		Third Year	
1	2.35	2.37	100.8
2	2.36	2.37	100.4
3	2.36	2.38	100.9
4	2 36	2.36	100.1
5	2.36	2.35	99.8
6	2.35	2 36	100 6
Ave.	2.36	2.37	100.4

TABLE 8

NORTH CAROLINA SPECIFICATIONS FOR ASPHALT CEMENT AND RAPID CURING CUTBACK ASPHALT

	Grade AP-3	Grade RC-2
Penetration at 77° F	85-100	
Flash Point (Open Cup)°	347+	
Loss on Heating	1.0-	
Penetration of Residue at 77° F		
Percent of original	60+	
Ductility	100+	
Total Bitumen Soluble in CS_2, %	99.5+	
Proportion of Bitumen Soluble in CCL_4, %	99.0+	
Spot Test	Neg. +	
Water, Percent by Volume	0.5-	
Flash Point, Tag, °F	80+	
Viscosity, Saybolt-Furol at 140° F, Sec.	100-200	
Distillation Test:		
Distillate, Percentage by Volume of Total Distillate to 680° F		
To 437° F		40+
To 500° F		65+
To 600° F		87+
Residue from Distillation to 680° F, Percent Volume by Difference		67+
Penetration		80-120
Ductility		100+
Soluble in CCL_4, %		99 5+
Spot Test		Neg. +
Temperature for Application °F		90-160