

ASPHALT ADDITIVES STUDY

CONSTRUCTION REPORT

by

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16. Abstract This report documents the construction of control and additive-modified bituminous concrete test sections on Route NJ 41, Section 3A. This widening and realignment project utilizes full-depth bituminous construction, with five asphalt additives (Chemcrete, Texcrete, Solar Laglugel, 3M's #5990, and Plus Ride) being used in the 1½-inch top course. Each test section, approximately 36 ft. wide and 1740 ft. in length, is identical from subbase to bottom course, varying only in the additive-modified top course. The comparative performance of these test sections will be monitored over a five-year period; the monitoring plan and baseline measurements are provided in this report. The "controlled environment" provided for during construction of these test sections should permit definitive conclusions to be made as to the cost-benefit value of these additives. Preliminary recommendations regarding production and construction of additive-modified bituminous mixes are also presented.					
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PART ONE - INTRODUCTION

1.1 RESEARCH OBJECTIVE

The addition of natural and synthetic compounds to bituminous mixtures in order to improve specific performance properties is becoming more and more popular. There are dozens of these asphalt additives on the market today, many touted as increasing cracking resistance, low temperature flexibility, and overall durability. The purpose of this study is to determine the costs and benefits associated with the use of selected additives in field installations.

This research study will proceed in two stages. In Stage I, the use of additives in the top course of full depth bituminous construction will be investigated. Stage II will be devoted to the use of asphalt additives in overlay construction. This report documents the construction of asphalt additive-modified surface course on new full-depth bituminous pavement. Initial laboratory and field test results are also presented.

1.2 MATERIALS IN TEST

Since the mid-1960s, asphalt additive research and development has been increasing significantly. In the last five years, the NJDOT's Materials Committee has been inundated with literature extolling the virtues of numerous problem-solving additives. Many of these additives increase the initial construction cost considerably, but are claimed to decrease long-term maintenance costs and hence, overall life-cycle costs. A review of the literature reveals that the states are showing more interest in using additives to solve problems of premature pavement distress. Following extensive laboratory testing, five additives were chosen for field evaluation by the NJDOT: Chemkrete, Texcrete, Solar Laglugel, 3M's #5990, and Plus Ride. The bid prices for the Department's standard mix and for each additive-modified mix are shown in Table 1.

TABLE 1

INITIAL COST OF ADDITIVE CONSTRUCTION

<u>Item</u>	<u>Bid Price (per ton mix)</u>
Standard I-4 Mix	\$ 25.90
Chemkrete	35.00
Texcrete	47.00
Solar Laglugel	43.00
3M's #5990	114.00
Plus Ride	56.00

Chemkrete, manufactured by the Lubrizol Corporation, is a heavy metal (Manganese)-based additive which was premixed with AC-10 asphalt at a rate of one-to-thirty by weight. The manufacturers' claims are increased strength and lower temperature susceptibility.

Texcrete Latex is a synthetic rubber emulsion (69% rubber solids) manufactured by Dow Chemical Corporation. It was added to the pugmill through a port cut for this purpose, ten seconds after the addition of AC-20. The latex solids replaced 3% of the required asphalt cement. Latex rubber is claimed to reduce brittleness, increase toughness and crack resistance, and to improve stability at high temperatures.

Solar Laglugel is a nylon resin formulation supplied by Solar Asphalt of America, Inc. It was supplied, premixed with AC-20, in a ratio of 1.33% by weight of the AC-20. Solar Laglugel is designed to increase rutting resistance, improve low temperature flexibility, and resist stripping. It has been used previously in New Jersey on county and township roadways.

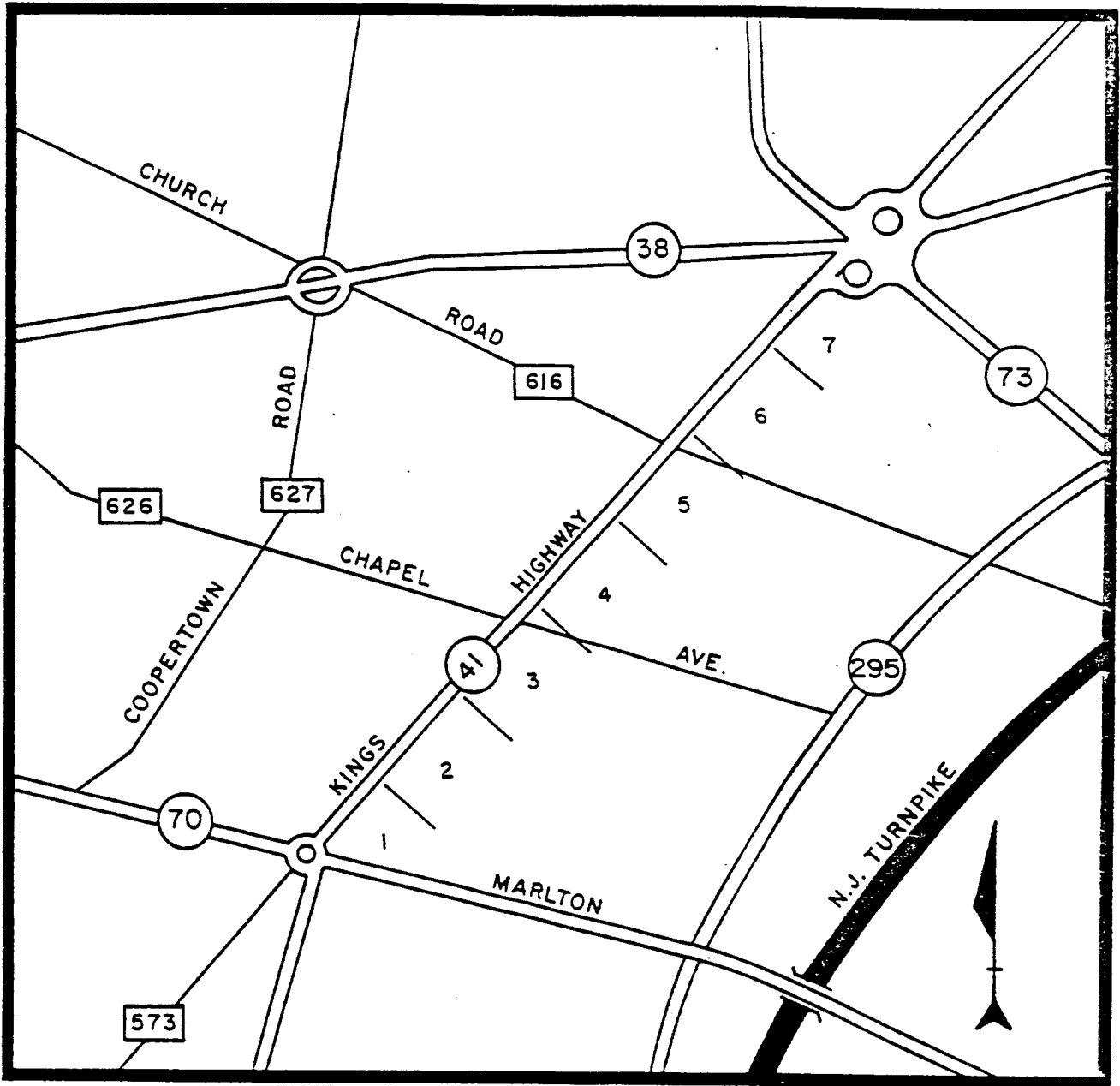
Asphalt Concrete Stabilizing Additive #5990 is a product of 3M Corporation. It consists of a granular polyolefin blend, which was fed at a rate of 8.33 pounds per one ton of mixture into the pugmill by conveyor after normal mixing for twenty seconds. It is claimed to increase rutting and wear resistance, and to improve low temperature flexibility. This product was originally marketed overseas under the name "Asphadur" and has shown promise in our laboratory testing program.

Plus Ride is a proprietary bituminous concrete mix designed by the All Seasons Surfacing Corporation. It consists of a gap-graded mix design, in which rubber granules, obtained from grinding scrap automobile tires, are substituted for the aggregates omitted from the gap. Three percent rubber (by weight) was incorporated into the bituminous mix by blending aggregate and rubber in the pugmill for fifteen seconds prior to introducing the asphalt cement. Plus Ride's design permits a high percentage of AC-20 to be used in the mix (7.7% in this mix design) and is claimed to increase flexibility, durability, skid resistance, crack resistance, and to promote self-deicing of the pavement.

1.3 TEST PROJECT

The field locations selected for this research study are the newly constructed, northbound lanes of Route NJ 41, Section 3A in Cherry Hill (see Figure 1). This portion of Route 41 is a high-volume roadway (1983 AADT: 11,200 VPD) with predominantly retail business on the southbound and a mostly residential community on the perimeter of the northbound roadway. The construction of this widening and realignment project commenced in the summer of 1983. The southbound roadway and all but the 1½-inch top course on the northbound roadway were completed prior to January, 1984. Construction of the top course was delayed by the onset of cold weather.

FIGURE 1. LOCATION OF ROUTE 41, SECTION 3A PROJECT



KEY

1	Control (I-4) Section	592+36 to 611+50
2	Chemcrete-Modified Section	611+50 to 628+90
3	Texcrete-Modified Section	628+90 to 646+50
4	Solar Laglugel-Modified Section	646+50 to 663+75
5	3M's #5990-Modified Section	663+75 to 681+10
6	Plus Ride Section	681+10 to 698+50
7	Crushed Gravel Section	698+50 to 707+50 (NB & SB)

The northbound lanes on Route 41, Section 3A consist of two twelve-foot driving lanes and a twelve-foot shoulder. The driving lanes utilized full-depth construction: 6 inches of subbase (I-2), 6 inches of gravel base (I-5), 6 inches of bituminous stabilized base course, 1½ inches of medium aggregate bituminous concrete (MABC) bottom course and 1½ inches of additive-modified bituminous concrete (AMBC) top course (see Figure 2). The shoulder was constructed with 6 inches of subbase (I-2), 8 inches of gravel base (I-5), 4 inches of bituminous stabilized base, 1½ inches of MABC bottom course and 1½ inches of top course composed of the AMBC. Each test section, approximately 1740 feet in length, is composed of 600 tons of additive-modified bituminous concrete.

The northbound roadway was open to traffic (minus the 1½ inch top course) through the 1983-1984 winter and spring without any apparent problems. Cross-sections, rolling straightedge and Mays meter data were collected in April, 1984, prior to construction of the top course so as to note any surface distortions on the binder which may be a factor in the future performance of the test sections.

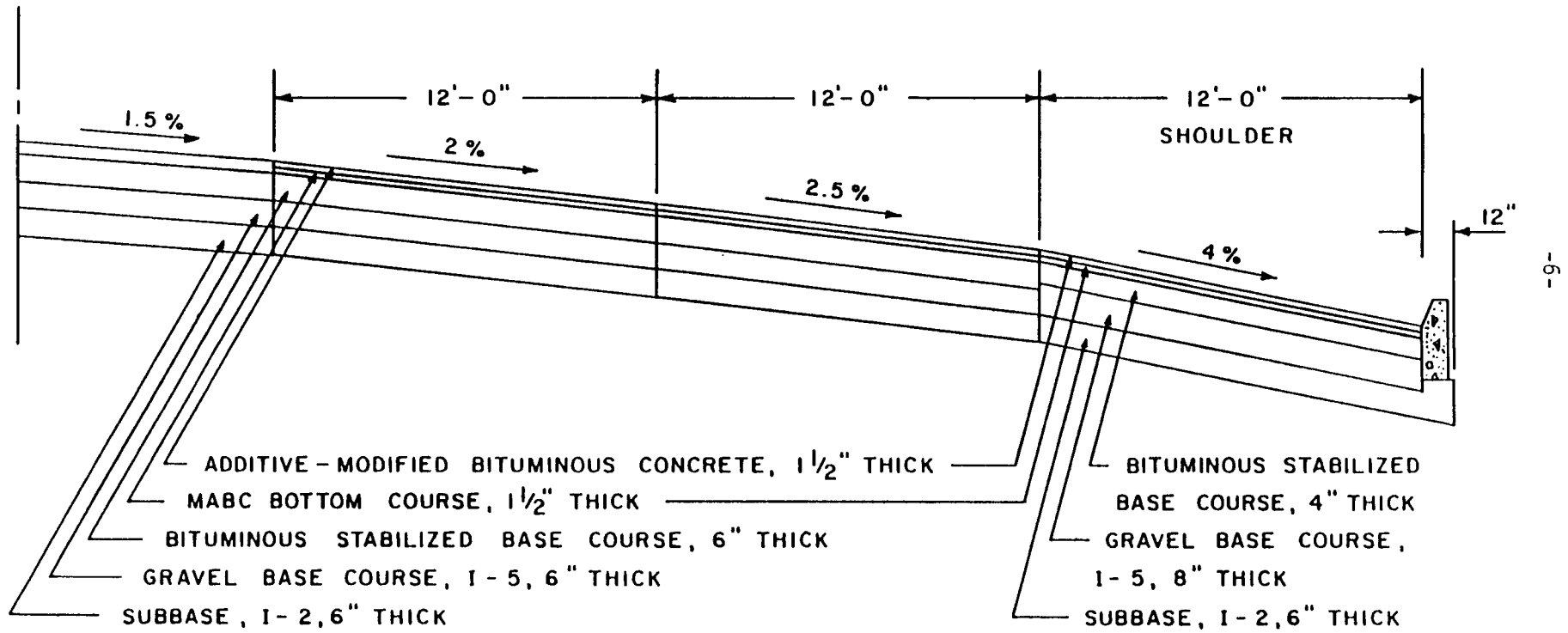
1.4 RESEARCH METHODOLOGY

1.4.1 General: This research study will be conducted in two stages. Stage I consists of the construction and five-year evaluation of the test sections on Route 41, Section 3A. Stage II provides for the construction and five-year evaluation of AMBC overlay test sections. Many asphalt additives currently in the market, including those used on Route 41, are claimed to prevent or retard distress typical in resurfacings, such as reflection cracking. These claims will be addressed in Stage II of this study.

Stage I, the evaluation of AMBC used in the top course of full-depth construction, allows for the opportunity to study each additive-modified mix

FIGURE 2 - TYPICAL SECTION

ROUTE 41 NB, SECTION 3A



under controlled conditions. The entire length of the job should provide equivalent performance from the subbase to the top course, varying only in the additive-modified top 1½ inch course. Future performance of the roadway should be indicative of the effect of the additives incorporated into the top course.

Two control sections were constructed at the Route 41 location. At the southern end of the project, the control section has a standard MABC (I-4) wearing course. At the northern end of the project, the control section has a crushed gravel friction course. Between these control sections, the five additive-modified test sections were placed contiguously. These seven sections were constructed in an eight-day period.

1.4.2 Field Performance: Field performance of the additive-modified test sections will be judged relative to the two control sections. Biannual inspections of the surface condition of each section will be conducted. Extent of cracking, rutting, skid resistance, and roughness will be determined. Texture measurements will be made if texture-related problems become apparent.

BIANNUAL PROGRAM OF FIELD TESTS

<u>Description of Test</u>	<u>Property Measured</u>
1. Condition Survey	Extent of Cracking
2. Rut depths	Extent of Rutting
3. Cross-Sections	Surface Deformation
4. 10-ft. Rolling Straightedge	Roughness
5. ASTM E-274	Skid Resistance
6. Mays Ridemeter	Present Serviceability Index
7. Sandpatch	Texture

1.4.3 Laboratory Performance: As part of the laboratory evaluation of the additive-modified mixes, Marshall specimens, mixture samples, and liquid asphalt cement samples were obtained. Temperature susceptibility will be quantified for those additives which can be premixed with asphalt cement. Also, resilient modulus, using the Mark V Resilient Modulus Non-Destructive Testing Device, will be determined. These last two measures are "special" tests, designed to quantify some of the unique properties claimed by the proponents of additive-modified bituminous concrete. The resilient modulus test method is presented in Appendix A.

Eight cores per test section were tested for density and percent air voids. Three cores per section were extracted for composition analysis and Abson recovery. During the five-year evaluation period, three core samples per test section will be checked for voids, density, and asphalt properties. Nuclear density measurements will be taken to complement these data.

ANNUAL PROGRAM OF LABORATORY TESTS

1. Composition Analysis
2. Asphalt Properties
 - a. Viscosity at 140°F
 - b. Viscosity at 275°F
 - c. Penetration at 77°F
3. Percent Air Voids
4. Density
5. Resilient Modulus

PART TWO- CONSTRUCTION

2.1 GENERAL

Prior to top course construction, Route 41, Section 3A northbound was swept and stations were marked on the curb every twenty-five feet. Each morning, before paving, the longitudinal cold joint from the 1983 southbound construction was cut vertically using a front-end loader fitted with a circular saw. This joint was squared off the length of the test section scheduled for the day, then cleaned and tacked.

Top course construction on Route 41 NB began on August 1, 1984. The job was scheduled to run seven working days, mixing and placing one special mix per day, including an I-4 control section and a crushed gravel friction course section. The work was completed according to the following schedule:

TABLE 2
DAILY CONSTRUCTION LOG

<u>Date</u>	<u>Mix</u>	<u>Stations (NB)</u>	<u>Avg. Air Temp.</u>
8/1/84	Chemcrete	611 + 50 to 628 + 90	80°F
8/2/84	Texcrete	628 + 90 to 646 + 50	80°F
8/3/84	Solar Laglugel	646 + 50 to 663 + 75	78°F
8/4/84	3M's #5990	663 + 75 to 681 + 10	82°F
8/6/84	Plus Ride	681 + 10 to 698 + 50	78°F
8/7/84	Crushed Gravel	698 + 50 to 707 + 50 (NB & SB)	80°F
8/8/84	Control	592 + 36 to 611 + 50	76°F

The temperature throughout this period ranged from 75°F to 90°F. Except for a slight half-hour drizzle on day 2, the job was completed under clear skies.

The contractor for the job was Conti Construction Company, and three asphalt plants (owned by Trap Rock Industries) were used for producing the mixes. The mixes containing the liquid binders (i.e., Chemkrete, Texcrete, and Solar Laglugel), and the Crushed Gravel Friction course were produced at Trap Rock's Florence, New Jersey plant. This is a baghouse type batch plant. (See Figure 3.)

The mixtures containing the solid additives (3M's #5990 and Plus Ride) were produced at the Columbus plant, a wet scrubber-type batch plant, adapted with a conveyor feed system for introducing the additives to the pugmill (see Figure 4). Initially, the I-4 control mix was produced at the Runnemede plant. Electrical problems at the plant forced an unexpected shutdown before the I-4 section was completed. The remainder of the I-4 material was produced at the Florence plant.

An average 0.02 gal. per sq. yd. of RS-1 tack coat was applied to the binder prior to paving the travel lanes and shoulder. All traffic was immediately shifted to run on the shoulder, so the tack coat was tracked considerably in the shoulder before being overlaid. The northbound surface course was placed in three passes: the inside lane was paved first, then the outside lane, and finally, the shoulder. A Blaw-Knox PF-500 paver was used throughout the job. Steel-wheeled rollers (one three-wheel breakdown and one vibratory finish roller) were used for compaction. Except for minor problems resolved with the first two truckloads of each special mix, there were no difficulties paving or compacting any of the bituminous mixes.



FIGURE 3. TRAP ROCK'S FLORENCE, NEW JERSEY PLANT

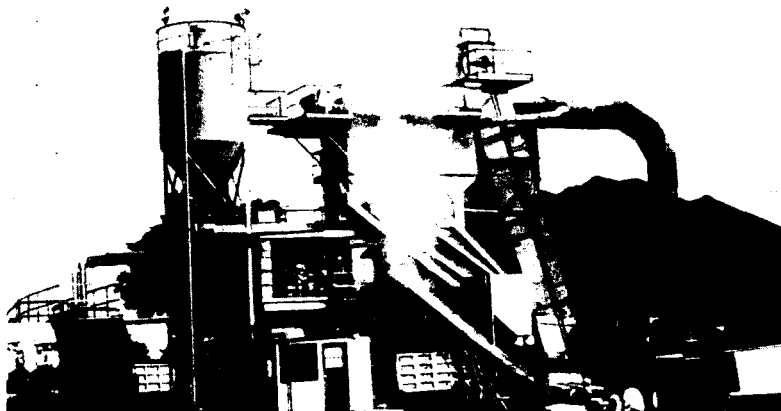


FIGURE 4. TRAP ROCK'S COLUMBUS, NEW JERSEY PLANT

2.2 DEVELOPMENT OF MIX DESIGNS AND SAMPLING PLAN

The special additive-modified mixes required that special attention be given to mix design, sampling, and testing. The Bureau of Materials took the lead in modifying standard mix designs and sampling plans so as to ensure the high quality of the additive mixes. The mix designs are presented in Appendix B.

Some of the additives used required higher mixing and laydown temperatures than standard, as well as special mixing and compacting procedures (see Table 3). To ensure that these unique mixing and laydown temperature specifications were achieved, the temperature of each truckload of material was checked at the plant, as well as on the road. For future reference, each truckload placed in the driving lanes was also located by starting and ending station.

Five truckloads of each additive-modified mix were sampled each day. The sampling and testing program is outlined below.

SAMPLING AND TESTING - each mixture

5 Mixture samples

- a. Composition Analysis
- b. Absorbance Recovery

2 Liquid Asphalt Cement samples

- a. Viscosity at 140°F
- b. Viscosity at 275°F
- c. Penetration at 77°F
- d. Flash Point COC °F
- e. Test on Residual Asphalt after Thin Film Oven Test
 1. Loss on Heating
 2. Viscosity at 140°F

TABLE 3. HANDLING ADDITIVE-MODIFIED MIXES

NAME OF SPECIAL MIX	METHOD OF ADDING THE ADDITIVE	MIXING PROCEDURE	MIXING TEMPERATURE	LAYDOWN TEMPERATURE	COMPACTION	AMOUNT OF ADDITIVE USED
CHEMKRETE	Preblended with AC-10	Normal Dry & Wet Mixing Times	Normal (280°F)	Normal (290°F)	Normal	30 Parts AC-10 to 1 Part Chemcrete
TEXCRETE	Metered in gallons	Normal Dry, Add AC-20 Mix 10 sec, Add Latex, Mix 8-10 sec.	325°F-360°F	300°F Min.	Immediately behind Paver	0.55 gal. per ton of mix
SOLAR LAGLUGEL	Preblended with AC-20	Normal Dry & Wet Mixing Times	Normal (280°F)	Normal (290°F)	Normal	1.33 lbs. per 100 lbs. of AC-20
3M'S #5990	Preweighed bags (25 lb.)	Normal Dry, Add AC-20, Mix 20 sec, Add #5990, Mix 60 sec.	375°F Min.	350°F	Immediately behind Paver	8.33 lbs. per ton of mix
PLUS RIDE	Preweighed bags (50 lb.)	Normal Dry, Add rubber Mix 15 sec, Add AC-20 Mix till uniform.	300°F-350°F	300°F Min.	Immediately behind Paver	60 lbs. per ton of mix

20 Marshall Specimens (4 per each mix sample)

- a. 7 for one day Marshall
- b. 5 for nine day Marshall
- c. 5 for one day indirect tensile test
- d. 3 for future resilient modulus test

The above program was used for all mixes except Chemkrete. The following slightly modified program was used for the Chemkrete samples:

19 Marshall Specimens

- a. 5 for one day Marshall
- b. 5 for nine day Marshall
- c. 1 for 134 day Marshall
- d. 3 for one day indirect tensile test
- e. 3 for nine day indirect tensile test
- f. 2 for future resilient modulus test

The results of these initial laboratory tests are discussed in Part Three of this report and are tabulated in Appendices C and D.

2.3 FIELD OBSERVATIONS

2.3.1 Chemkrete Modified Section: The Chemkrete-modified asphalt was supplied preblended to the Florence plant and consisted of thirty parts AC-10 to one part Chemkrete. Otherwise, the mix design is the same as for the project control job mix formula. Chemkrete-modified mix was produced and placed using standard procedures. The average paving temperature was 290°F. The mix appeared slightly drier than a standard I-4 and exhibited a slight amount of

swelling on compaction. Small cracks spaced every few inches (heat checks) appeared after compaction, but healed after a night of traffic. The Chemcrete section appeared tender two hours after compaction and felt spongy, yielding to foot pressure three hours after laydown, at which time traffic was allowed back on the section. However, the section did stand up to traffic overnight, scarring in only a few locations where apparently sharp turns were made by vehicles (see Figure 5). One week later, these scars were less noticeable; the bituminous surface healed somewhat under traffic.

2.3.2 Texcrete-Modified Section: The Texcrete latex-modified bituminous concrete required slight plant modifications, but no change to the I-4 mix design was required. The latex was supplied in 55 gallon drums and was metered through a system provided by Texcrete in a trailer and introduced to the pugmill through an access port which was cut for this purpose (see Figures 6, 7). Latex rubber was incorporated into the mix at the rate required to yield three percent rubber solids by weight of AC-20. After mixing the aggregate and AC-20 for 10 seconds, the latex was injected into the pugmill, then mixed an additional 10 seconds. Mixing temperature was designed to result in a mix discharge temperature of 325°F to 360°F. The discharge temperature requirements were not difficult to achieve, with temperatures ranging from 325°F to 350°F and laydown temperatures from 310°F to 350°F.

The first truckload at 325°F was dumped into the cold paver, cooling rapidly, and thereby making the mix sticky and difficult to work. The additive manufacturer specified a 300°F minimum laydown temperature, but when mat temperatures fell below 310°F, raking appeared more difficult. Subsequent loads were hotter and paving was completed without further difficulties.

2.3.3 Solar Laglugel-Modified Section: Solar Laglugel was premixed with AC-20, at a rate of 1.33% by weight. The mix design was otherwise the same as

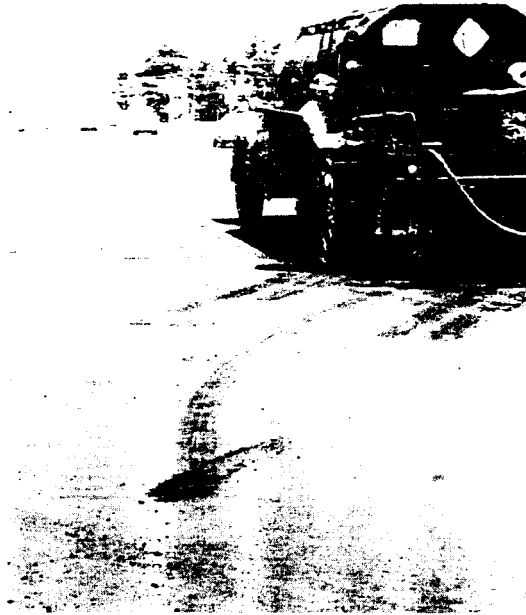


FIGURE 5. SCAR IN CHEMKRETE SECTION



FIGURE 6. TEXCRETE'S METERING SYSTEM



FIGURE 7. PLANT MODIFICATIONS FOR TEXCRETE

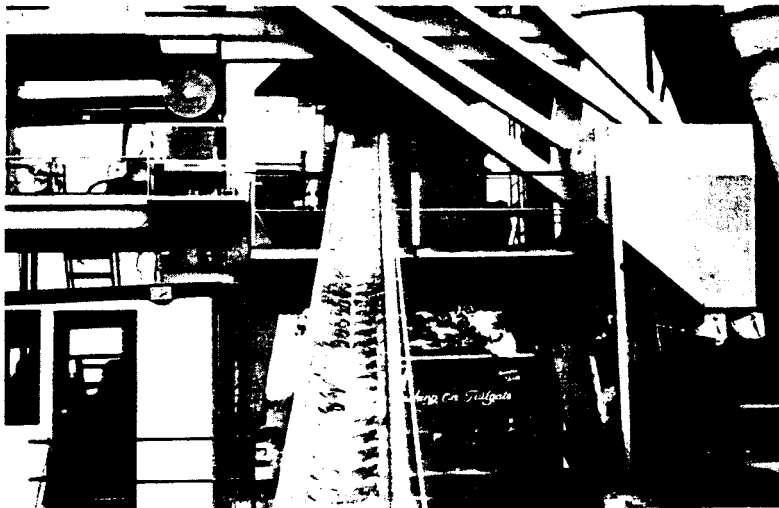


FIGURE 8. PLANT MODIFICATIONS FOR 3M'S #5990

the I-4 control job mix formula. The AC-20/Solar Laglugel mixture was circulated in the tank overnight and continued recirculating in the morning before and during use. Normal pugmill mixing and paving procedures were followed. Paving temperatures ranged from 275°F to 320°F. Workers complained of an odor behind the paver, but this appeared to be only a minor nuisance. After compaction, a slight, waxy sheen formed on the pavement surface, but seemed to have no deleterious effect on the section. An interesting observation made about this section was that, when the transverse cold joint was cut the following day, the entire twelve-foot section of Solar Laglugel mix broke off in one piece. This suggests that the Solar Laglugel-modified mix was more cohesive than the other mixes.

2.3.4 3M's #5990-Modified Section: 3M's #5990 additive-modified concrete was produced at the Trap Rock Columbus plant using an I-4 mix design. The additive was supplied in preweighed bags which were emptied onto a conveyor belt running to the pugmill (see Figure 8). Twenty-five pounds of additive were used per three-ton batch. After 20 seconds of mixing AC-20 with aggregate, the additive was dropped into the pugmill and mixed for another 60 seconds. Discharge temperatures were required to be a minimum of 375°F. Minimum laydown temperature of 350°F was required. The Columbus plant was used because the high temperatures required prohibited the use of a baghouse dust collector.

This mix arrived at the site, ranging from 350°F to 375°F, except for the first truck. The first truck had cooled to 330°F, so it was decided to unload it second, after the paver had heated up. This strategy was successful; at 330°F no laydown problems were encountered. Some trucks were unloaded at as high as 375°F (90°F above New Jersey standard laydown temperature), producing an

excess of smoke behind the paver and causing the rake men to drop back. During finish rolling, the 3M representative at the site observed that the steel-wheeled rollers tended to shove the mat slightly. The roller operator was cautioned to minimize side-to-side motions of the equipment.

2.3.5 Plus Ride-Modified Section: Plus Ride was also mixed at the Columbus plant, since the conveyor system was already in place. Three 50-pound bags of rubber granules were used per 2½-ton batch. Although the sheer, polyethylene bags were used intact, many of the bags had split open and spilled over the makeshift loading dock; stronger bags should be required in the future.

As noted earlier, Plus Ride requires a special gap-graded mix design (see Appendix B) with a target asphalt cement content of 7.7%. The Plus Ride mix was extremely wet, taking on the appearance of a wet, coarse, open-graded mix (see Figure 9). Temperatures at the plant ranged from 290°F to 370°F (Target: 300-350°F). At the site three truckloads under 300°F were extremely difficult to handle; the mix seemed to become more sticky as it cooled. The most unique characteristic of the mix was that the truckloads of mix, rather than being mounded, arrived at the site completely level (see Figure 10). Complaints from the truck drivers that the Plus Ride ruined their tarps (they could not be cleaned) appeared justified. At first, compaction was difficult because the rubberized mix stuck to the breakdown rollers. The use of a soapy solution for lubrication alleviated this problem.

Smoke and odor problems were reported during the construction of this test section. Another problem developed when the tack coat distributor truck failed to work properly. A thick and highly variable tack coat was spread on this section, averaging 0.03 gallons per square yard. Several puddles of tack coat had to be ladled up with shovels. Still, tack coat could be seen to bleed up through

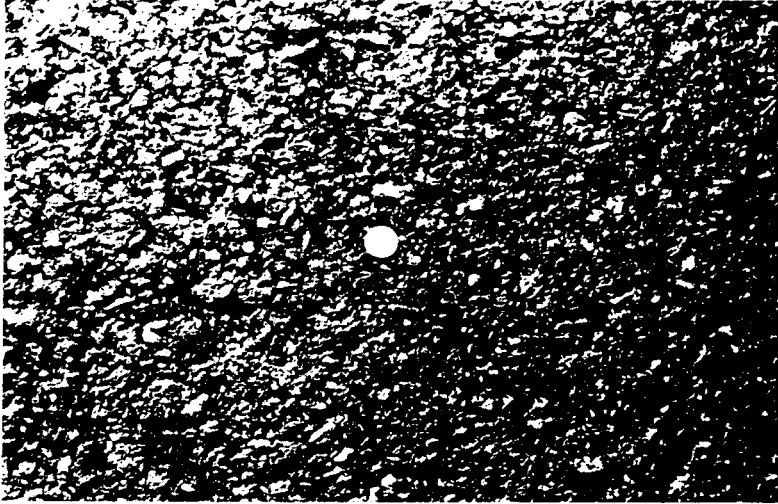


FIGURE 9. PLUS RIDE MAT

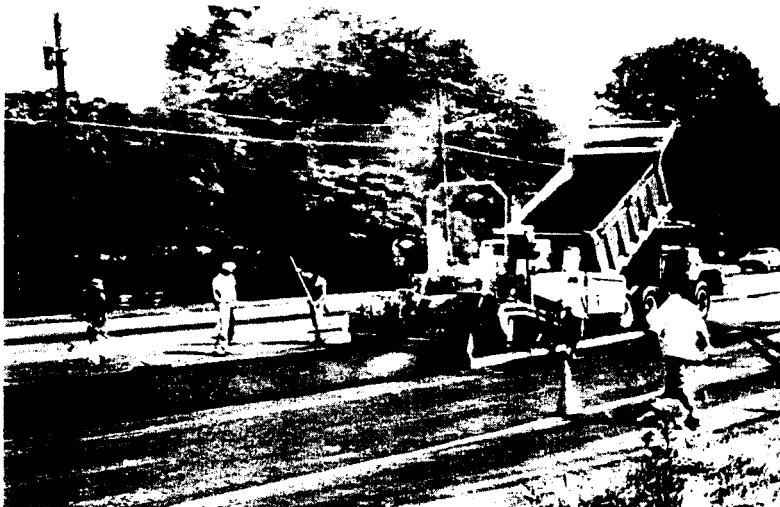


FIGURE 10. LEVEL LOADS OF PLUS RIDE

the mat almost immediately. The location of the worst areas were documented and this will be taken into account in future performance evaluations.

2.3.6 Control Section (Mix I-4): The control section, which runs from the Route 70 - Route 41 circle on the south end of the job to Daytona Avenue, was placed without major difficulties. The I-4 produced at the Runnemede plant was placed on the inside lane and from 602 + 80 to 611 + 50 on the outside lane. Plant shutdown made it necessary to complete the job at the Florence plant. This material was placed from the circle to 602 + 80 on the outside lane and on the shoulder from the circle to 611 + 50. The direction of paving for these northbound lanes was north to south, so as to minimize traffic problems at the circle.

Tack coat distribution problems which plagued construction on August 6 and 7 were minimal throughout the control section. Only at the north end of the control strip was the tack coat excessive.

2.3.7 Crushed Gravel Friction Course: A crushed gravel friction course was installed on the sixth day of the Route 41 project. The north end of the job, a tight inclined curve with ramps to Route 73 and Route 38, required a high skid resistant surface. The crushed gravel friction course was produced at the Florence plant and was placed in both the northbound and southbound lanes.

As an adjunct to this project, skid resistance and road roughness measurements on the various test sections will be compared to those obtained on this friction course, as well as those on the I-4 control section.

PART THREE - TEST RESULTS AND DISCUSSION

3.1 GENERAL

The results of the initial laboratory and field tests are discussed below. All laboratory testing was performed by the NJDOT Central Laboratory in Trenton, New Jersey. Marshall test results represent an average of the one and nine day tests unless otherwise noted. The additional aging had little or no effect on the mixes. Resilient modulus tests have not yet been performed. Laboratory test data is tabulated in Appendices C, D, and E, and illustrated graphically in Figure 11. Initial field test results are discussed in Section 3.3.

3.2 LABORATORY TEST RESULTS

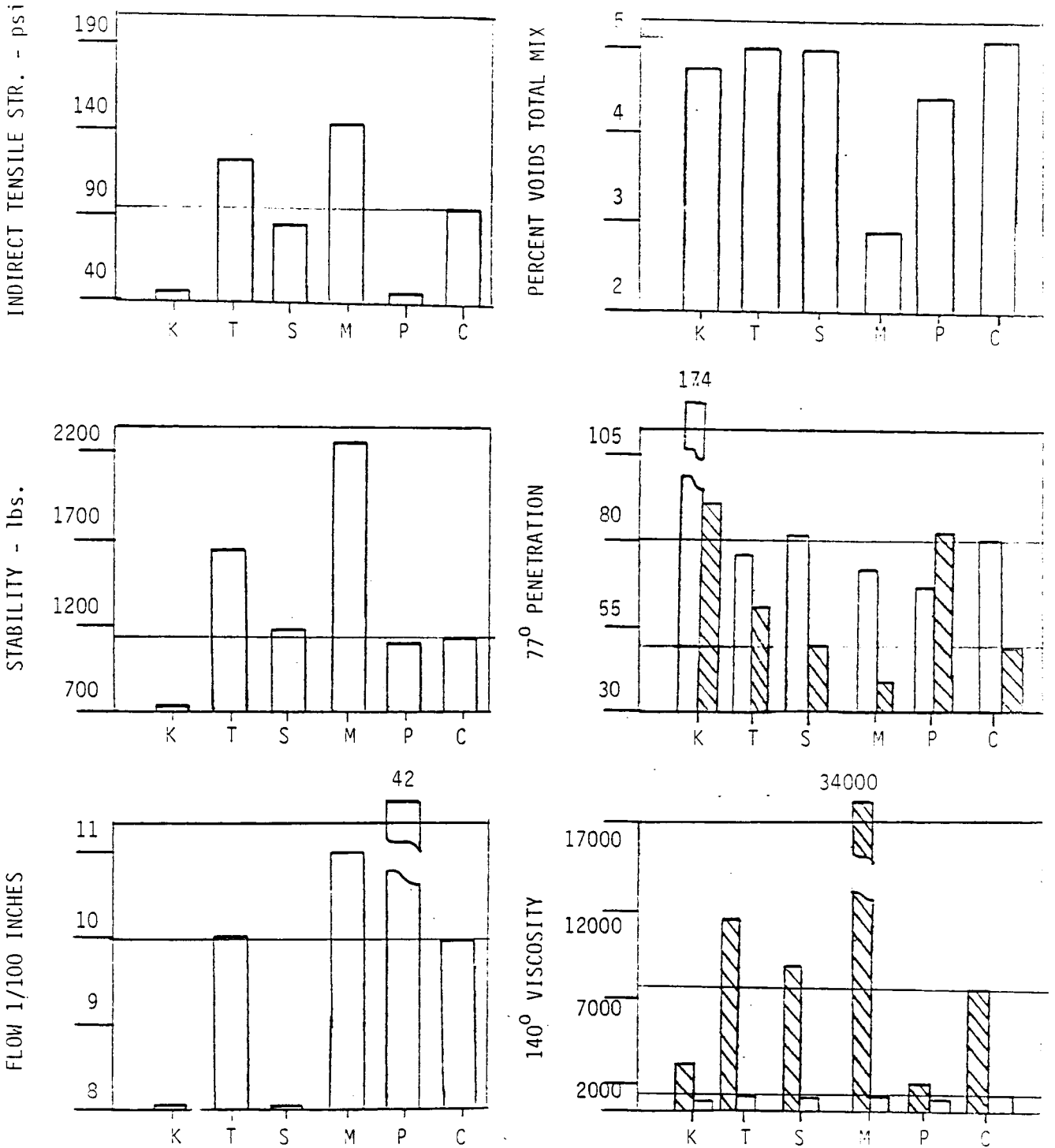
3.2.1 Chemcrete-Modified Mix: The average Marshall stability was 730 pounds; this would not comply with the New Jersey standard specification of 1,000 pound minimum stability. However, the claim of the manufacturer is that Chemcrete-modified bituminous concrete starts out with a lower stability and increases as it ages. Specimens were tested at one day, nine day, and one hundred thirty-four days to check this claim. These results are listed below:

TABLE 4

EFFECT OF AGING ON CHEMKRETE STABILITY


<u>Sample No.</u>	<u>Marshall Stability (pounds) at 140°F</u>		
	<u>1-day</u>	<u>9-day</u>	<u>134-day</u>
2K	310	250	--
8K	970	920	--
13K	630	550	--
19K	530	670	860
25K	1060	1420	--

FIGURE 11. COMPARATIVE LABORATORY TEST RESULTS



KEY

K = Chemcrete
 T = Texcrete
 S = Solar Laglugel
 M = 3M's #5990
 P = Plus Ride
 C = Control

 = Recovered AC

Only the last two samples showed increased stability with time. However, even after 134 days, the stability is markedly lower than the 1000-pound specification minimum.

The indirect tensile strength test yielded an average of 49.3 psi for Chemkrete. New Jersey has no specification for this test (see Appendix F for test method), so relative values must be discussed. Chemkrete's indirect tensile strength was the lowest value for all the mixes. The control mix achieved 94.0 psi and the Plus Ride mix was measured to be 49.4 psi. Indirect tensile strength was not measured after aging.

All the results of the Abson recovery indicate that the Chemkrete-modified binder is softer than would have been achieved using a straight AC-10 or AC-20. Abson recovery on Chemkrete cores support this theory as well.

3.2.2 Texcrete-Modified Mix: Compositional analysis complies with the New Jersey specification, except for a deviation on the #50 sieve. Normally, a three percent average from the target value is permitted. The average of the five samples tested deviated by 3.5%. However, standard procedures specify five samples in 2,000 ton lots, compared to the sampling rate in this project of five samples in 600 ton lots. Under normal construction procedures, quality control efforts at the plant would have corrected this deviation. No performance problems are expected from this slight deviation.

Marshall stability test results all comply with standard specifications. Indirect tensile strength of 116 psi is the second highest strength of all the mixes. Abson recovery data appear normal.

3.2.3 Solar Laglugel-Modified Mix: The indirect tensile strength of 88 psi is less than that of the control mix. This value was the fourth highest strength

of the six mixes. Penetration at 77°F was expected to decrease with the addition of Solar Laglugel, thus increasing rutting resistance and stability. This decrease was not observed. Penetration at 77°F for the AC-20 used averaged 84, while the Solar Laglugel modified AC-20 averaged 86.

Composition analysis, Marshall stability, flow and voids were all within specification. Marshall stability averaged 100 pounds greater than the control.

3.2.4 3M's #5990-Modified Mix: Marshall stability for this mix was the highest of all the mixes, 2260 pounds, more than 1100 pounds greater than the control mix. Indirect tensile strength, 154 psi, was also the highest strength observed. Compositional analysis complied with all of New Jersey specifications.

Abson recovery analysis suggests that the effect of incorporating the 3M product was to yield a very hard modified-asphalt binder. The recovered penetration at 77°F averages 37. One of the manufacturer's claims is that rutting resistance would be increased by modifying bituminous concrete with #5990 additive. A hard asphalt would contribute to increased rutting resistance. As mentioned previously, this mix was produced at high temperatures (discharge temperatures from 355°F to 390°F). It is unknown whether this hard recovered asphalt is a function of the additive, or a result of high mixing temperatures. In this connection, it should be noted that the 3M Company suggests that the use of the Abson recovery procedure on their product is of questionable value, since the process changes the properties of the recovered additive-modified asphalt.

A somewhat higher void content in the cores, 4.8% compared to 2.9% in the Marshall specimens, is of interest. This may be explained by this additive's tendency to induce swelling or expansion in the mix as it cures. This feature has been previously observed in the laboratory and may well have occurred in the

experimental section, thus increasing the void content. An unusual decrease in average recovered viscosity at 140°F, from 34,083 poise to 12,339 poise was noted. It may be due to the inclusion of an outlier in the data.

3.2.5 Plus Ride-Modified Mix: Plus Ride was the only mixture which employed a non-standard gradation and asphalt content specification. This mixture's gradation is significantly different from the standard I-4 mix design used in the other six mixes (see Appendix B). The composition analysis complied with the manufacturer's specifications, except for the percent asphalt cement. Average test results indicated 6.9 percent, while the target was 7.7 percent. Since the asphalt content achieved on all of the other five mixes were close to the target values, other factors must be considered. Specifically, since Plus Ride is a very rich mixture, it is possible that some of the AC-20 separated from the aggregates during sampling, hence yielding erroneously low asphalt content values. It was noted, for example, that asphalt cement stuck to the sampling equipment and the cardboard sampling boxes. The core results indicate 7.4 percent asphalt. This suggests that the asphalt content was in fact close to the target value, but this fact was obscured by the sampling method specified for (loose) bituminous mix samples.

Marshall stabilities for Plus Ride average 1,000 pounds, which just complies with New Jersey 1,000 pound minimum specification. However, a low stability (target: 720 pounds) was expected. The average flow value was 42, the design value was 33. Voids of 4.4% in the Marshall specimen complies with New Jersey specifications. Indirect tensile strength averaged 49.4 psi, the second lowest value reported for any of the mixes.

Abson recovery analysis indicates a softer asphalt cement recovered than the AC-20 used (the original AC-20 was tested for penetration at 77°F and

averaged 73; the recovered asphalt had an average penetration value of 89). However, the presence of rubber particles in the mix might have influenced the test results on the recovered asphalt.

Air void content and recovery analysis on cores indicate that the excess tack coat was drawn up through the top course, resulting in lower percent air voids. An intentionally biased core sample was taken in a very heavily tacked location, and yielded 0.3% air voids, and a relatively high penetration compared to the other core samples (92 vs. 68 and 73). The results of the four-inch core analysis (see Appendix E) suggest that the target value of 3% air voids would have been attained if tack coat effects were discounted.

3.2.6 Control Mix: All test results met New Jersey standard specifications. Indirect tensile strength of 94 psi was the third highest strength of all the mixes.

3.3 TEMPERATURE SUSCEPTIBILITY DISCUSSION

The temperature susceptibility of an asphalt cement is an indicator of potential construction and performance problems. High temperature-susceptible asphalts have been associated with tender pavements during construction and with increased low temperature cracking and high temperature rutting after construction (Ref. 1). Recently, increased awareness as to the importance of temperature susceptibility has helped to promote the use of additives to enhance this quality in asphalt cements. Several of the additives used in this project are claimed to improve asphalt cement temperature susceptibility (Chemkrete, 3M's #5990 and Solar Laglugel).

A variety of equations for calculating temperature susceptibility have been used in other states. However, the New Jersey Department of Transportation

does not routinely perform temperature susceptibility analysis and hence has not adopted any of these equations as a standard. For purposes of this report, the Pen/Vis number (77-275°F), calculated from the following equation, was used (Ref. 2).

$$PVN = \left(\frac{4.258 - 0.7967 \log P - \log V}{0.7951 - 0.1858 \log P} \right) (-1.5)$$

where P = penetration at 77°F, dmm

V = viscosity at 275°F, cs

At present, only additives which can be premixed with asphalt can be analyzed for temperature susceptibility. No test method exists for analyzing additive-modified mixes where the additive is blended in the mix itself. Table 5 shows the calculated PVN values for the control and modified asphalt cements.

TABLE 5

TEMPERATURE SUSCEPTIBILITY OF ASPHALT ADDITIVES

<u>Item</u>	<u>PVN</u>
Standard AC-10	-1.17
Chemkrete modified AC-10	-.007
AC-20 used with Solar Laglugel	-.017
Solar Laglugel modified AC-20	+.069
AC-20 used in Control	- .51

The literature suggests that lower values of PVN correspond with a highly temperature-susceptible asphalt. Unfortunately, since New Jersey does not routinely test asphalt cements for temperature susceptibility, no substantial data base exists for analyzing the significance of these results. The variability of the data is also unknown, hence this analysis is limited to preliminary observations only.

As shown in Table 5, a standard AC-10 (meeting New Jersey specifications) displayed a PVN of -1.17, while the additive-modified asphalts and the AC-20s have greater values. The PVN for the additive-modified AC-20 is greater than that of the original AC-20. As mentioned previously, these additives are claimed to improve the temperature susceptibility qualities of an asphalt cement. The results shown in Table 5 suggest that this may have occurred; the temperature susceptibility of the binder appears to decrease when modified with these additives. More information on temperature susceptibility and asphalt additives is clearly needed for this analysis. Research work on this subject will continue as an adjunct to this study.

3.4 FIELD TEST RESULTS

3.4.1 Skid Resistance: Skid tests were conducted on the additive-modified test sections in August, 1984 and December, 1984. These tests were performed with a two-wheel skid trailer in conformance with ASTM E-274. The results of these tests are shown in Table 6.

TABLE 6
SKID RESISTANCE DATA

<u>Test Section</u>	<u>SN 40 AVG</u>	
	<u>8/84</u>	<u>10/84</u>
Control	45	45
Chemcrete	44	48
Texcrete	46	47
Solar Laglugel	50	50
3M's #5990	50	50
Plus Ride	31	39
Crushed Gravel	48	45

SN values adjusted to 40 mph, and averaged over both lanes, currently range from a low of 39 (Plus Ride) to a high of 50 (Solar Laglugel and 3M's #5990). It is expected that skid resistance on the Plus Ride section will improve with time and traffic as the tack coat on the surface wears off. Even for the short period of time covered in this report, it appears that the skid resistance on the Plus Ride section is already improving. Periodic skid tests will be continued to monitor this change.

3.4.2 Rutting: Average rut-depths were measured with the Novak, Dempsey Laser Road Surface Tester. This van-mounted device uses eleven lasers to measure road surface conditions at up to 55 miles per hour. The average rut-depth data obtained are tabulated below. There is very little rutting at present on any of the test sections. Rut-depths will be measured every fifty feet with a ten foot straightedge as soon as the weather permits.

TABLE 7
RUT-DEPTH DATA

<u>Test Section</u>	<u>Rut-depth, in.</u>
Control	.035
Chemcrete	.028
Texcrete	.028
Solar Laglugel	.028
3M's #5990	.024
Plus Ride	.051
Crushed Gravel	.051

3.4.3 Roughness: The as-constructed smoothness of the control and test sections was evaluated on the basis of measurements taken with a 10-foot rolling straightedge, New Jersey's standard smoothness acceptance testing device.

This equipment consists of a 10-foot metal beam that rolls on hard rubber wheels and suspends an indicator wheel at its midpoint. As the straightedge is pushed along the roadway, surface irregularities are transmitted from the indicator wheel to an enlarged scale which indicates the magnitude of the deviation (0 to 1/2-inch in 1/16-inch increments) and its nature (i.e., bump or depression). The length of a deviation exceeding 1/8-inch in 10 feet is automatically marked on the pavement in colored dye by a cam-activated dye release mechanism.

The output of the rolling straightedge is evaluated in terms of a summary statistic known as the "Percent Defective Length". Percent defective length is computed by adding the lengths of individual surface defects exceeding a 1/8-inch in 10 foot tolerance, dividing this sum by the total length tested and multiplying by 100 to convert to percent.

In New Jersey, the output of the rolling straightedge is evaluated on the basis of historically observed correlations between the extent of straightedge defects and pavement rideability as measured by a BPR-type roughometer (see Table 8).

As outlined in Table 9, New Jersey specifications require payment reductions for new bituminous pavements which display a percent defective length of 1.4 or more.

TABLE 8
RIDING QUALITY EQUIVALENTS OF NEW JERSEY STRAIGHTEDGE DATA
(Bituminous Pavements)

<u>Rideability Rating</u>	<u>Percent Defective Length</u>
Good	Less than 0.75
Fair	0.75 - 2.0
Poor	2.0 - 3.5
Very Poor	3.5 or more

TABLE 9
NEW JERSEY SMOOTHNESS ACCEPTANCE SCHEDULE
(New Bituminous Pavements)

<u>Lot* Percent Defective Length</u>	<u>Reduction of Payment Per Lot, Percent</u>
1.3 or less	None
1.4 - 2.3	12
2.4 - 3.4	30
3.5 or more	Remove and Replace or no pay

*A smoothness acceptance lot is equal to the day's tonnage of surface course.

The results of the Route 41 smoothness testing are shown in Table 10. As outlined in that tabulation, the percent defective length values observed for the control and four of the five additive-modified sections are indicative of "Good" rideability. The percent defective length value observed for the Plus Ride section is indicative of "Poor" rideability and would be considered unacceptably rough under current Department specifications.

TABLE 10
ROUGHNESS MEASUREMENTS

<u>Test Section</u>	<u>Average Percent Defective Length</u>	<u>Equivalent Rideability Rating</u>
Control	Zero	Good
Chemcrete	0.20	Good
Texcrete	0.17	Good
Solar Laglugel	0.20	Good
3M's #5990	0.61	Good
Plus Ride	2.36	Poor

Field notes show that in two locations in the Plus Ride section corresponding to high deviations, the paver was laying the mat too thick and adjustments requiring rake and shovel work were made. This excessive handwork obviously could have contributed in part to the observed surface roughness.

3.4.4 Cross-Sections: A cross-section survey was conducted at four locations in each test section, at two hundred foot intervals and at one hundred-foot intervals in the stopping area paved with 3M's #5990 AMBC (Church Road intersection). These cross-section data show the transverse profile of the

outside lane throughout the test sections on Route 41 northbound. These measurements will be repeated bi-annually so as to monitor any pushing, shoving, or rutting of the surface course.

3.4.5 Condition Survey: The condition of the test sections to date, prior to the 1984-85 winter, is good to excellent. No cracking or significant rutting has been observed. The condition survey at this point is limited to locating bleeding and other surface irregularities. Roughness has already been discussed in Section 3.4.3. Bleeding has been observed at Station 659 + 60, inside lane, in the Solar Laglugel section and throughout the Plus Ride section in both lanes. One scarred location was observed in the Chemcrete section at approximately 612 + 0 in the inside lane. Some unidentified yellow, waxy spots have been located in the Solar Laglugel section. These locations have been cored and sent to a testing agency for chemical analysis.

3.4.6 Nuclear Density: Nuclear density data were collected at the same time cores were extracted from the test sections using a Troxler Model 3411 Nuclear Moisture-Density Gauge. The relationship between the core densities and the nuclear densities (cores taken from nuclear density sites) is the important factor here. This relationship is presented graphically in Figure 12 and will be used in future density calculations, so as to minimize the number of cores required to characterize the density distribution throughout the test sections. Almost all of the nuclear density data suggests that, within a 95% confidence level, a linear relationship (correlation coefficient = 0.86) exists between density measured at the site with the nuclear gauge and density of cores as determined in the laboratory.

The degree of compaction achieved on the test sections is expressed in terms of air void content. Percent air voids determined from eight cores per

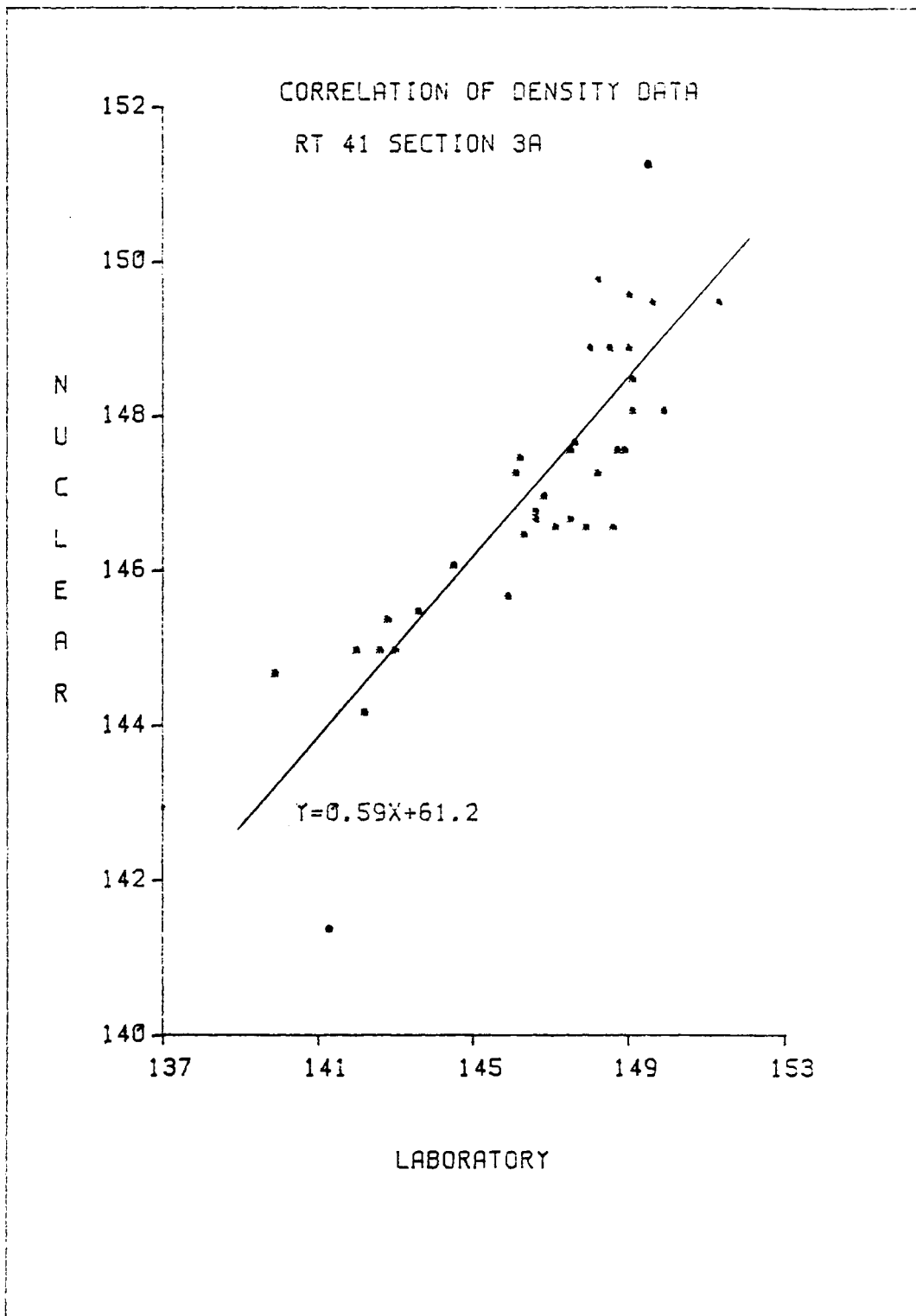


FIGURE 12

section can be found in Table 11. All air void data fell within New Jersey specifications (2-8%), except for two single data points from the Plus Ride section. This anomaly with Plus Ride is almost certainly due to the excessive tack coat applied, as discussed previously in Section 3.2.5.

TABLE 11
CORE ANALYSIS

<u>Test Section</u>	<u>% Air Voids</u>	
	<u>Average</u>	<u>Range</u>
Control	3.0	2.5-4.5
Chemkrete	3.9	2.5-5.7
Texcrete	5.6	4.5-7.7
Solar Lalugel	5.1	3.8-6.2
3M's #5990	4.9	3.3-6.9
Plus Ride	2.4	1.2-3.8

PART FOUR - CONCLUSIONS

The actual production and paving operations went quite well for all seven mixes. This may be an understatement, considering that five experimental mixes, each requiring different handling techniques at the plant and on the site, were produced and placed in a five-day period. The laboratory test data and the initial field test data are, on the whole, consistent with New Jersey specifications and design criteria. Therefore, the Department of Transportation has an excellent, controlled test environment for monitoring the performance of the five asphalt additives used on Route 41, NB, Section 3A.

PART FIVE - PRELIMINARY RECOMMENDATIONS

1. In future asphalt additive construction work, it is recommended that the additive manufacturer be required to:

- a. submit Material Safety Data Sheets on the additive,
- b. submit Material Safety Data Sheets on the additive-modified bituminous mixture, detailing air contaminants generated at mixing and paving temperatures,
- c. monitor air quality in the vicinity of the plant and paver; if deemed necessary by the research engineer.

2. Plus Ride is a very different type of bituminous mix and requires more care in handling than usual. Tarps can be easily ruined by contact and should perhaps be coated or lubricated before using, or omitted altogether. Soap must be used on all steel-wheeled rollers, or the mix will stick. The absolute minimum amount of tack coat should be used, since the mix has a high asphalt content. Extra care should be taken when sampling Plus Ride mix, because the wetness of the mix causes separation in the trucks, as well as in the sampling boxes.

3. High roughness values and low skid resistance figures in the Plus Ride section are the reasons for some concern at this early stage of the research study. Skid numbers are expected to continue to increase. Roughness will continue to be monitored.

4. The nuclear density gauge appears to be a good tool for measuring density in the field. This instrument should be employed as a matter of course in all research work dealing with bituminous mixes.

REFERENCES

1. Button, J. W. et al, "Influence of Asphalt Temperature Susceptibility on Pavement Construction and Performance", NCHRP Report 268, 1983.
2. Puzinauskas, V. P., "Properties of Asphalt Cements", Proceedings, Association of Asphalt Paving Technologists, Vol. 48, 1979.
3. "Instructions for the Mark V Resilient Modulus Non-Destructive Testing Device", abstracted from the original, copyright 1984, Retsina Company.
4. Modified from "Test Procedures for Characterizing Dynamic Stress-Strain Properties of Pavement Materials", Special Report 162, TRB, NRC, National Academy of Sciences, Washington, D.C., 1975.

APPENDIX A
RESILIENT MODULUS TEST METHOD

INSTRUCTIONS FOR THE MARK V RESILIENT MODULUS
NON-DESTRUCTIVE TESTING DEVICE (Ref. 3)

THEORY

An Elastic modulus or Young's modulus of an elastic material is defined as:

$$\frac{\text{stress}}{\text{strain}} = \text{modulus}$$

where the duration of loading does not change the value obtained. In viscoelastic material, the same relationship is applied. However, the conditions of the test, when using viscoelastic materials, must be defined because short loading periods can give much higher modulus values than long loading periods. This is because long loading periods allow more flow to occur. Moduli that are time-dependent are referred to as Resilient Moduli or as Stiffness Moduli. Frequently, moduli determined for very long loading times are referred to as Creep Moduli.

OPERATING PRINCIPLE

The Mark V Resilient Modulus Non-Destructive Testing (Mr) Device functions by applying a 250 millisecond load pulse across the vertical diameter of a cylindrical specimen, and sensing the resultant deformation across the horizontal diameter, for either 0.05 or 0.10 seconds after the beginning of the specimen deformation. The specimen diameter may vary from 3.5 to 4.0 inches and thickness from 1 to 3 inches. Optimum specimen diameter is 4.0 inches and the optimum thickness is 2.75 inches. Loads on the specimen normally vary from 10 lbs. to 75 lbs. Specimen deformations range from 1000 to 2000 microinches.

Diametral loading (application of a load across the vertical diameter of a cylinder) results in a deformation across the horizontal diameter. The vertical

load, p , and the horizontal deformation, d , are related to the Resilient Modulus, M_r , Poissons ratio, ν , and the specimen thickness, t , as follows:

$$\frac{p(\nu + 0.2734)}{t(d)} = M_r$$

If p is in lb., or kg., and t and d are in in., or cm., in the above equation, the units of M_r will be in lb/in², or kg/cm².

Thus, by measuring the thickness of the specimen and deformation resulting from a known pulsating load, the Resilient Modulus, or M_r , can be calculated. A Poissons ratio of 0.35 has been shown to be a reasonable value to use in this calculation for sound asphalt-treated materials. Higher or lower values may be used for other materials.

TESTING HINTS

Each specimen should be tested at least twice; once across each perpendicular diameter. Usually, the values will agree within 10%. If they differ by more, repeat the test. A consistent difference greater than 10% is the result of a nonisotropic specimen. If the difference is severe (over 50%) a new sample should be made.

To insure accuracy of readings, periodically turn the mode switch to Set up and check the transducers. One at a time, back off each transducer until it is retracted into its housing. Each retraction should change the display meter reading a small amount. If there is no reduction in the display meter reading, then contact between the specimen and one of the transducers may have been lost (i.e., the yoke may have slipped or a piece of the specimen may have been displaced.) If contact has been lost, repeat testing of the specimen before rotating.

Creep Testing

Creep Modulus (M_c) is the same kind of measurement as the Resilient Modulus (M_r). The term Creep Modulus is used as a convenience to indicate relatively long loading times, compared to the loading times used in most dynamic tests (such as 250 milliseconds in Operate mode using the Mark V.) Loading times of any length can be obtained by switching to Creep mode. Convenient times at which readings can be taken are: 10, 100, and 1000 seconds. By plotting moduli versus time on a log-log scale, curves can be generated which allow extrapolation from 0.01 second to one end to 10,000 seconds on the other end.

A recorder trace is considerably more convenient to use than the meter for following the Creep deformation. A recorder (REC) connection is provided on the back panel of the Mark V. A recorder having an impedance greater than 5000 ohms, and having input ranges from 50 millivolts to 10 volts full scale will be sufficiently accurate. The recorder output will be negative (from 0 to negative volts), so the recorder should be set up appropriately. The recorder can be operated simultaneously with the Mark V display meter in Creep, Set up, or Operate modes.

SAMPLE PREPARATION AND HANDLING FOR M_r MEASUREMENTS

Core Samples

The Mark V is made to handle samples that are 4 inches in diameter, and from 1-1/2 to 3 inches thick. The ideal thickness is 2-3/4 inches. Cores may be taken from a pavement by cutting with a 4 inch diamond-grit coring machine. Water can be used as the coring fluid when cutting sound asphalt cement. However, air or nitrogen should be used when coring friable pavements. Most asphalt emulsion treated pavements are easier to core using air or nitrogen.

The resultant cores will be as long as the pavement is thick. These may then be cut into layers corresponding to the structure of the road. (Base, overlays, etc.). A diamond saw, such as is used to cut rock samples, works well to slice core sections. The circumference of a core sample is often rough and sometimes stones fall out. These rough areas may be filled with plaster of Paris without significantly affecting the Mr results.

All specimens should be stored at the desired test temperature for at least 8 hours before testing. Heat transfer on an asphalt cement sample is very slow. It takes 4 to 8 hours for the center of the core to come to equilibrium with the outside temperature, depending on the temperature differential.

Lab Manufactured Samples

The best way to make test samples in the lab is with the California Kneading Compactor (ASTM D-1561). Follow the ASTM procedure, and make a 2-3/4 inch specimen. Emulsion mixes may be cured in the mold and tested at intervals to determine the rate of buildup of material strength. Uncured, soft mixes should be tested using the confinement kit. Cured emulsion mixes and those made with hot asphalt can be tested normally. Again, be sure to store the sample at test temperature for at least 8 hours, prior to testing.

APPENDIX B
MIX DESIGNS

NEW JERSEY DEPARTMENT OF TRANSPORTATION
BITUMINOUS CONCRETE MIX DESIGN

DATE 8-5-83

PROJECT Route 41 Section 3A & Route 154 Section 1C M-4145(104)

JOB CODE 9828-004

PRODUCER T.K.I.

PLANT LOCATION Columbus, N.J. or FLORENCE

CONTRACTOR Conti Construction Co.

ADDRESS S. Plainfield, N.J.

SIEVE SIZE	Solar		JOB MIX FORMULA (Total percent passing each sieve)		Asphadur-3M		Latex	
	Mix No. I-4 FORMULA	AVG. of 5	Mix No. I-4 FORMULA	AVG. of 5	Mix No. I-4 FORMULA	AVG. of 5	Mix No. I-4 FORMULA	Tex Crete AVG. of 5
3"								
1 1/2"								
1"	100	100	100	100	100	100	100	100
3/4"	97	95-100	97	95-100	97	95-100	97	95-100
3/8"	86	75-95	86	75-95	86	75-95	86	75-95
3/4"	74	65-85	74	65-85	74	65-85	74	65-85
#4	53	35-65	53	35-65	53	35-65	53	35-65
#8	42.0	38.0-46.0	42.0	38.0-46.0	42.0	38.0-46.0	42.0	38.0-46.0
#30								
#50	17.5	14.5-20.5	17.5	14.5-20.5	17.5	14.5-20.5	17.5	14.5-20.5
#100								
#200	4.4	3.0-5.8	4.4	3.0-5.8	4.4	3.0-5.8	4.4	3.0-5.8
ASPH.								
CONT. *	5.0	4.55-5.45	5.0	4.55-5.45	5.0	4.55-5.45	5.0	4.55-5.45

*See remarks on reverse side.

PERCENT ASPHALT CEMENT BASED ON THE TOTAL WEIGHT OF MIXTURE

CRITERIA - ORIGINAL MIX DESIGN

	MIX NO. Lagugel	MIX NO. Nophalt	MIX NO. 5990	MIX NO. Tex Crete
Stability-Lbs.	1700	1700	1700	1700
Flow Value-0.01"	11	11	11	11
Air Voids-percent	3.0	3.0	3.0	3.0
VMA-percent	14.678	14.678	14.678	14.678
Mix Design by	112	112	112	112
Date Approved	J. Kujalowicz	J. Kujalowicz	J. Kujalowicz	J. Kujalowicz
Verification Plug-S/N	9-28-81	4-28-81	9-28-81	9-28-81
Job Mix Formula	292046	292046	292046	292046
Amended-Date & Sieves				

THE TEMPERATURE OF THE MIXTURE AT DISCHARGE FROM THE PLANT OR SURGE AND STORAGE BINS SHALL BE MAINTAINED AT A MINIMUM OF 15 DEGREES ABOVE THE LAYDOWN TEMPERATURE. IN NO CASE SHALL THE MIXTURE TEMPERATURE EXCEED 325 DEGREES F.

DISTRIBUTION

- Bureau of Inspection
- Bureau of Quality Control
- Regional Construction Engineer
- Bituminous Laboratory
- Core Drill Group
- Resident Engineer
- Contractor
- Supplier
- Regional Materials Office (2) 201-431-4504
- 1 Material (1) 201-431-4504-5864



MIX NO. <u>I-4</u>	PER CENT	APPARENT Specific Gravity	COMPONENTS - - PRODUCER AND LOCATION
Bin No. 5			
Bin No. 4	16.2	2.680	Better Materials (Argillite), Penns Park, Pa.
Bin No. 3	24.7	2.669	Better Materials (Argillite), Penns Park, Pa.
Bin No. 2	14.7	2.660	Better Materials (Argillite), Penns Park, Pa.
Bin No. 1	36.1	2.650	Clayton Sand, Jackson, N.J.
Filler	3.3	2.900	T.R.I., Kingston
Asph. Content *	5.0	1.025	AC-20 & Solar Laglugel
Maximum Theoretical Specific Gravity: 2.497			
Approximate Cold Feed Proportions: 20% #57, 41.5% #8, 35% Sand			

MIX NO. <u>I-4</u>	PER CENT	APPARENT Specific Gravity	COMPONENTS - - PRODUCER AND LOCATION
Bin No. 5			
Bin No. 4	16.2	2.680	Better Materials (Argillite), Penns Park, Pa.
Bin No. 3	24.7	2.669	Better Materials (Argillite), Penns Park, Pa.
Bin No. 2	14.7	2.660	Better Materials (Argillite), Penns Park, Pa.
Bin No. 1	36.1	2.650	Clayton Sand, Jackson, N.J.
Filler	3.3	2.900	T.R.I., Kingston
Asph. Content *	5.0	1.025	AC-10 & Nophalt CHEMFRETE
Maximum Theoretical Specific Gravity: 2.497			
Approximate Cold Feed Proportions: 20% #57, 41.5% #8, 35% Sand			

MIX NO. <u>I-4</u>	PER CENT	APPARENT Specific Gravity	COMPONENTS - PRODUCER AND LOCATION
Bin No. 5			
Bin No. 4	16.2	2.680	Better Materials (Argillite), Penns Park, Pa.
Bin No. 3	24.7	2.669	Better Materials (Argillite), Penns Park, Pa.
Bin No. 2	14.7	2.660	Better Materials (Argillite), Penns Park, Pa.
Bin No. 1	36.1	2.650	Clayton Sand, Jackson, N.J.
Filler	3.3	2.900	T.R.I., Kingston
Asph. Content *	5.0	1.025	AC-20 + 8.33 POUNDS / TON ADDITIVE 5990 (3M'S)
Maximum Theoretical Specific Gravity: 2.497			
Approximate Cold Feed Proportions: 20% #57, 41.5% #8, 35% Sand			

MIX NO. <u>I-4</u>	PER CENT	APPARENT Specific Gravity	COMPONENTS - - PRODUCER AND LOCATION
Bin No. 5			
Bin No. 4	16.2	2.680	Better Materials (Argillite), Penns Park, Pa.
Bin No. 3	24.7	2.669	Better Materials (Argillite), Penns Park, Pa.
Bin No. 2	14.7	2.660	Better Materials (Argillite), Penns Park, Pa.
Bin No. 1	36.1	2.650	Clayton Sand, Jackson, N.J.
Filler	3.3	2.900	T.R.I., Kingston
Asph. Content *	5.0	1.025	AC-20 & Larex Tex Crete
Maximum Theoretical Specific Gravity: 2.497			
Approximate Cold Feed Proportions: 20% #57, 41.5% #8, 35% Sand			

REMARKS: * Solar Laglugel - Preblended with 1.33% Solar Laglugel per 100 lbs AC-20
 Nophalt - Preblended ³⁰ parts AC-10 to 1 part Nophalt
 5990 Additive ^{8.33} pounds per 2000 pound batch
 Tex Crete - Blend of 96 lbs. AC-20 (4.8%) and .55 gallons Tex Crete per batch.

RECEIVED
 BUREAU OF QUALITY CONTROL
 AUG 11 1983

U.S. DEPT. OF TRANSPORTATION

BITUMINOUS CONCRETE MIX DESIGN

DATE 11-28-83

PROJECT Route 41 Section 3A & Route 154 Section 1C M-4145(104)

JOB CODE 9828-004

PRODUCER T.R.I.

PLANT LOCATION Columbus, N.J.

CONTRACTOR Conti Construction Company

ADDRESS S. Plainfield, N.J.

JOB MIX FORMULA
(Total percent passing each sieve)

SIEVE SIZE	Mix No. - Plus Ride		Mix No.		Mix No.		Mix No.	
	FORMULA	AVG. of 5	FORMULA	AVG. of 5	FORMULA	AVG. of 5	FORMULA	AVG. of 5
2"								
1 1/2"								
1"	100	100						
3/4"	96	100						
3/8"	57	50-62						
1/4"	37	30-45						
#10	25.5	19-32						
#16								
#30	18.5	12-23						
#50								
#100								
#200	9.8	7-11						
* ASPH. CONT.	7.7	7.25-8.15						

* PERCENT ASPHALT CEMENT BASED ON THE TOTAL WEIGHT OF MIXTURE

CRITERIA - ORIGINAL MIX DESIGN

	MIX NO. Plus Ride	MIX NO.	MIX NO.	MIX NO.
Stability-Lbs.	720			
Flow Value-0.01"	33			
Air Voids-percent	3.0			
VMA-percent	19			
Wt/Sq. Yd. Inth. Thick	106			
Mix Design by	J. Smith (NJDOT)			
Date Approved	10-6-83			
Verification Plug-S/N	NA			
Job Mix Formula	-			
Amended-Date & Sieves	-			

THE TEMPERATURE OF THE MIXTURE AT DISCHARGE FORM THE PLANT OR SURGE AND STORAGE BINS SHALL BE MAINTAINED AT A MINIMUM OF 15 DEGREES ABOVE THE LAYDOWN TEMPERATURE. IN NO CASE SHALL THE MIXTURE TEMPERATURE EXCEED 325 DEGREES F.

DISTRIBUTION

- Bureau of Inspection
- Bureau of Quality Control
- Regional Construction Engineer
- Bituminous Laboratory
- Core Drill Group
- Resident Engineer
- Contractor
- Supplier
- Regional Materials Office (2)
- Region #4 (3)

Signed F. Palms

BIN PULLS

MIX NO. ^{Plus} <u>Ride</u>	PER CENT	APPARENT Specific Gravity	COMPONENTS - - PRODUCER AND LOCATION
Bin No. 5	3.0		Rubber Granules - All Seasons, Bellevue, Washington
Bin No. 4	26.8		Argillite - Better Materials, Penns Park, Pa.
Bin No. 3	25.9		Argillite - Better Materials, Penns Park, Pa.
Bin No. 2	14.7		Argillite - Better Materials, Penns Park, Pa.
Bin No. 1	13.0		Clayton Sand, Jackson Twp. New Jersey
Filler	8.9		T.R.I., Kingston
Asph. Content	7.7		West Bank Oil

Maximum Theoretical Specific Gravity: 2.331
 Approximate Cold Feed Proportions: 50% #57, 25% #8, 15% Sand

MIX NO. _____	PER CENT	APPARENT Specific Gravity	COMPONENTS - - PRODUCER AND LOCATION
Bin No. 5			
Bin No. 4			
Bin No. 3			
Bin No. 2			
Bin No. 1			
Filler			
Asph. Content			

Maximum Theoretical Specific Gravity: _____
 Approximate Cold Feed Proportions: _____

MIX NO. _____	PER CENT	APPARENT Specific Gravity	COMPONENTS - PRODUCER AND LOCATION
Bin No. 5			
Bin No. 4			
Bin No. 3			
Bin No. 2			
Bin No. 1			
Filler			
Asph. Content			

Maximum Theoretical Specific Gravity: _____
 Approximate Cold Feed Proportions: _____

MIX NO. _____	PER CENT	APPARENT Specific Gravity	COMPONENTS - - PRODUCER AND LOCATION
Bin No. 5			
Bin No. 4			
Bin No. 3			
Bin No. 2			
Bin No. 1			
Filler			
Asph. Content			

Maximum Theoretical Specific Gravity: _____
 Approximate Cold Feed Proportions: _____

RECEIVED
 BUREAU OF MATERIALS
 DEC 5 1983
 N.I. DEPT. OF TRANSPORTATION

REMARKS: - The selected AC content of 7.7% was based on recommendations by Mr. Robert N. Linden, Technical Advisor for All Seasons Surfacing Corporation that the optimum AC content occurs when the voids are 3.0%.

APPENDIX C
LABORATORY TEST RESULTS - ASPHALT CEMENT

November 13, 1984

Grade AC 10 plus Chemcrete

Serial No. 360849

360850

Charged To Rt. 41, Sec. 3A and Rt. 154, Sec. 1C M4145 (104)

Proposed Use Bituminous Concrete

Producer West Bank Oil

Origin Petty's Island

Sample Taken From	Storage Tank @ Florence, N.J.		
Quantity Represented	30 Ton		
Marks on Sample	10K	29K	
Sampled By	K. Middelisen, J. Scott		
Grade Specified			
Lot No. Shipped From			
Submitted on Inspector's Daily Report No.			
Date Taken	8-1-84		
Date Received at Laboratory	8-2-84		
Laboratory Serial No.	360849	360850	
Seal No.			

REPORTED TO

TESTS

ANALYSES

REQUIRED

Min. Max.

Straight
AC-10 Specs.

TESTS	ANALYSES	REQUIRED	Min.	Max.
Viscosity, 140° F, Poises	800	855	800	1200
Viscosity, 275° F, C _s	294	298	250	
Penetration, 77° F, 100 g, 5 sec.	177	171	80	
Flesh Point, CDC, ° F.	450	450	425	
Tests on Residue, TFOT				
Loss on Heating, %	0.88	1.36		
Ductility, 60° F, 5 cm/min., Cm.				
Viscosity, 140° F, Poises	2362	2461		4000
Viscosity Ratio, 140° F.				

REMARKS:

Pre-blended at the West Bank Oil Company, Petty's Island, N.J.
1 part Chemcrete
30 Parts AC-10

SIGNED _____

C-1

ANALYSES OF ASPHALT CEMENT

November 13, 1984

Grade AC-20

Serial No. 361019

361020

Charged To Rt. 41, Sec. 3A and Rt. 104, Sec. 1C M4145(104)

Proposed Use Bituminous Concrete - Texcrete

Producer West Bank Oil

Origin Petty's Island

Sample Taken From	Storage Tank @ Florence, NJ	
Quantity Represented	30 Tons	
Marks on Sample	8T	27T
Sampled By	E. Connolly	
Grade Specified		
Lot No. Shipped From		
Submitted on Inspector's Daily Report No.		
Date Taken	8-2-84	
Date Received at Laboratory	8-6-84	
Laboratory Serial No.	361019	361020
Seal No.		

REPORTED TO

TESTS	ANALYSES		REQUIRED	
			Min.	Max.
Viscosity, 140° F, Poises	2027	2035	1600	2400
Viscosity, 275° F, Cs	393	400	300	
Penetration, 77° F, 100 g, 5 sec.	79	77	60	
Flash Point, CDC, ° F.	615	610	450	
Tests on Residue, TFOT				
Loss on Heating, %	0.13	0.12		
Ductility, 60° F, 5 cm/min., Cm.				
Viscosity, 140° F, Poises	4906	4611		8000
Viscosity Ratio, 140° F.				

REMARKS:

Straight AC-20 -- 0.55 Gallon of latex sprayed into the pug mill, for each ton of mix, during the normal mixing cycle.

SIGNED _____

NEW JERSEY DEPARTMENT OF TRANSPORTATION

ANALYSES OF ASPHALT CEMENT

Form LB-16 12/74

November 13, 1984

Grade AC-20

Serial No. 361021

Charged To Rt. 41, Sec. 3A & Rt. 154, Sec. 1C M4145(104)

Proposed Use Bituminous Concrete - Solar Laglugel

Producer West Bank Oil

Origin Petty's Island

Sample Taken From	Delivery Truck @ Florence, NJ
Quantity Represented	30 tons
Marks on Sample	OS
Sampled By	J. Smith
Grade Specified	
Lot No. Shipped From	
Submitted on Inspector's Daily Report No.	
Date Taken	8-2-84
Date Received at Laboratory	8-6-84
Laboratory Serial No.	361021
Seal No.	

REPORTED TO

TESTS	ANALYSES	REQUIRED	
		Min.	Max.
Viscosity, 140° F, Poises	2437	1600	2400
Viscosity, 275° F, Cs	515	300	
Penetration, 77° F, 100 g, 5 sec.	86	60	
Flash Point, COC, ° F.	550	450	
Tests on Residue, TFOT			
Loss on Heating, %	0.34		
Ductility, 60° F, 5 cm/min., Cm.			
Viscosity, 140° F, Poises	5111		8000
Viscosity Ratio, 140° F.			

REMARKS:

On 8-2-84, after batching was completed for the Texcrete special mixture, there was 40,000 pounds of AC-20 in the storage tank. (See results on page 18.) We then added 486 pounds of Solar Laglugel to the storage tank. A new delivery of AC-20 arrived and was being pumped off. It was not possible to sample from the dome of the delivery truck, a sample was obtained from the delivery line at the end of the delivery. Later, 324 pounds of Solar Laglugel was added to the storage tank, making a total of 810 pounds of Solar Laglugel in 60,000 pounds of AC-20 (1.35%).

The above results are not typical for the AC-20 received on this project. Because of the sampling method used, the results reported may not be representative of the AC-20 received.

JS:kml

C-4

SIGNED _____

ANALYSES OF ASPHALT CEMENT

Grade AC 20

Serial No. 361166

361167

Charged To Rt. 41, Sec. 3A and Rt. 154, Sec. 1C

Proposed Use Bituminous Concrete - Plus Ride

Producer West Bank Oil

Origin Petty's Island

Sample Taken From	Storage Tank @ Columbus, N.J.	
Quantity Represented	30 Ton	
Marks on Sample	9P	20P
Sampled By	E. Connelly	
Grade Specified		
Lot No. Shipped From		
Submitted on Inspector's Daily Report No.		
Date Taken	8-6-84	
Date Received at Laboratory	8-7-84	
Laboratory Serial No.	361166	361167
Seal No.		

REPORTED TO

TESTS	ANALYSES		REQUIRED	
			Min.	Max.
Viscosity, 140° F, Poises	1968	2064	1600	2400
Viscosity, 275° F, Cs	476	414	300	
Penetration, 77° F, 100 g, 5 sec.	71	74	60	
Flash Point, CDC, ° F.	610	605	450	
Tests on Residue, TFOT				
Loss on Heating, %	0.19	0.07		
Ductility, 60° F, 5 cm/min., Cm.				
Viscosity, 140° F, Poises	5161	4341		8000
Viscosity Ratio, 140° F.				

REMARKS:

Straight AC-20

60 lbs. of Plus Ride per Ton - Hand dumped into the pug mill - during the normal mixing cycle

SIGNED _____

APPENDIX D

LABORATORY TEST RESULTS - BITUMINOUS MIX SAMPLES

Truck Number 2K 8K 13K 19K 25K

Load Temp.	290°	290°	290°	280°	280°		Ave.	Target
Sieve	% Passing							
1"	100	100	100	100	100		100	100
3/4"	96	96	95	93	94		96	97
1/2"	92	93	92	90	87		91	86
3/8"	84	76	84	73	73		78	74
#4	55	49	56	48	49		51	53
#8	44.0	39.6	43.1	43.3	40.6		42.1	42.0
#50	19.5	13.7	16.1	17.8	15.2		16.5	17.5
#200	6.9	3.3	4.3	6.2	1.6		4.5	4.4
AC	4.95	5.08	4.83	5.20	5.07		5.03	5.0

Marshall Specimens								
Stability	280	940	590	600	1240		730	
Flow	9	8	8	8	10		8	
Indirect Tensile Strength	17.7	73.8	45.7	49.9	59.6		49.3	
% Voids	6.9	3.8	5.6	4.8	2.6		4.7	

Absorption Recovery								
PSH	123	76	80	104	85		94	
140 Vis.	1787	4547	4362	2420	3341		3291	
275 Vis.	477	828	834	597	704		688	

MIXTURE SAMPLES
AUG. 1984

Truck Number	5T	11T	116T	21T	27T			
Load Temp.	325°	340°	350°	350°	340°		Ave.	Target
Sieve			% Passing					
1"	100	100	100	100	100		100	100
3/4"	94	99	96	97	100		97	97
1/2"	86	92	90	91	96		91	86
3/8"	76	84	79	81	84		81	74
#4	50	55	53	51	54		53	53
#8	42.1	42.9	42.3	42.8	45.0		43.0	42.0
#50	13.3	13.1	14.3	13.9	15.5		14.0	17.5
#200	3.1	3.8	5.3	3.5	4.0		3.9	4.4
AC	4.75	4.86	4.78	4.92	5.14		4.89	5.0

Marshall Specimens

Stability	1430	1560	2160	1640	1360		1630
Flow	10	10	12	9	8		10
Indirect Tensile Strength	107.7	100.5	139.8	116.3	117.9		116.4
% Voids	5.3	5.0	3.7	5.9	5.0		5.0

Abson Recovery

PEH	33	82	61	65	64		61
140 Vis.	¹⁰⁰ VISC.	6288	13946	10758	16329		11830
275 Vis.		2845	1722	2578	2552	3079	2555

MIXTURE SAMPLES
AUG. 1984

Truck Number 45 115 185 225 275

Load Temp.	290°	280°	285°	295°	295°		Ave.	Target
Sieve	% Passing							
1"	100	100	98	100	100		100	100
3/4"	99	94	95	96	95		96	97
1/2"	94	90	88	88	90		90	86
3/8"	78	78	78	79	78		78	74
#4	51	53	56	52	52		53	53
#8	44.3	46.7	46.6	45.7	43.4		45.3	42.0
#50	17.0	18.1	18.0	18.3	17.2		17.7	17.5
#200	4.8	6.6	5.5	5.0	5.0		5.4	4.4
AC	4.98	4.66	4.71	5.01	4.83		4.84	5.0

Marshall Specimens

Stability	1030	1380	1220	1000	1380		1200
Flow	8	9	8	7	8		8
Indirect Tensile Strength	82.8	93.5	85.2	87.8	93.3		88.5
% Voies	5.4	4.1	5.2	5.0	5.4		5.0

Abson Recovery

PEN	56	55	47	52	53		53
140 Vis.	7504	8924	11246	11779	11090		10107
275 Vis.	947	1039	1129	1184	1112		1082

MIXTURE SAMPLES
AUG. 1987

Truck Number	3M	9M	15M	21M	25M		Ave.	Target
Load Temp. °F	390	365	370	350	365			
Sieve	% Passing							
1"	100	100	98	100	100		100	100
3/4"	96	96	96	96	97		96	97
1/2"	92	90	90	90	92		91	86
3/8"	78	78	82	81	82		80	74
#4	52	50	53	50	52		51	53
#8	44.4	39.8	41.9	39.9	40.4		41.3	42
#50	16.4	14.0	15.9	16.0	14.6		15.4	17.5
#200	4.0	4.4	5.7	5.6	4.9		4.9	4.4
AC	5.35	5.00	5.25	5.00	4.79		5.08	5.0

Marshall Specimens								
Stability	2200	2260	2220	2310	2320		2260	
Flow	10	10	13	11	12		11	
Indirect Tensile Strength	161	152	121	167	171		154	
% Voids	3.4	3.0	2.6	2.3	3.3		2.9	

Absorption Recovery								
PEN	28	34	50	34	37		37	
140 Vis.	80,107	29,044	18,813	25,052	16,492		34,083	
275 Vis.	2762	1675	1433	1575	1181		1725	

MIXTURE SAMPLES

AUG. 1984

Truck Number	4P	11P	112P	31P	212P		Ave.	Target
Load Temp.	335°	325°	340°	310°	325°			
Sieve	% Passing							
1"	100	100	100	98	100		100	100
3/4"	92	91	92	82	88		89	96
1/2"	73	68	75	65	68		70	
-3/8"	57	54	60	56	56		57	57
1/4"	41	37	44	41	41		41	37
#10	23	20	26	26	25		24	25.5
#30	18.2	16.4	20.8	20.9	20.2		19.3	18.5
#200	8.2	8.1	9.6	8.6	8.4		8.6	9.8
AC	7.34	6.36	6.89	6.86	7.02		6.89	7.7

Marshall Specimens

Stability	940	930	900	1140	1090		1000	
Flow	48	39	34	43	48		42	
Indirect Tensile Strength	52.8	46.6	53.5	44.5	49.4		49.4	
% Voigs	4.2	6.5	4.0	3.1	4.3		4.4	

Absorption Recovery

PEN	76	68	103	86	112		89	
140 Vis.	2491	3397	1662	1956	1306		2162	
275 Vis.	600	681	503	481	419		537	

MIXTURE SAMPLES
AUG. 1984

Truck Number	4C	11C	15C	22C	26C		Ave.	Target
Load Temp. °F	305	300	320	305	300			
Sieve	% Passing							
1"	100	100	100	100	100		100	100
3/4"	95	98	92	94	96		95	98
1/2"	88	90	87	84	87		87	87
3/8"	70	77	74	70	75		73	70
#4	47	50	49	49	50		49	50
#8	40.5	46.4	44.4	44.6	44.9		44.2	41.0
#50	13.4	15.4	14.6	14.4	15.3		14.6	16.0
#200	4.0	4.7	4.8	4.6	5.4		4.7	4.4
AC	4.33	5.05	4.55	4.73	4.81		4.69	5.0

Marshall Specimens

Stability	1080	1047	1410	980	1096		1100	
Flow	9	10	10	11	10		10	
Indirect Tensile Strength	94	96	102	96	84		94	
% Voias.	5.6	6.3	4.6	5.4	3.6		5.1	

Abson Recovery

PEN	51	53	60	54	50		54	
140 Vis.	11.795	8468	5292	7032	8388		8195	
275 Vis.	1.005	944	885	800	880		903	

APPENDIX E
LABORATORY TEST RESULTS - PAVEMENT CORES

ROUTE: 41

SECTION: 3A

CHEMKRETE

CONTRACTOR:

PRODUCER (A) T.R.I. FLORENCE

PRODUCER (B)

PRODUCER (C)

DATE COMPLETED: 1984, DEC.

LOT NO.	CORE NO.	LOCATION	STATION	LANE	OFF SET	DATE CUT	MIX NO.					MIX NO.						
							THICK-NESS	BULK SP. GR.	EST. \bar{V}_5 (%)	\bar{D}_M	AIR \bar{V}_5 VOIDS (%)	THICK-NESS	BULK SP. GR.	EST. \bar{V}_5 (%)	\bar{D}_M	AIR \bar{V}_5 VOIDS (%)		
6	X 76	K	612+56	R1	8.0	12-20	1.92	2.402	LOW HIGH	5.7 2.475	2.9							
6	X 77	K	615+29	R2	6.0	12-18	1.66	2.389		2.487	3.9							
6	X 78	K	619+80	R1	9.0	12-20	1.71	2.397		2.487	3.6							
6	X 79	K	621+86	R2	1.0	12-18	1.73	2.347		2.487	5.7							
6	X 80	K	623+39	R1	7.0	12-20	1.92	2.424		2.487	2.5							
							$\bar{B}_5 =$	2.391	3.7			$\bar{B}_5 =$						
6	X 81	K	627+45	R2	5.0	12-18	1.37	2.375		2.487	4.5							
8	X 106	K	614+92	ROS	6.0	12-17	1.63	2.364		2.487	4.9							
8	X 107	K	617+34	ROS	11.0	12-17	1.78	2.434		2.487	2.1							
8	X 108	K	622+23	ROS	2.0	12-17	1.44	2.361		2.487	5.1							
							$\bar{B}_5 =$					$\bar{B}_5 =$						
4" CORES																		
							$\bar{B}_5 =$						$\bar{B}_5 =$					

E-1

1. CALC. EST. \bar{V}_5 (%) FOR EACH VOIDS LOT USING THE AVER. BLK. SP. GR. (\bar{B}_5) & THE AVER. MAX. DENSITY (\bar{D}_m), FIRST FOR THE LOW & THEN FOR THE HIGH PRODUCER.
2. WHEN BOTH EST. \bar{V}_5 (%) ARE WITHIN 2.5 TO 7.5, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MIXTURES WTD. AVER. MAX. DENSITY (\bar{D}_m).
3. WHEN EITHER EST. \bar{V}_5 (%) IS NOT WITHIN 2.5 TO 7.5%, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MAX. DENSITY (\bar{D}_m) FOR THAT SPEC SOLVENT IMMERSION TEST METHOD.

8" CORES

Core Number	1K	2K	3K			Ave.	Target
SIEVE				% PASSING			
1"	100	100	100			100	100
3/4"	96	99	99			98	97
1/2"	80	97	91			89	86
3/8"	70	84	77			77	74
#4	48	52	51			50	53
#8	40.0	43.0	43.0			42.0	42.0
#50	15.5	16.0	15.5			15.7	17.5
#200	4.3	5.8	4.3			4.8	4.4
AC	4.75	5.00	5.00			4.92	5.0
% AIR VOIDS	3.1	3.3	5.6			4.0	
ABSON RECOVERY							
PEN	75	78	74			76	
140 VIS.	3329	3069	3504			3301	
274 VIS.	687	567	670			641	

ROUTE: RT. 41

SECTION: 3A Texcrete

CONTRACTOR:

PRODUCER (A) T.R.I. Florence

PRODUCER (B)

PRODUCER (C)

DATE COMPLETED: 1984, DEC.

MIX NO. I-4

MIX NO.

LOT NO.	CORE NO.	LOCATION	STATION	LANE	OFF SET	DATE CUT	THICK-NESS	BULK SP. GR.	EST. \bar{V}_5^1 (%)		D _M	AIR VOIDS (%)	THICK-NESS	BULK SP. GR.	EST. \bar{V}_5^1 (%)		D _M	AIR VOIDS (%)
									LOW	HIGH					LOW	HIGH		
6	X82	T	630+73	R1	8.0	12-20	1.86	2.371	LOW	HIGH	3.1	4.5			LOW	HIGH		
6	X83	T	633+30	R2	4.0	12-18	1.43	2.395			2.508	4.5						
6	X84	T	637+27	R1	10.0	12-20	1.57	2.315			2.508	7.7						
6	X85	T	637+90	R2	3.0	12-18	1.63	2.364			2.508	5.7						
6	X86	T	642+92	R1	8.0	12-20	1.68	2.379			2.508	5.1						
							$\bar{B}_5 =$						$\bar{B}_5 =$					
6	X87	T	645+04	R2	3.0	12-18	1.71	2.357			2.508	6.0						
8	X109	T	633+32	ROS	10.0	12-17	1.60	2.315			2.508	7.7						
8	X110	T	637+71	ROS	2.0	12-17	1.60	2.356			2.508	6.1						
8	X111	T	641+72	ROS	7.0	12-17	1.73	2.342			2.508	6.6						
							$\bar{B}_5 =$				AVE. 6.0		$\bar{B}_5 =$					
4 ⁿ CORES																		
							$\bar{B}_5 =$						$\bar{B}_5 =$					

E-3

- CALC. EST. \bar{V}_5 (%) FOR EACH VOIDS LOT USING THE AVER. BLK. SP. GR. (\bar{B}_5) & THE AVER. MAX. DENSITY (\bar{D}_m), FIRST FOR THE LOW & THEN FOR THE HIGH PRODUCER
- WHEN BOTH EST. \bar{V}_5 (%) ARE WITHIN 2.5 TO 7.5, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MIXTURES WTD. AVER. MAX. DENSITY (\bar{D})
- WHEN EITHER EST. \bar{V}_5 (%) IS NOT WITHIN 2.5 TO 7.5%, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MAX. DENSITY (\bar{D}_m) FOR THAT SPECIMEN USING THE SOLVENT IMMERSION TEST METHOD.

Core Number	11	2T	3T	% PASSING		Ave.	Target
1"	100	100	100			100	100
3/4"	95	100	98			98	97
1/2"	88	92	93			91	86
3/8"	78	83	81			81	74
#4	52	56	53			54	53
#8	40.5	44.0	42.5			42.3	42.0
#50	11.5	15.0	13.5			13.3	17.5
#200	2.8	4.6	3.1			3.5	4.4
AC	4.70	4.65	4.70			4.68	5.0
% AIR VOIDS	4.3	4.4	5.2			4.6	
ABSON RECOVERY							
PEN	47	54	47			49	
140 VIS.	17163	15780	16748			16564	
274 VIS.	1964	2109	2054			2042	

8" CORES

DEC. 1984

PROJECT RT 415 sec 38 & RT 154 sec 10 TYPE OF MIX Concrete

ROUTE: 41 SECTION: 3A Solar Laglugel CONTRACTOR:

PRODUCER (A) T.R.I. Columbus PRODUCER (B) PRODUCER (C)

DATE COMPLETED: 1984, DEC. MIX NO. I-4 MIX NO.

LOT NO.	CORE NO.	LOCATION	STATION	LANE	OFF SET	DATE CUT	THICK-NESS	BULK SP. GR.	EST. \bar{V}_s (%)			THICK-NESS	BULK SP. GR.	EST. \bar{V}_s (%)			
									LOW	S.I.	HIGH			LOW	S.I.	HIGH	
6	X88	S	647+23	R1	7.0	12-20	1.81	2.349		3.1	6.2						
6	X89	S	651+33	R2	4.0	12-18	1.83	2.366		2.483	4.7						
6	X90	S	653+17	R1	11.0	12-20	1.52	2.343		2.483	5.6						
7	X91	S	656+70	R2	3.0	12-18	1.65	2.352		2.483	5.3						
7	X92	S	658+45	R1	9.0	12-20	1.55	2.364		2.483	4.8						
							$\bar{B}_5 =$						$\bar{B}_5 =$				
7	X93	S	662+70	R2	1.0	12-18	1.64	2.388		2.483	3.8						
8	X112	S	647+17	ROS	5.0	12-17	1.77	2.348		2.483	5.4						
8	X113	S	656+83	ROS	11.0	12-17	1.92	2.370		2.483	4.6						
							$\bar{B}_5 =$			AVE. 5.0			$\bar{B}_5 =$				
4" CORES																	
							$\bar{B}_5 =$						$\bar{B}_5 =$				

E-5

1. CALC. EST. \bar{V}_s (%) FOR EACH VOIDS LOT USING THE AVER. BLK. SP. GR. (\bar{B}_5) & THE AVER. MAX. DENSITY (\bar{D}_m), FIRST FOR THE LOW & THEN FOR THE HIGH PRODUCER
 2. WHEN BOTH EST. \bar{V}_s (%) ARE WITHIN 2.5 TO 7.5, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MIXTURES WTD. AVER. MAX. DENSITY (\bar{D})
 3. WHEN EITHER EST. \bar{V}_s (%) IS NOT WITHIN 2.5 TO 7.5%, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MAX. DENSITY (\bar{D}_m) FOR THAT SPECIMEN USING THE SOLVENT IMMERSION TEST METHOD.

DEC. 1984

8" CORES

Core Number	1S	2S	3S			Ave.	Target:
SIEVE				% PASSING			
1"	100	100	100			100	100
3/4"	99	98	97			98	97
1/2"	94	92	92			93	86
3/8"	80	82	80			81	74
#4	52	56	53			54	53
#8	43.0	48.0	44.5			45.2	42.0
#50	15.0	19.5	18.5			17.7	17.5
#200	4.6	6.5	5.9			5.7	4.4
AC	4.45	5.10	4.95			4.8	5.0

% AIR VOIDS	4.3	4.5	3.2			4.0	
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ABSON
RECOVERY

PEN	39	61	53			51	
140 VIS.	14,705	6118	6292			9038	
274 VIS.	1315	931	923			1056	

ROUTE: 41 SECTION: 3A 3M'S #5990 CONTRACTOR:

PRODUCER (A) T.R.I. COLUMBUS PRODUCER (B) PRODUCER (C)

DATE COMPLETED: 1984, DEC. MIX NO. T-4 MIX NO.

LOT NO.	CORE NO.	LOCATION	STATION	LANE	OFF SET	DATE CUT	THICK-NESS	BULK SP. GR.	EST. \bar{V}_5 (%)		AIR \bar{V}_5 (%)	THICK-NESS	BULK SP. GR.	EST. \bar{V}_5 (%)		AIR \bar{V}_5 (%)	
									LOW	HIGH				LOW	HIGH		
7	X94	M	666+03	R1	5.0	12-20	1.80	2.338		5+	4.9						
7	X95	M	667+32	R2	9.0	12-18	1.83	2.370		2.455	3.5						
7	X96	M	671+03	R1	2.0	12-20	1.73	2.302		2.755	6.2						
7	X97	M	672+79	R2	8.0	12-18	1.55	2.375		2.755	3.3						
7	X98	M	676+28	R1	5.0	12-20	2.29	2.349		2.455	4.3						
							$\bar{B}_5 =$					$\bar{B}_5 =$					
7	X99	M	679+11	R2	11.0	12-18	1.73	2.286		2.455	6.9						
8	X114	M	663+96	ROS	8.0	12-17	1.66	2.313		2.455	5.8						
8	X115	M	668+83	ROS	4.0	12-17	1.55	2.348		2.455	4.4						
8	X116	M	672+15	ROS	11.0	12-17	0.85	2.231		2.455	9.1						
8	X117	M	679+94	ROS	3.0	12-17	1.72	2.392		2.455	2.6						
							$\bar{B}_5 =$					$\bar{B}_5 =$					
8	X118	M	681+09	ROS	3.0	12-17	1.63	2.298		2.455	6.4						
											AVE.	5.2					
4" CORES																	
							$\bar{B}_5 =$					$\bar{B}_5 =$					

E-7

- CALC. EST. \bar{V}_5 (%) FOR EACH VOIDS LOT USING THE AVER. BLK. SP. GR. (\bar{B}_5) & THE AVER. MAX. DENSITY (\bar{D}_m), FIRST FOR THE LOW & THEN FOR THE HIGH PRODUCER.
- WHEN BOTH EST. \bar{V}_5 (%) ARE WITHIN 2.5 TO 7.5, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MIXTURES WTD. AVER. MAX. DENSITY (\bar{D}_m)
- WHEN EITHER EST. \bar{V}_5 (%) IS NOT WITHIN 2.5 TO 7.5%, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MAX. DENSITY (\bar{D}_m) FOR THAT SPECIMEN USING THE SOLVENT IMMERSION TEST METHOD.

8" CORES

Core Number	1M	2M	3M			Ave.	Target
SIEVE				% PASSING			
1"	100	100	100			100	100
3/4"	97	89	98			95	97
1/2"	87	85	92			88	86
3/8"	78	74	81			78	74
#4	51	48	53			51	53
#8	41.5	37.5	40.5			39.8	42
#50	14.5	14.5	14.0			14.3	17.5
#200	4.2	5.4	5.0			4.9	4.4
AC	5.00	4.85	5.05			4.97	5.0

% AIR Voids	4.2	5.4	4.8			4.8	
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ABSON
RECOVERY

PEN	35	33	39			36	
140 VIS.	10,619	13,426	12,972			12,339	
274 VIS.	1019	1002	1113			1045	

ROUTE: 41							SECTION: 3A Plus Ride					CONTRACTOR:				
PRODUCER (A) T.R.I. Columbus							PRODUCER (B)					PRODUCER (C)				
DATE COMPLETED: 1984, DEC.							MIX NO.					MIX NO.				
LOT NO.	CORE NO.	LOCATION	STATION	LANE	OFF SET	DATE CUT	THICK-NESS	BULK SP. GR.	EST. \bar{V}_5 (%)	\bar{D}_M	AIR VOIDS (%)	THICK-NESS	BULK SP. GR.	EST. \bar{V}_5 (%)	\bar{D}_M	AIR VOIDS (%)
7	X100	P	683+41	R1	9.0	12-20	1.58	2.291	LOW HIGH	5.1 2.320	1.2			LOW HIGH		
7	X101	P	686+38	R2	3.0	12-18	1.63	2.276		2.331	2.4					
7	X102	P	688+98	R1	7.0	12-20	1.44	2.242		2.331	3.8					
7	X103	P	690+96	R2	4.0	12-18	1.50	2.288		2.331	1.8					
7	X104	P	694+79	R1	10.0	12-20	1.96	2.264		2.331	2.9					
							$\bar{B}_5 =$					$\bar{B}_5 =$				
7	X105	P	697+77	R2	3.0	12-18	1.77	2.278		2.331	2.3					
8	X119	P	691+00	ROS	6.0	12-17	1.60	2.180		2.331	6.5					
8	X120	P	694+25	ROS	5.0	12-17	1.22	2.260		2.331	3.0					
4" CORES							$\bar{B}_5 =$			AVE. 3.0		$\bar{B}_5 =$				
							$\bar{B}_5 =$						$\bar{B}_5 =$			

E-9

1. CALC. EST. \bar{V}_5 (%) FOR EACH VOIDS LOT USING THE AVER. BLK. SP. GR. (\bar{B}_5) & THE AVER. MAX. DENSITY (\bar{D}_m), FIRST FOR THE LOW & THEN FOR THE HIGH PRODUCER
 2. WHEN BOTH EST. \bar{V}_5 (%) ARE WITHIN 2.5 TO 7.5, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MIXTURES WTD. AVER. MAX. DENSITY (\bar{D}_m)
 3. WHEN EITHER EST. \bar{V}_5 (%) IS NOT WITHIN 2.5 TO 7.5%, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MAX. DENSITY (\bar{D}_m) FOR THAT SP. SOLVENT IMMERSION TEST METHOD.

DEC. 1904

8" CORES

Core Number	1P	2P	3P			Ave.	Target
SIEVE				% PASSING			
1"	100	100	100			100	100
3/4"	97	95	94			95	96
1/2"							
3/8"	63	62	59			61	57
1/4"	50	50	44			48	37
#10	28	29	28			28	25.5
#30	22	22	22			22	18.5
#200	10.5	9.5	8.9			9.6	9.8
AC	7.1	7.5	7.5			7.4	7.7

% AIR VOIDS	2.6	0.3	3.4			2.1	
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ABSON
RECOVERY

PEN	68	92	73			78	
140 VIS.	4448	2130	3416			3331	
274 VIS.	688	542	587			606	

ROUTE: 41

SECTION: 3A

CONTRACTOR: CONTROL

PRODUCER (A) T.R.I. FLORENCE		PRODUCER (B) T.R.I. RUNNEMEDE		PRODUCER (C)					
LOT NO.	CORE NO.	LOCATION	STATION	LANE	DATE CUT	MIX NO. I-4		MIX NO.	
						THICKNESS	BULK SP. GR.	EST. V ₅ (%)	THICKNESS
1	X4	C'	594+13	R2	12-18	1.47	2.383	2.452	2.8
1	X6	C'	601+54	R2	12-18	1.63	2.387	2.452	2.6
9	X123	C'	600+25	ROS	12-17	1.16	2.351	2.452	4.1
9	X124	C'	604+04	ROS	12-17	1.99	2.400	2.452	2.1
9	X125	C'	611+30	ROS	12-17	1.81	2.340	2.452	4.6
						$\bar{B}_5 =$		AVE. 3.2	
1	X5	C	598+67	R1	12-20	1.66	2.381	2.452	2.9
1	X7	C	605+75	R1	12-20	2.21	2.386	2.452	2.7
1	X8	C	608+32	R2	12-18	1.59	2.342	2.452	4.5
						$\bar{B}_5 =$		AVE. 3.4	
4" CORES									
						$\bar{B}_5 =$			

1. CALC. EST. V₅ (%) FOR EACH VOIDS LOT USING THE AVER. BLK. SP. GR. (\bar{B}_5) & THE AVER. MAX. DENSITY (\bar{D}_m), FIRST FOR THE LOW & THEN FOR THE HIGH PRODUCER.
 2. WHEN BOTH EST. V₅ (%) ARE WITHIN 2.5 TO 7.5, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MIXTURES WTD. AVER. MAX. DENSITY (\bar{D}_m).
 3. WHEN EITHER EST. V₅ (%) IS NOT WITHIN 2.5 TO 7.5, COMPUTE THE AIR VOIDS FOR EACH SPECIMEN USING THE BLK. SP. GR. & THE MAX. DENSITY (\bar{D}_m) FOR THAT SPECIMEN USING THE IMMERSION TEST METHOD.

DEC. 1984

8" CORES

Core Number	1C	2C	3C			Ave.	Target
SIEVE				% PASSING			
1"	100	100	100			100	100
3/4"	98	98	95			97	98
1/2"	92	93	85			90	87
3/8"	77	74	71			74	70
#4	52	46	50			49	50
#8	43.5	40.0	44.5			42.7	41.0
#50	15.5	13.0	15.0			14.5	16.0
#200.	5.1	4.7	5.1			5.0	4.7
AC	4.60	4.55	4.65			4.6	5.0
% AIR VOIDS	4.8	5.4	3.1			4.4	
ABSON RECOVERY							
PEN	46	58	52			52	
140 VIS.	11,327	5992	6690			8003	
274 VIS.	1137	835	938			987	

8" CORES

Core Number	1c'	2c'	3c'			Ave.	Target
SIEVE				% PASSING			
1"	100	100	100			100	100
3/4"	93	95	98			95	98
1/2"	83	89	87			86	87
3/8"	70	77	75			74	70
#4	46	51	50			49	50
#8	38.0	40.5	42.0			40.2	41.0
#50	15.0	16.5	16.5			16.0	16.0
#200	4.9	5.7	5.8			5.5	4.4
AC	4.70	4.75	4.95			4.8	5.0
% AIR VOIDS	4.7	5.2	3.8			4.6	
ABSON RECOVERY							
PEN	49	38	46			44	
140 VIS.	7825	11,778	9647			9749	
274 VIS.	923	1091	1000			3014	

APPENDIX F
INDIRECT TENSILE TEST METHOD

NEW JERSEY DEPARTMENT OF TRANSPORTATION
INDIRECT TENSILE TEST (Ref. 4)

The indirect tensile test involves loading a cylindrical specimen with compressive loads that act parallel to and along the vertical diametrical plane at room temperature. To distribute the load and maintain a constant loading area, the compressive load is applied through a 0.75-inch wide steel loading strip that is curved at the interface with the specimen and has a radius equal to that of the specimen. This loading configuration develops a relatively uniform tensile stress perpendicular to the direction of the applied load and along the vertical diametrical plane that ultimately causes the specimen to fail by splitting or rupturing along the vertical diameter (see Figure F-1). By measuring the applied load at failure and by continuously monitoring the loads and the horizontal and vertical deformations of the specimen, one can estimate indirect tensile strength.

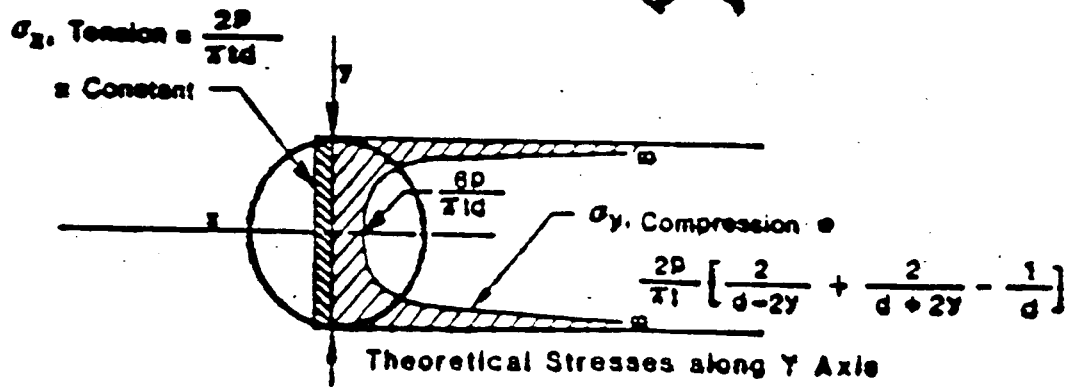
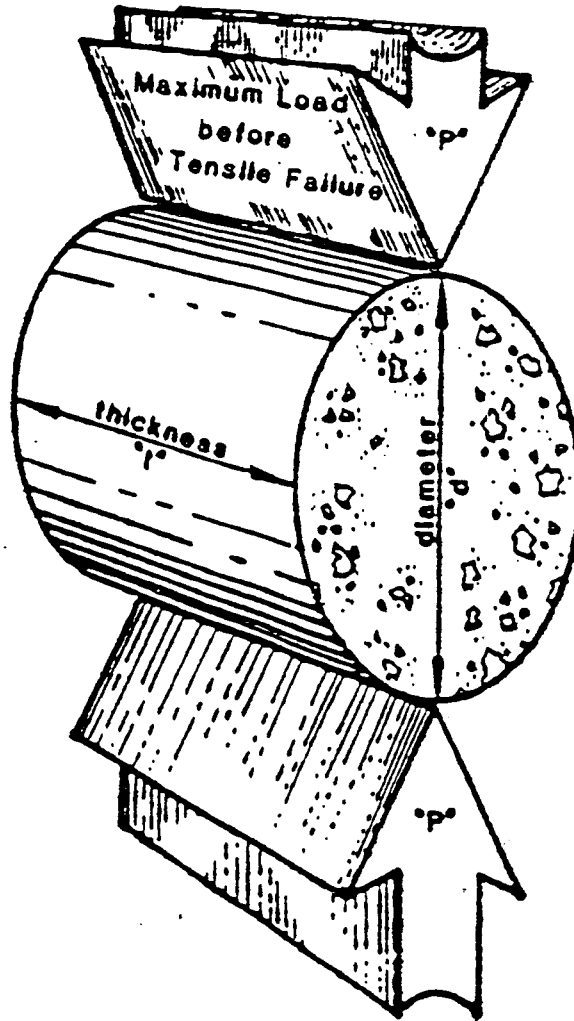
Test Equipment

The basic testing apparatus includes a loading system and a means of measuring the applied loads, horizontal deformations of the specimens, and vertical deformations of the specimens.

The loading system consists of loading equipment, a loading device, and loading strips. The external load can be supplied by any loading system that can apply compressive loads preferably at a prescribed loading rate. Ideally, a closed loop electrohydraulic system should be used to accurately control the loading rate. A relatively high deformation rate should be used to simulate rapidly applied pavement loadings. A deformation rate of 2 in./min. has been used.

Some type of loading device should be used to ensure that the loading platens and strips remain parallel during the test. A loading device that has

FIGURE F-1. INDIRECT TENSILE STRENGTH TEST



proved to be satisfactory is a modified, commercially available die set with upper and lower platens constrained to remain parallel during the test. Mounted on the upper and lower platens are 0.75 in. wide steel loading strips with a curved loading surface whose radius of curvature is equal to the radius of the specimen.

Deformation-and-Load-Measuring Equipment

Preferably, the load should be measured by a load cell to obtain electrical readouts that can be recorded continuously. Horizontal deformations of the specimens are measured by using a device basically consisting of 2 cantilevered arms with attached strain gauges. Deformation of the specimen or deflection of the arms at points of contact with the specimen has been calibrated with the output from the strain gauges mounted on the arms.

Vertical deformations are measured by a direct-current LVDT. The LVDT also can be used to control the vertical deformation rate during the test by providing an electrical signal related to the relative movements of the upper and lower platens if a closed-loop electrohydraulic load system is used.

Specimen Preparation

Marshall plug specimens can be tested. However, care should be exercised to ensure that the specimen does not have significant surface irregularities that will interfere with the proper seating contact between the specimen and the loading strips.

Test Procedure

Six steps make up the indirect tensile test procedure.

1. Determine the height and diameter of the specimen.
2. Carefully center the specimen on the lower loading strip.
3. Slowly lower the upper platen until light contact is made between the specimen and the upper loading strip.
4. Place the horizontal deformation measuring device with light contact between the arms and the specimen.
5. Load the specimen at a constant deformation rate.
6. Record the load versus horizontal deformation and load versus vertical deformation.

Calculation of Indirect Tensile Strength

The indirect tensile strength is then calculated in the following manner:

$$\text{Indirect tensile strength} = \frac{2P}{\pi t d}$$

where:

- P = maximum load before tensile failure
- t = thickness of the Marshall plug
- d = diameter of the Marshall plug.