Standard Title Page — Report on State Project

Report No.	Report Date	No. Pages	Type Report:	Project No. :
VTRC 91-IR6	June 1991	23	Interim	9251–020
			Period Covered:	Contract No. :

561

Title and Subtitle

Evaluation of Novophalt as an Additive in Asphalt

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Key Words

Polymer, rutting, Marshall, viscosity, voids, gyratory testing machine, creep test, resilient modulus, indirect tensile strength

Supplementary Notes

Abstract

Novophalt, which is an ethylene vinyl acetate polymer, was used as an asphalt additive in a test section in an attempt to determine whether it is useful in the prevention of rutting. A special blending unit was required to blend the asphalt cement and polymer at the hot mix plant; however, construction of the control and polymer test sections went smoothly with no problems. Various laboratory tests on the mixtures with and without polymer revealed some possible mixture deficiencies, which could cause pavement distress in the future.

Measurements 10 months after construction revealed excessive rutting in one section containing polymer. A follow-up coring investigation revealed that most of the rutting was confined to the underlying base mixture and was caused by a lack of control of aggregate gradation and asphalt content.

INTERIM REPORT

EVALUATION OF NOVOPHALT AS AN ADDITIVE IN ASPHALT

G. W. Maupin, Jr.

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the
Virginia Department of Transportation and
the University of Virginia)

Charlottesville, Virginia

June 1991
VTRC 91-IR6

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INTERIM REPORT

EVALUATION OF NOVOPHALT AS AN ADDITIVE IN ASPHALT

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INTRODUCTION

The rutting of pavements has worsened over the last few years because of increased traffic loads and increased tire pressures.[1,2] Considerable effort is now being made to improve the design procedures and specifications for asphalt concrete in order to cope with these problems. One of the possible solutions to the problem that has received a lot of attention is the development of various asphalt additives to improve serviceability by modifying the characteristics of the binder.

During high summer temperatures, the viscosity of asphalt binders may be reduced to a level that allows the pavement to deform excessively under traffic. Although hard asphalt cements can be used to counteract this problem, a second problem of cracking during cold temperatures is usually created. An ideal binder should possess high viscosity at high temperature and low viscosity at low temperature (low temperature susceptibility). Rubber and plastic additive are often added to asphalt cement as a means of increasing flexibility and reducing the temperature susceptibility of the asphalt concrete.

Although laboratory tests are used to demonstrate the benefits of using additives, field installations and follow-up performance evaluations are the most reliable method of judging their overall benefits. In 1986, test installations were installed and evaluated in the Lynchburg District. These installations included binders modified with three rubber polymers and one plastic polymer, an ethylene vinyl acetate. In 1989, the New Products Committee of the Virginia Department of Transportation asked the Research Council to evaluate another plastic polymer in a test section that was constructed in the Salem District. This plastic polymer was a polyolefin, and its performance would not necessarily be expected to be the same as that of the ethylene vinyl acetate because of differences in chemical make-up. This report describes the installation, test results, and performance (to date) of the 1989 test section, which uses Novophalt binder.

DESCRIPTION OF TEST SECTION

The test installation was included as part of a new construction project (6220-011-104, C-501) and is located at the intersection of Route 220 and Route 11 in the Salem District. It consisted of two sections of surface mixture (the control) and two sections of surface mixture containing Novophalt modified asphalt binder. In order to equalize the effect of traffic on both mixes, the sections were placed in a checkerboard fashion (see Figure 1). The typical cross section for the pavement is shown in Figure 2. The rate of application of the surface mixture was specified as 165 lb/yd^2, which is equivalent to 1.5 in thick, and the specified thickness of the asphalt base was 6.0 in.

MIXTURE DESIGNS

The design for the control and Novophalt surface mixtures, which were designed with a 75-blow Marshall compactive effort, is contained in Table 1. The binder for the control mixture was an AC-20 asphalt cement, and the binder for the experimental mixture was an AC-20 asphalt cement combined with 5 percent Novophalt. The base mixture design is also contained in Table 1. All mixtures contained 1 percent of hydrated lime as an antistripping additive. The sources of the materials are listed in Table 2.

CONSTRUCTION

The test sections were constructed on December 5-6, 1989, by Adams Construction Company of Roanoke Virginia in the sequence shown in Figure 3. Sections 1 and 2 were placed on December 5, and the remaining sections were placed on December 6. Although the paving was done in December, the air temperature was more than 50°F at all times.

A special blending unit was furnished by the Novophalt supplier at the asphalt concrete plant to blend the asphalt cement and Novophalt. No special equipment was required to place the mixtures. Compaction was accomplished with a 12-ton 3-wheel breakdown roller and an 8- to 10-ton vibratory finish roller operated in the static mode.

The temperatures of the control and Novophalt mixtures averaged 310°F to 315°F in the truck at the road and approximately 250°F on the mat surface behind the breakdown roller. These temperatures were obtained with an infrared thermometer, which measures the surface temperature; therefore, the temperature of the mixtures below the surface was probably slightly higher.

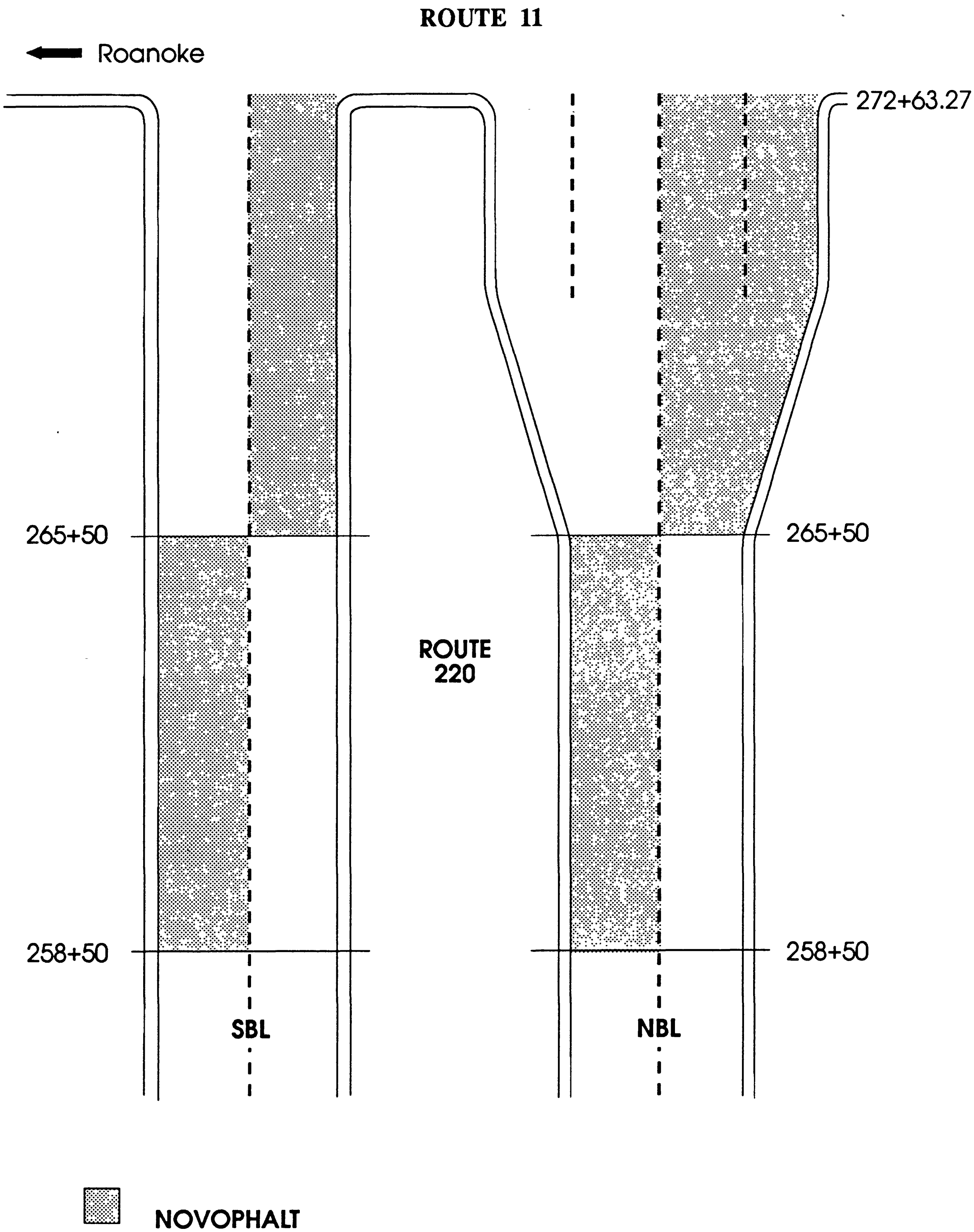
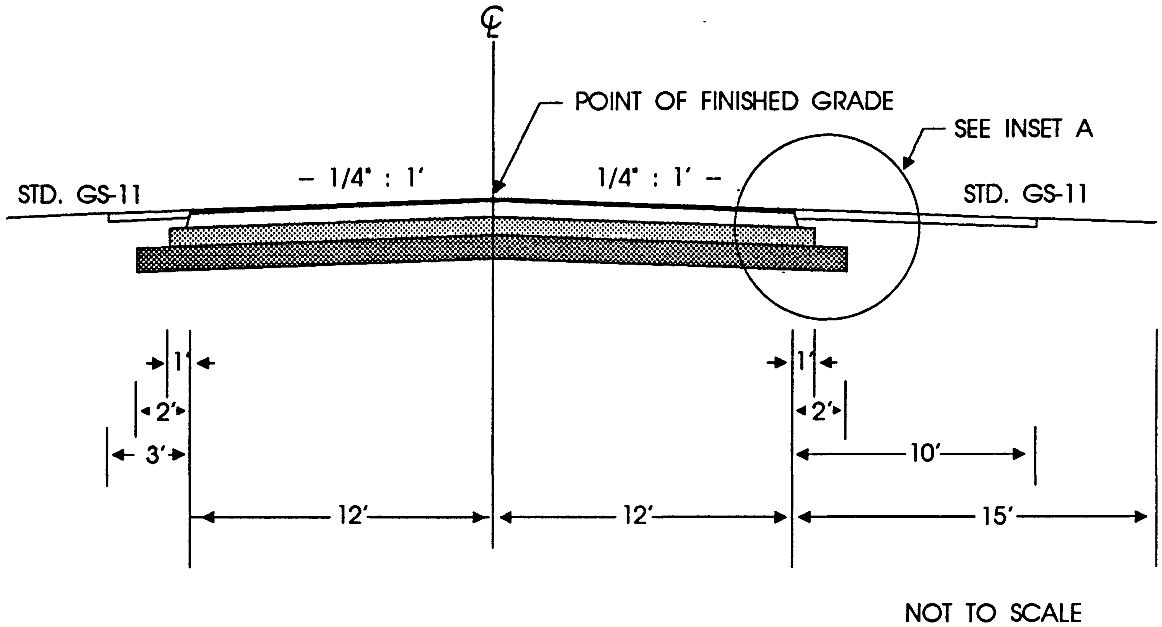
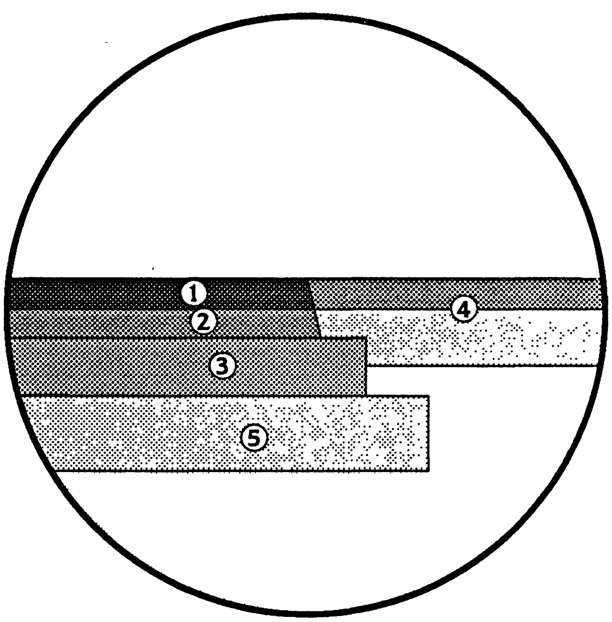


Figure 1. Location of test section.





INSET A

① ASPHALT CONCRETE SURFACE COURSE TYPE S-5 MOD., 165 LBS. PER SQ. YD.

② 6" ASPHALT CONCRETE BASE COURSE TYPE B-3

③ 6" CEMENT STAB. AGGREGATE BASE MATERIAL TYPE I NO. 21A OR 21B, 4% CEMENT BY WEIGHT (FOR SUBBASE)

④ STABILIZED SHOULDER
6" AGGR. BASE MAT'L TYPE I, NO. 21B WITH 3" ASPHALT CONC. BASE COURSE TY. B3, TO BE SEALED WITH LIQUID ASPHALT MAT'L CRS-2 AT THE RATE OF 0.35 GAL./SY. AND COVERED WITH COVER MAT'L NO.8 AT THE RATE OF 18 LBS. PER SQ. YD.

⑤ 8" AGGREGATE BASE MATERIAL TYPE I NO. 21B (FOR SUBBASE)

Figure 2. Typical cross section.

Table 1

MIXTURE DESIGN

Sieve	% Passing Surface	% Passing Base
1 1/2 in		100
3/4 in		69–77
1/2 in	97–100	
#4	53–61	38–46
#8		25–33
#30	20–26	
#200	4.2–6.2	3.9–5.9
Asphalt (percent)	4.9–5.5	4.1–4.7

Table 2

SOURCES OF MATERIALS

Surface Mixture		
50% #8's	Danville Vulcan Materials	Danville, Va.
20% Sand	Eden Sand Co.	Eden, N.C.
30% #10's	Martinsville Stone Co.	Fieldale, Va.
1.0% Hyd. Lime*	Virginia Lime Co.	Ripplemead, Va.
5.2% AC-20	Fuel Oil & Equipment Co.	Roanoke, Va.
5% Novophalt**	Novophalt America Inc.	Sterling, Va.
* By weight of aggregate ** By weight of asphalt cement		
Base Mixture		
30% B-3 Coarse Agg.	Blue-Ridge Stone	Blue Ridge, Va.
30% #68's	Blue-Ridge Stone	Blue Ridge, Va.
40% #10's	Blue-Ridge Stone	Blue Ridge, Va.
1% Hyd. Lime	Virginia Lime Co.	Ripplemead, Va.
4.4% AC-20	Fuel Oil & Equipment Co.	Roanoke, Va.

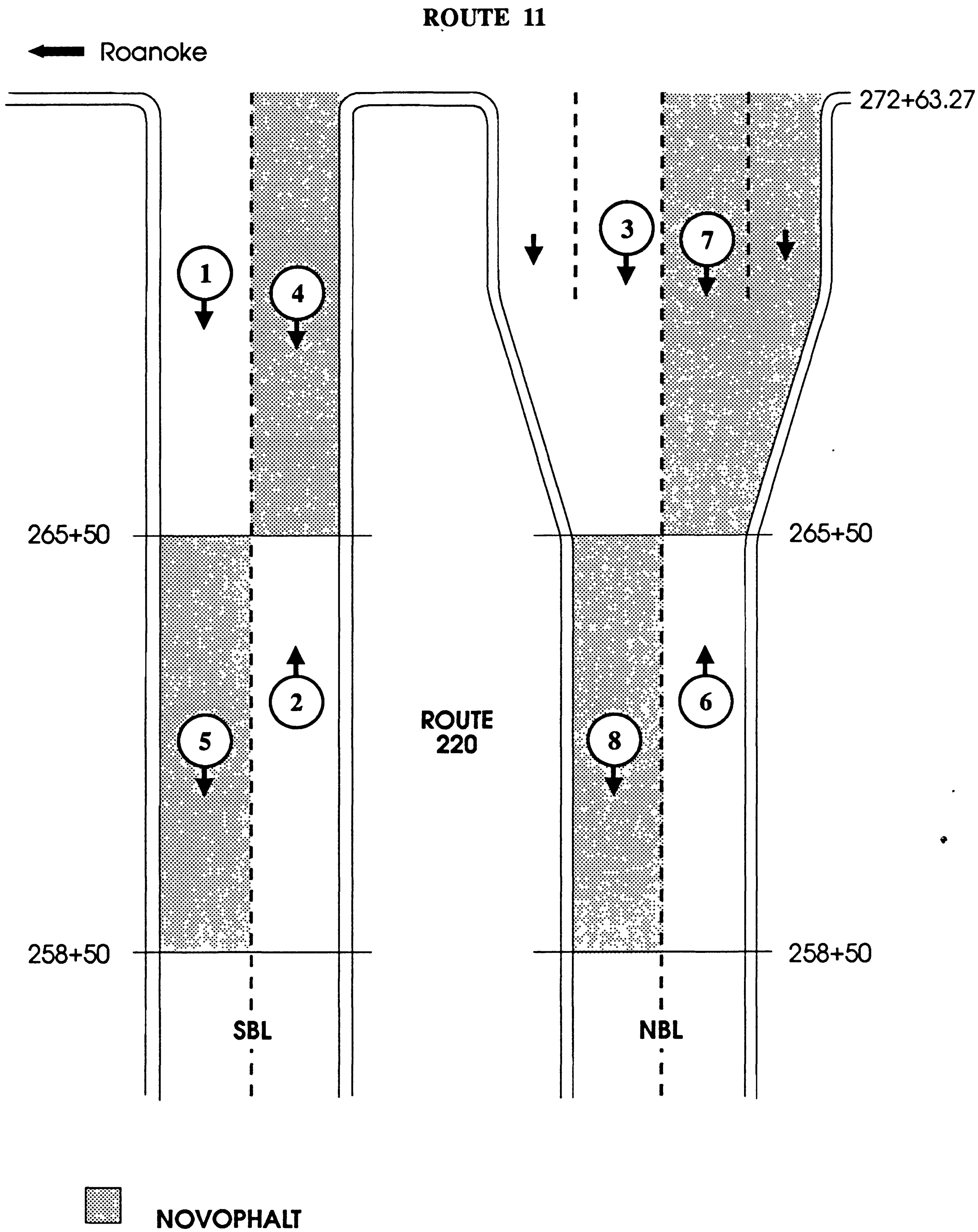


Figure 3. Paving sequence.

TESTING

Laboratory

Samples of the surface mixture and liquid binder were taken during construction and tested in the laboratory.

Viscosity Tests

Viscosity tests were performed on the binders when they were at 140°F and 275°F according to ASTM test methods D2171 and D2170[3], respectively. The results listed in Table 3 reveal that the addition of the polymer increased the viscosity of the binder at both 140°F and 275°F to approximately 150 percent of the original values. The increased viscosity should make the asphalt concrete mixture less susceptible to permanent deformation during high summer temperatures.

Extraction and Gradation Tests

Reflux extraction and gradation tests were performed on samples of plant mixture according to test methods ASTM D2172[3] and AASHTO T30-84.[4]

The results of tests by the Transportation Research Council and by the Virginia Department of Transportation's Salem District Materials Lab are listed in Table 4. The gradation of both mixtures is slightly finer than the design gradation. The Novophalt mixture tested by the Research Council had a much larger amount of material passing the No. 200 sieve.

Marshall Tests

Marshall tests were performed on samples of plant mixture according to ASTM D1559[3] using a 75-blow compactive effort. Determinations were made for voids in the total mixture (VTM), voids filled with asphalt (VFA), voids in the mineral aggregate (VMA), and stability (see Table 5). Also, the Virginia specifications and design criteria suggested by the Asphalt Institute are given. The Marshall

Table 3

VISCOSITY OF BINDERS

Binder	140°F	275°F
AC-20	1,886	410
Novophalt	4,761	1,018

Table 4

GRADATION OF MIXTURES SAMPLED DURING CONSTRUCTION

Sieve	Job Mix	% Passing Tests by Research Council Novophalt	Tests by Research Council Control	Tests by Salem District* Novophalt	Tests by Salem District* Control
1/2 in	100.0	100.0	100.0	100.0	100.0
3/8 in	——	94.8	93.0	95.0	95.0
#4	57.0	59.2	49.5	57.5	59.0
#8	——	43.2	36.6	41.5	43.0
#30	23.0	27.6	23.2	25.0	25.5
#50	——	19.7	16.5	17.0	17.5
#100	——	14.0	11.3	11.0	11.0
#200	5.2	9.4	6.7	6.2	6.8

*Average of 2 tests per mixture

Table 5

Marshall Limits and Results of Tests on Plant Mixtures

	VTM (%)	VFA (%)	VMA (%)	Stability (lb)
Virginia DOT	4–8*	60–75*	——	——
Asphalt Institute	3–5**	——	>14.5	>1500
Control Mixture	3.2	80.2	16.3	4060
Novophalt Mixture	4.5	71.9	15.9	3690

* Production limits
**Design limits

properties of both mixtures were within all criteria with the exception of the VFA for the control mixture, which was high. A high VFA indicates that the mixture possibly contained too much binder.

Core Voids

Determinations of specific gravity on cores removed from each section were performed according to AASHTO T166-83[4] to obtain VTM results (see Table 6).

There was no significant difference at a 95 percent confidence level between the average VTM of the control sections (10.8 percent) and the average VTM of the Novophalt sections (10.2 percent). The variability of VTM within some sections is higher than normal, possibly because such short sections were involved. As mentioned previously, the gradations of samples tested by the Research Council and the

Table 6

VOIDS (VTM) IN CORES TAKEN AFTER CONSTRUCTION (%)

Section	$\overline{X}$*	s**
1 Control	8.9	0.65
2 Control	12.9	1.11
3 Control	9.9	2.09
6 Control	11.3	1.84
4 Novophalt	8.4	2.28
5 Novophalt	10.6	1.65
7 Novophalt	9.2	2.43
8 Novophalt	12.6	0.98

* Average
** Standard Deviation

Salem District Materials Lab differed significantly for the Novophalt mixture, which was one of the sections with a high variability of VTM.

Gyratory Testing Machine

The gyratory testing machine (GTM) was used to test the mixtures according to ASTM D3387.[3] An initial gyratory angle of 1° and a vertical pressure of 120 psi (using the oil-filled mode of operation) was employed to give strength, compaction, and strain information. The specimens were compacted until the rate of compaction decreased to 1 pcf per 100 revolutions, which simulates the maximum compaction that the mixture will be subjected to under traffic. The three properties used to characterize the mixtures were final voids, shear strength, and gyratory stability index (GSI). According to the developer of the equipment, the air voids should be greater than 3 percent, the shear strength should be greater than 38 psi, and the GSI, which is an indicator of whether the mixture will undergo plastic deformation, should be less than 1.1.

The results of the GTM tests are presented in Table 7. The predicted VTM for the control pavement after traffic was less than the allowable, which indicates a potential for overdensification and bleeding. The shear strength for the Novophalt mixture was less than the allowable and only slightly above the minimum for the control mixture. The GSI result of the control mixture was 1.1, which is the maximum allowable value; therefore, this sample may have been rich in asphalt or fines, which apparently act as an asphalt extender in this mixture. These results indicate that both the control mixture and the Novophalt mixture had some deficiencies that could lead to future overdensification and instability in the pavement.

Compression Creep Test

Compression creep tests were performed on 2.5-in-thick by 4-in-diameter specimens prepared on the GTM to simulate the VTM of the pavement immediately

Table 7

RESULTS OF GTM TESTS

Mixture	Shear Strength (psi)	GSI	VTM (%)
Suggested Limits	>38	<1.10	>3.0
Control	39	1.10	2.5
Novophalt	32	1.07	3.7

after construction (approximately 10 percent). The tests were conducted at 104°F using an axial loading of 30 psi for 60 min. The specimens were preloaded for 2 min, unloaded, and allowed to rest for 5 min before the test load was applied. Axial deformation was recorded in order to develop a strain-time curve, and after 60 min, the load was removed, and the recovered deformation was recorded for an additional 60 min. The primary properties of interest were stiffness modulus after 60 min of loading and unrecovered axial strain after 60 min of relaxation.

The creep test results are listed in Table 8. The moduli are a measure of the ability of the mixture to resist deformation under static loading, and the unrecovered strain is a measure of the inability of the mixture to rebound completely from deformation when the load is removed. There was no significant difference at a 95 percent confidence level in the average values for the two mixtures; therefore, no difference in the ability of the mixtures to resist slow-moving loads is predicted by this test.

Table 8

CREEP TEST RESULTS

Mixture	Modulus at 60 min (psi)	Unrecovered Strain (%)
Control	6,670	0.200
Novophalt	7,810	0.128

Resilient Modulus and Indirect Tensile Strength

"The resilient modulus is the ratio of repeated stress to corresponding recoverable strain during loading."[5] The resilient modulus test, which is a dynamic test, produces results that represent the moduli of asphalt under traffic loading better than tests with static or slow loading.

The resilient modulus test at 104°F was performed with the Schmidt device (ASTM D4123)[3] using the same specimens that were used in the creep test. The moduli were computed using the following formula:

$$MR = P(\mu + 0.273)/tD$$

where:

MR = resilient modulus (psi)

P = applied load (lb)

μ = Poisson's ratio (assume 0.35)

t = thickness of specimen (in)

D = horizontal deformation (in).

The indirect tensile strengths were determined using the same specimens as used in the previous two tests. The tests were performed at 104°F at a vertical deformation rate of 2 in/min. The strength was computed by

$$ST = 2P_u/td$$

where:

P_u = ultimate applied load required to fail the specimen (lbf)

t = thickness of specimen (in)

d = diameter of specimen (in).

The resilient moduli and indirect tensile strengths are listed in Table 9. There was a significant difference at a 95 percent confidence level between the averages of resilient modulus for the two mixtures and also between the averages of indirect tensile strength. The higher values for the Novophalt mixture indicate a tendency of the Novophalt mixture to resist deformation better than the control mixture.

Table 9

RESILIENT MODULI AND INDIRECT TENSILE STRENGTH

Mixture	Resilient Modulus (psi)		Indirect Tensile Strength (psi)	
	$\bar{X}$	σ	$\bar{X}$	σ
Control	70000	2100	52	2.3
Novophalt	119000	21600	67	5.9

Field Tests

The transverse profile of each section was measured with a Dipstick Road Profiler immediately after construction and again after being under traffic for one summer to determine the rutting that was taking place. The Dipstick Profiler is an electronic device that is walked across the pavement to measure the profile of the surface.

The profiles that were developed for each of the sections are shown in Figures 4 through 13. The profiles of the sections adjacent to the intersection were measured 40 ft from the intersection, and those for the sections farthest from the intersection were measured at midsection. Each of the sections will be measured at the same locations during future surveys to detect further rutting.

The rut depth of the sections farthest from the intersection was generally less than 0.2 in, which is not considered to be a problem. However, rut depth increases in the sections in the northbound lane near the intersection. This increase is to be expected because the traffic stops here for the light. The northbound traffic lane that contained the Novophalt mixture had rutting approaching 1 in, which is severe. Although the traffic has not been counted, it is believed that this lane is subjected to much more truck traffic than the other lanes.

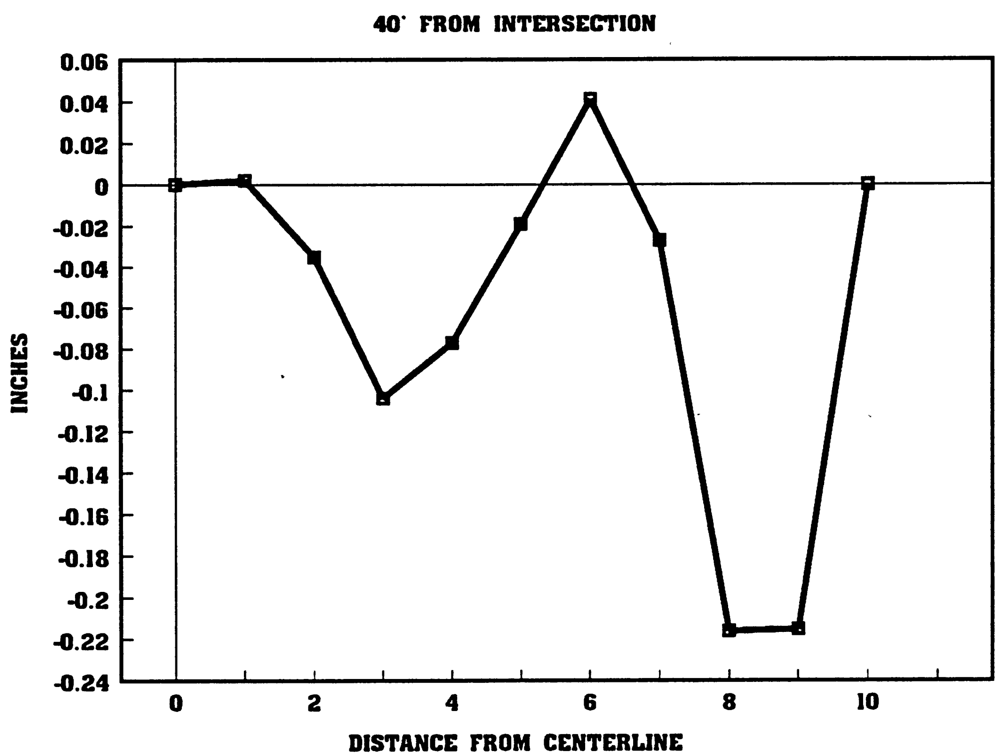


Figure 4. Rte. 220 profile: control (SBTL).

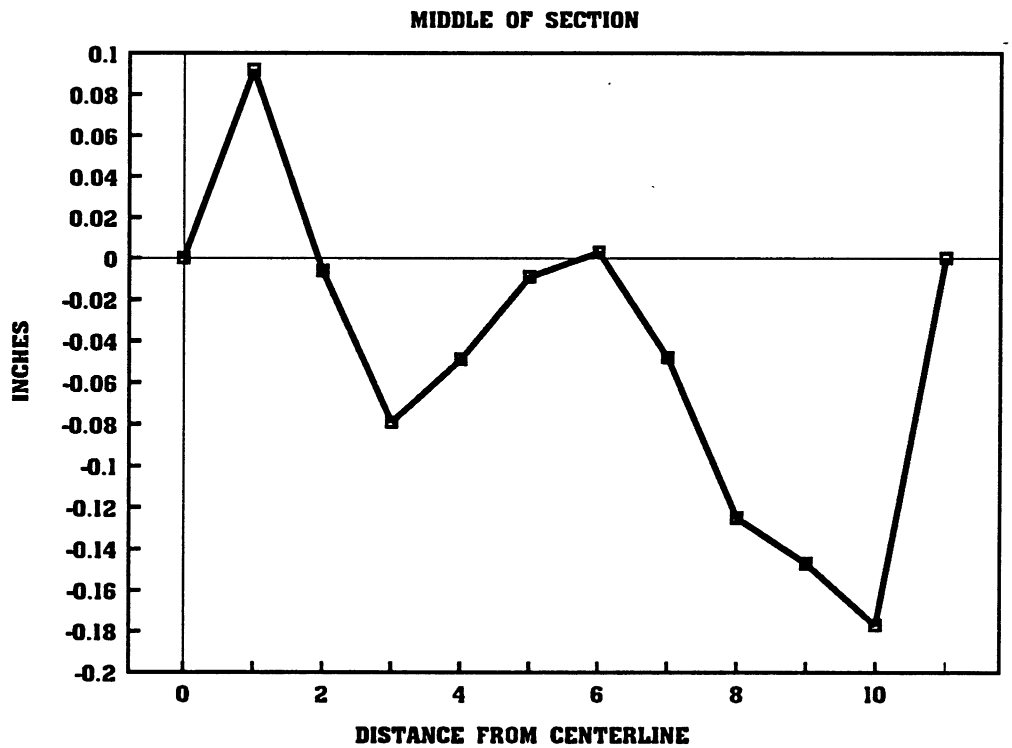


Figure 5. Rte. 220 profile: Novophalt (SBTL).

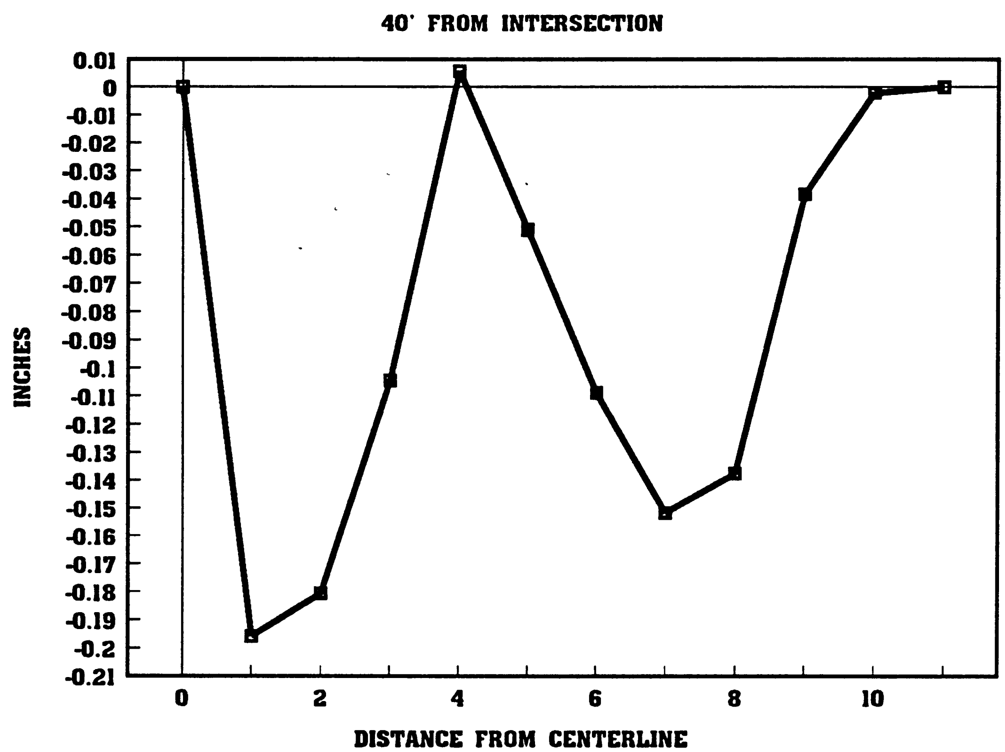


Figure 6. Rte. 220 profile: Novophalt (SBPL).

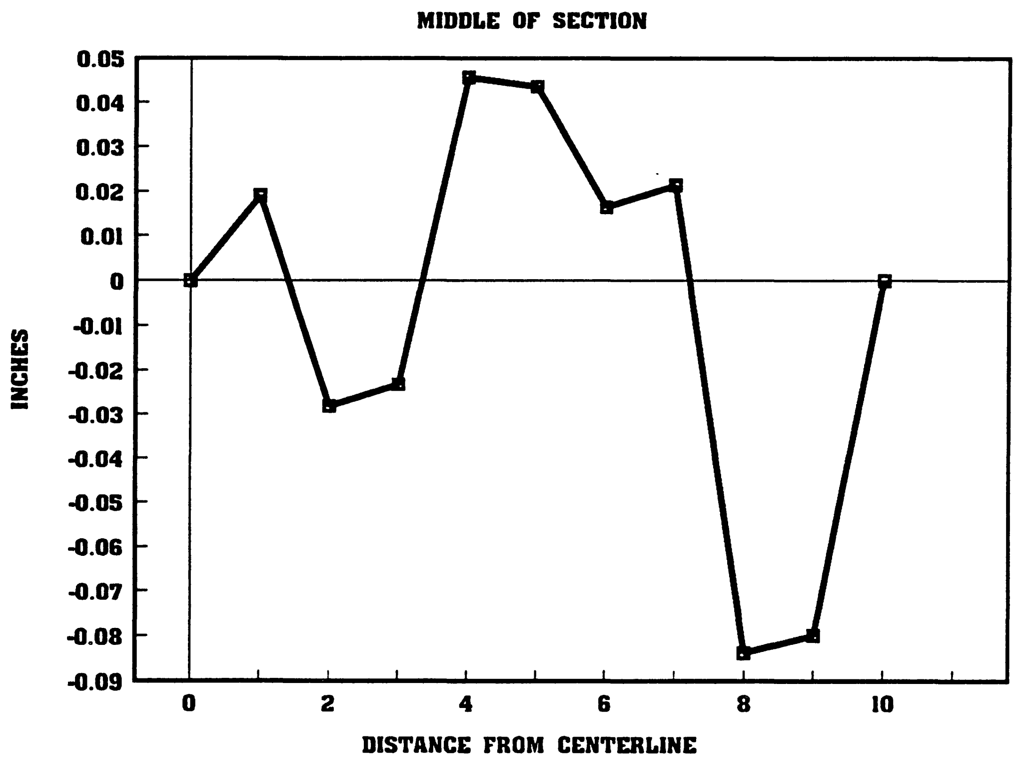


Figure 7. Rte. 220 profile: control (SBPL).

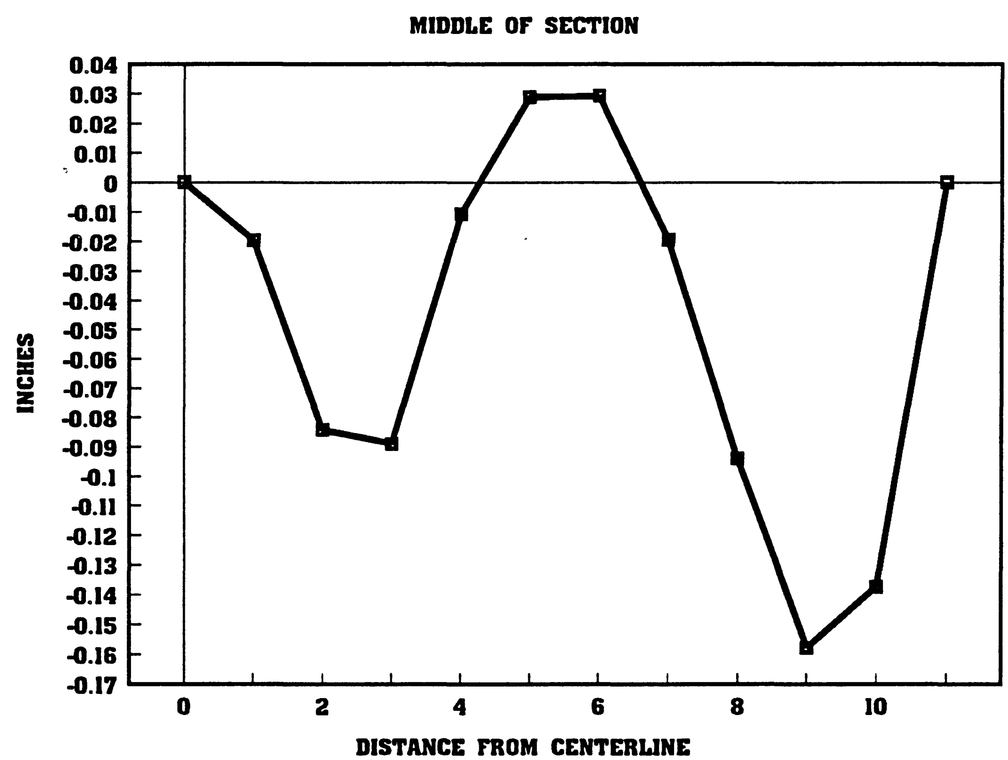


Figure 8. Rte 220 profile: control (NBTL).

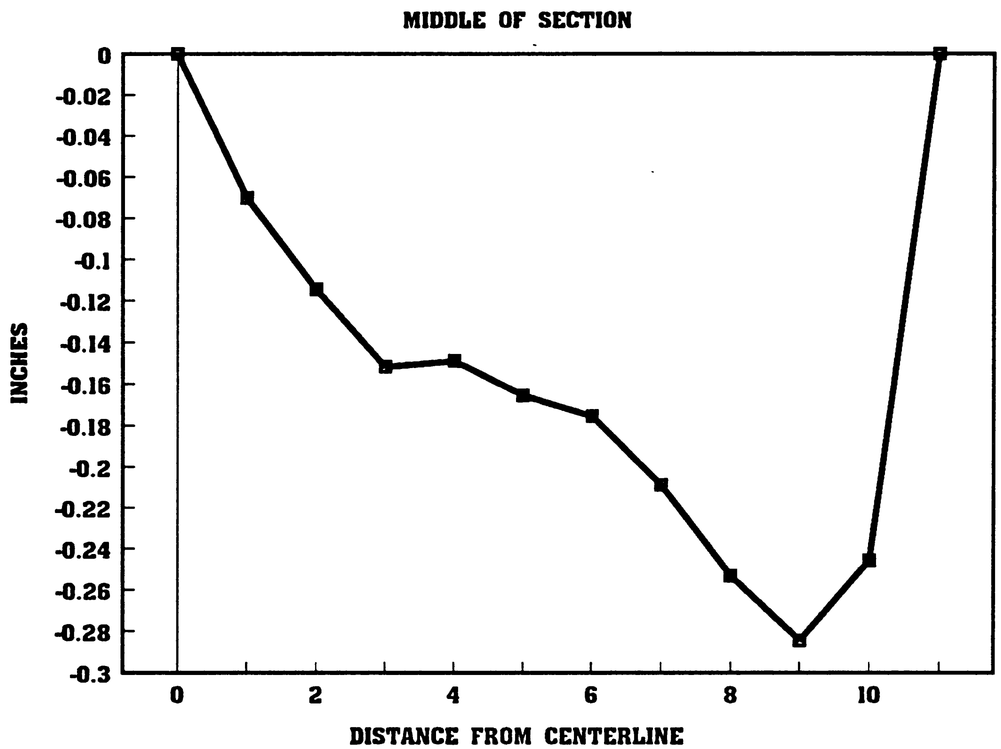


Figure 9. Rte 220 profile: Novophalt (NBPL).

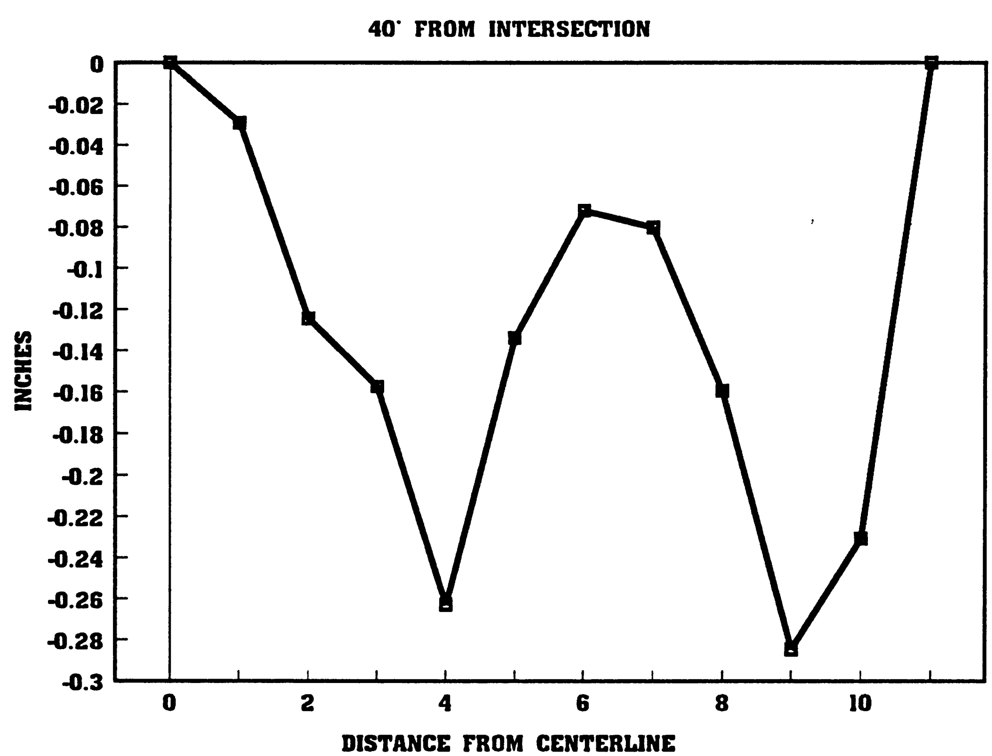


Figure 10. Rte 220 profile: control (NBPL).

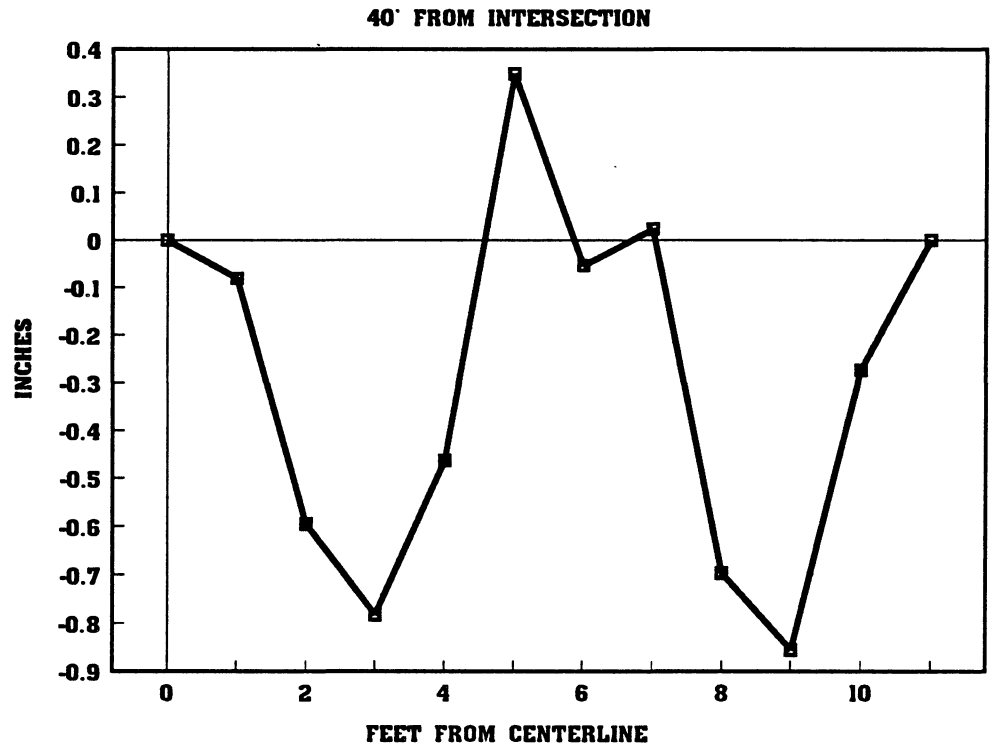


Figure 11. Rte. 220 profile: Novophalt (NBTL).

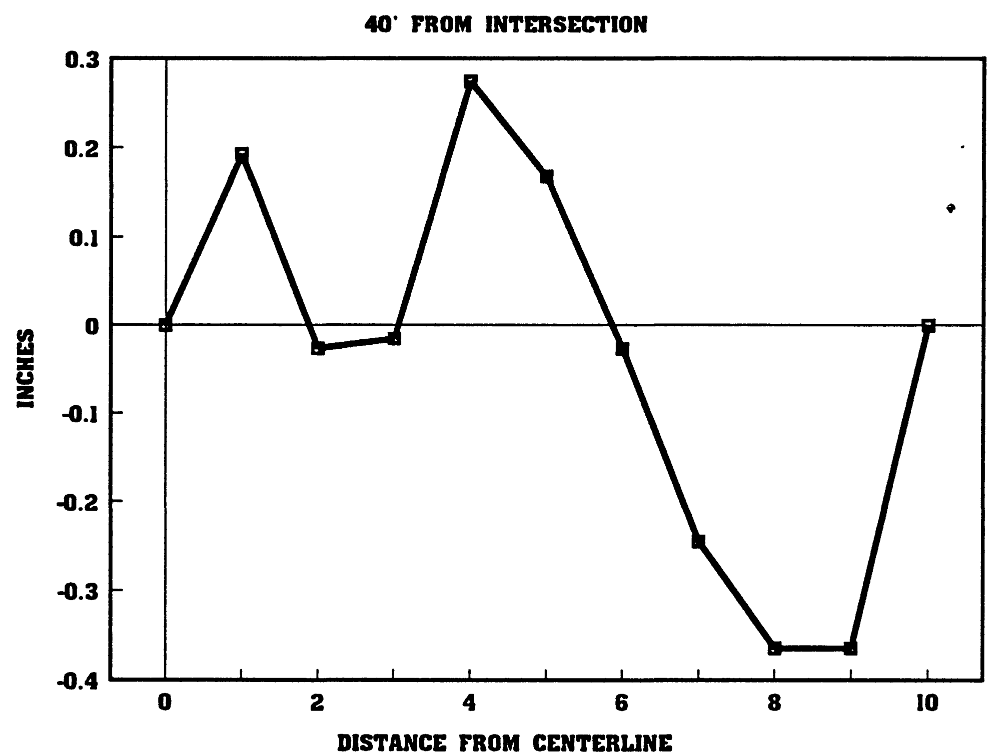


Figure 12. Rte. 220 profile: Novophalt (turn lane).

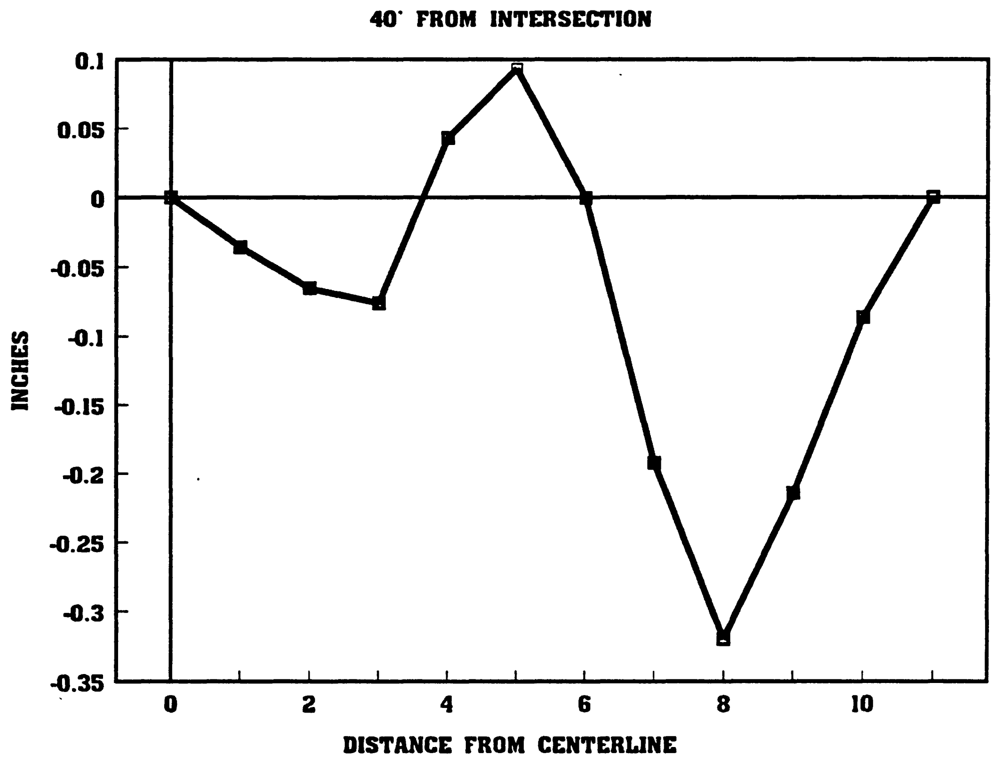


Figure 13. Rte. 220 profile: control (turn lane).

Additional Testing

Some additional tests were conducted to try to determine where the rutting was occurring in the pavement structure and what its cause was. Five cores were removed from both the Novophalt and control sections near the intersection (Figure 14). The thickness of the layers was measured, and the gradation was determined for both the extracted surface and base mixtures using the extracted aggregate.

Figure 15 shows the thickness of the surface and base layers from the cores that were removed from the Novophalt and control sections, and Tables 10 and 11 list the average thickness and estimated rutting, respectively. Two observations can be made from the graph: (1) the surface and base layers were thicker in the control section than in the Novophalt section, and (2) most of the rutting appeared to be confined to the base mixture in the Novophalt section. The estimate for rutting of the asphalt concrete layers was based on the assumption that the stabilized stone base had not rutted.

The estimated rutting was less than 0.2 in for the surface layer in the Novophalt section, but it averaged 0.8 in. in the base layer. The estimated rutting was

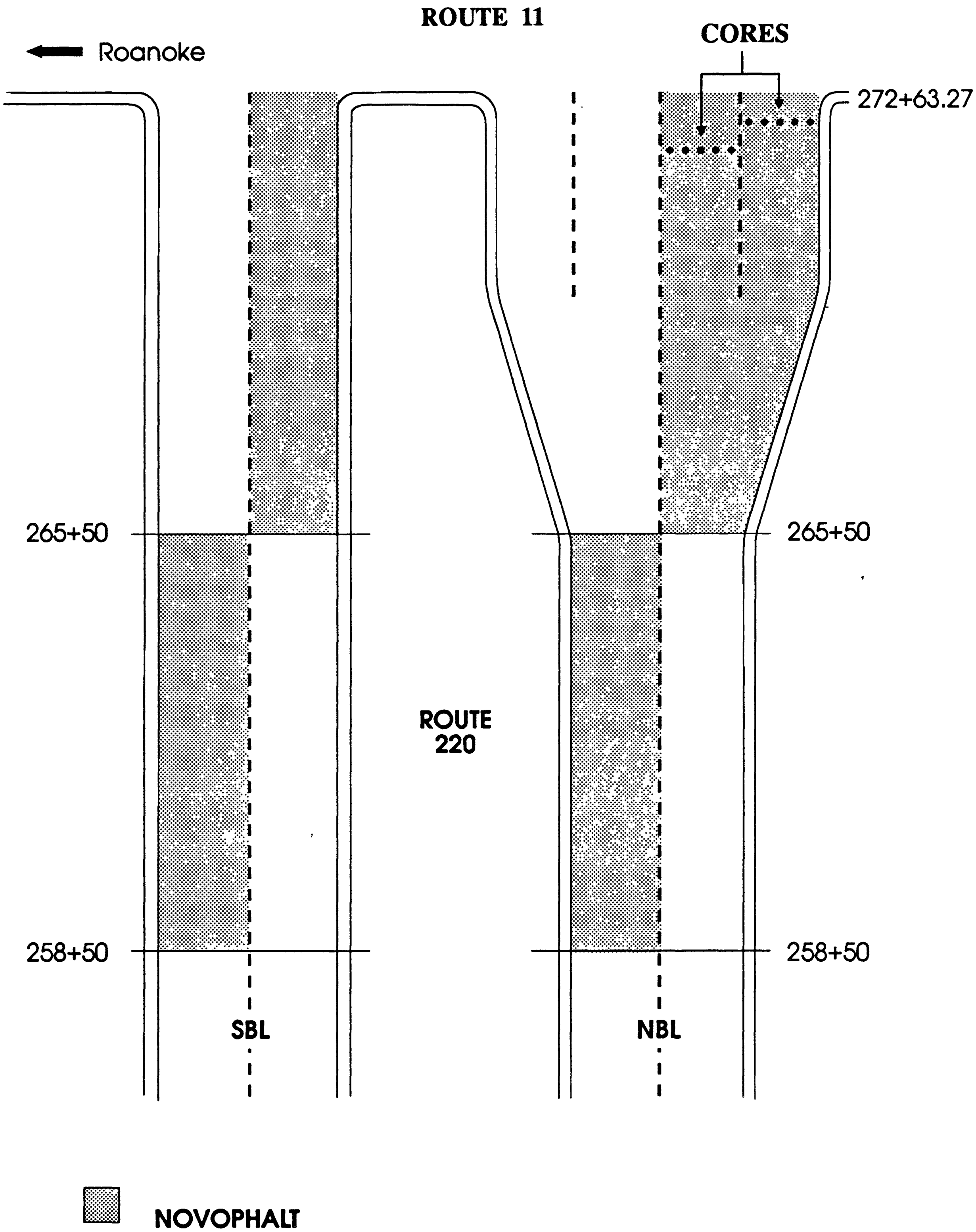


Figure 14. Location of cores.

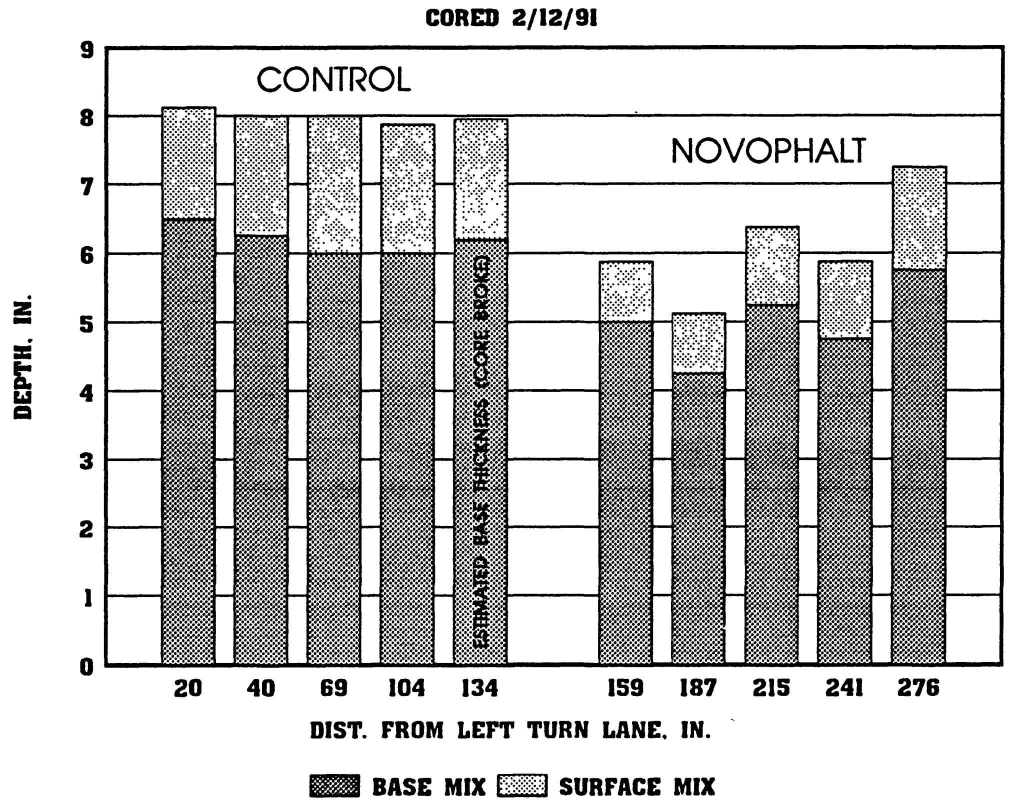


Figure 15. Thickness of cores.

Table 10

AVERAGE THICKNESS FROM CORES

	CONTROL SECTION		NOVOPHALT SECTION	
	Base	Surface	Base	Surface
Designed thickness (in)	6.0	1.5	6.0	1.5
Avg. measured thickness (in)	6.2	1.8	5.0	1.1

negligible for both the surface and base layers in the control section. These estimates compare favorably with the total rutting that was measured with the Dipstick Profiler. These tests show that the rutting is primarily confined to the base layer of asphalt concrete, which is surprising. Asphalt base is generally found to be very stable, and the occurrence of rutting in this layer is very unusual. The thickness of the surface layer and base layer in the control section was slightly greater than the specified thickness, but the thickness of the asphalt concrete layers in the Novophalt section was appreciably less than the specified thickness.

Table 11

RUTTING

	Surface OWP*	Surface IWP*	Base OWP	Base IWP	Total OWP	Total IWP
Cores						
Control	0	0	0	—	0	0
Novophalt	0.1	0.1	0.7	0.9	0.8	1.0
Dipstick						
Control**					0.2	0.2
Novophalt					1.0	1.0

* Outside wheel path (OWP), inside wheel path (IWP)
**Measurements were closer to intersection than location of cores

Extraction and gradation tests were performed on the cores to try to determine why excessive rutting occurred. The Novophalt mixture was much finer than the specifications allowed, and the excessive amount of material passing the No. 200 sieve would have tended to make the mixture overly dense and susceptible to rutting. The air voids (Table 12) were much lower in the Novophalt surface mixture than in the control mixture. The air voids have decreased from approximately 10 percent to about 3 percent in the Novophalt mixture and to about 6 percent in the control mixture. Even though the air voids are low in the Novophalt mixture, it is possible that the additive is helping to alleviate rutting. Additives such as polymers tend to make the mixture more elastic and less susceptible to permanent deformation; however, they should not be considered as a cure-all for poor mixture gradation. The control mixture is also finer than the specifications allow; however, the material passing the No. 200 sieve is not as high as in the Novophalt mixture, and significant rutting has not occurred. The base mixture under both surface mixtures is much finer than the design gradation, and the asphalt content is also about 0.5 percent higher than specified. Both of these occurrences may result in mixtures with low air voids and instability. In fact, the air voids of the cores from the base mixture are low. The air voids of the base mixture under the Novophalt mixture were 3.4 percent (which is very low), whereas the voids of the base mixture under

Table 12

AIR VOIDS (VTM) IN CORES (%)

Section	Surface Mixture	Base Mixture
Control	5.8	6.3
Novophalt	3.1	3.4

the control mixture was considerably higher (6.3 percent). The low air voids under the Novophalt were probably caused by a concentration of heavier traffic loads (more trucks) in that lane combined with less-than-desirable mixture properties.

DISCUSSION

Construction of the test sections went smoothly with no problems. The only exception to normal construction practice that was required for the Novophalt mixture was a special unit to blend the asphalt cement and polymer. However, slightly higher-than-normal mixing and compaction temperatures were used as recommended by the supplier.

The gradations of extracted samples of mixtures taken during construction were finer than specified, especially for the Novophalt mixture tested by the Research Council. Although the air voids of cores taken soon after construction were approximately 10 percent, air voids of cores taken recently have dropped significantly. The initial high air voids may indicate that more compactive effort during construction would have yielded densities closer to the densities resulting after 1 year of traffic. It is certainly desirable to obtain as much of the ultimate density as possible with compaction equipment rather than with traffic.[6] The air voids were also variable from section to section, indicating a lack of good quality control. Admittedly, quality control is more difficult for short sections as in this project.

Low shear strength, high GSI, and low predicted voids in the tests with the gyratory testing machine indicated possible problems with both mixtures. Resilient modulus and indirect tensile tests showed that the Novophalt mixture may be slightly better than the control mixture; however, creep tests did not indicate an appreciable difference between the two mixtures.

Rut depth measurements taken 10 months after construction in the Novophalt section in the northbound traffic lane near the intersection were excessive; therefore, additional cores were taken and analyzed in an attempt to determine the cause of the problem. The majority of the rutting appeared to be confined to the base layer. Extraction and gradation tests reveal that the gradation of the base mixture under both the control and the Novophalt mixtures is finer than the specifications required and the asphalt content is about 0.5 percent higher than specified. Both of these undesirable mixture properties probably contributed to the overdensification and rutting in the base mixture. Voids of the base mixture have decreased to approximately 3 percent in the Novophalt section where rutting has occurred.

In summary, it appears that rutting has been caused by a poor quality asphalt base mixture and not by the experimental Novophalt mixture. Since all sections are subjected to additional traffic, further differences between the performance of the control and Novophalt surface mixtures may become apparent.

Periodic rutting measurements and visual evaluations of the test section will continue. If significant rutting develops in other sections, it may be necessary to take full-depth cores to determine if the rutting is the result of failures in the base layer or in the surface layer. The next evaluation is scheduled for the fall of 1991 after the pavement has been subjected to another summer of traffic.

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