STATE STUDY NO. 67-21 and 67-23

FINAL REPORT

EVALUATION OF SOIL MOISTURE BARRIER

Prepared by

Gary Browning, P.E.

June 1999

Conducted by

Mississippi Department of Transportation

Research Division

In Cooperation with the

U.S. Department of Transportation

Federal Highway Administration

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/MS-DOT-RD-99-21 & 23		

4. Title and Subtitle
EVALUATION OF SOIL MOISTURE BARRIER

5. Report Date
June 1999

6. Performing Organization Code
MS-DOT-RD-99-21 & 23

7. Author(s)
Gary Browning

8. Performing Organization Report No.

9. Performing Organization Name and Address
Mississippi Department of Transportation
Research Division
P O Box 1850
Jackson MS 39215-1850

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Federal Highway Administration

13. Type Report and Period Covered
Final Report

14. Sponsoring Agency Code

15. Supplementary Notes
Conducted in cooperation with the U.S. Department of Transportation Federal Highway Administration

16. Abstract
This report is an extension report and examines one of the measures being tried to stabilize the development of pavement damage on expansive soils, which is the use of horizontal moisture barriers. The moisture barrier will not stop horizontal flow, but is designed to stop rainwater from penetrating into the subgrade soils thus reducing soil swelling, measured by a reduction in the moisture variance.

On both sides of the roadway, the moisture barrier begins 9' (2.74 m) from the pavement centerline, extends to 6' (1.83 m) beyond the bottom of the ditch, and is under a minimum of 18" (0.46 m) of soil. The performance of the moisture barrier was measured twice yearly by moisture sampling and four times yearly by roadway roughness measurements.

The moisture barriers on both project did not reduce the IRIs or the moisture variance, as they were expected to do. Future use of this design of horizontal moisture barriers on pavements is not recommended. The moisture barrier did not produce a smoother ride than the unprotected pavement in the roughness tests or reduce the moisture variance.

17. Key Words	18. Distribution Statement
Moisture barrier, Pavements, Expansive soils	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	67	

Form DOT F 1700.7 (8-72)

NOTICE

`

ACKNOWLEDGMENT

The study reported herein was conducted by the Mississippi Department of Transportation (MDOT) under the sponsorship of the Federal Highway Administration (FHA), Mississippi Division Office. This work was accomplished during the period May 1991 through December 1995 under the supervision of Mr. Alfred B. Crawley, Research Engineer. This report was prepared by Gary S. Browning of the MDOT Research Division.

The author wishes to express his appreciation to the many people whose efforts contributed to this study. Acknowledgment is made to Roger Tingle of the Research Division for his support during the performance testing and other aspects of the project. Additional acknowledgment is made to involved personnel in the Fifth District of MDOT for their help in collecting the moisture samples.

TABLE OF CONTENTS

Section Page

CHAPTER 1: INTRODUCTION 1

BACKGROUND 1
OBJECTIVES 2
SCOPE 2

CHAPTER 2: DESIGN AND CONSTRUCTION 4

DESCRIPTION OF MATERIALS 4
CONSTRUCTION........ 5
ECONOMICS 6

CHAPTER 3: TEST RESULTS AND DISCUSSION 13

ROUGHNESS TESTS 13
MOISTURE TESTS 14
SUMMARY OF AVERAGES, VARIANCES, AND STANDARD DEVIATIONS. 24
DISCUSSION OF RESULTS 30

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS 31

CONCLUSIONS 31
RECOMMENDATIONS 31

REFERENCES 32

APPENDIX A 33

ROUGHNESS RESULTS 33

APPENDIX B 36

MOISTURE RESULTS 36
MOISTURE TESTS AT THE FOUR -TEST SITES PAST AND UNDER THE MOISTURE BARRIERS. 37
COMPARING PERCENT MOISTURES AT THE TEST DEPTHS. 45
MOISTURE CONCLUSIONS 47

APPENDIX C 50

SPECIFICATIONS 50

LIST OF FIGURES

Figure Page

Figure 1. Project 1 location in Scott county. 7
Figure 2. Project 2 location in Scott and Newton counties. 7
Figure 3. Typical section. 8
Figure 4. Rolls of moisture barrier fabric. 8
Figure 5. Fabric installed in median ditch. 9
Figure 6. Fabric partially covered. 9
Figure 7. Installing concrete ditch. 10
Figure 8. Seeding the grass. 10
Figure 9. A finished ditch. 11
Figure 10. Taking soil samples. 11
Figure 11. Water standing at moisture barrier. 12
Figure 12. Project 1 IRI values with and without moisture barriers. 13
Figure 13. Project 2 IRIs with and without moisture barriers. 14
Figure 14. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound past the moisture barrier. 16
Figure 15. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound under the moisture barrier. 16
Figure 16. Project 1 Percentages of moisture past the moisture barrier at 461+50 (14 + 066.548) westbound. 17
Figure 17. Project 1 Percentages of moisture under the moisture barrier at 461+50 (14 + 066.548) westbound. 17
Figure 18. Project 1 Percentages of moisture past the moisture barrier at 460+50 (14 + 036.068) eastbound. 18
Figure 19. Project 1 Percentages of moisture under the moisture barrier at 460+50 (14 + 036.068) eastbound. 18
Figure 20. Project 1 Percentages of moisture past the moisture barrier at 702+00 (21 + 397.003) eastbound. 19
Figure 21. Project 1 Percentages of moisture under the moisture barrier at 702+00 (21 + 397.003) eastbound. 19
Figure 22. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound past the moisture barrier. 20
Figure 23. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound under the moisture barrier. 20
Figure 24. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound past the moisture barrier. 21
Figure 25. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound under the moisture barrier. 21
Figure 26. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound past the moisture barrier. 22
Figure 27. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound under the moisture barrier. 22
Figure 28. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound past the moisture barrier. 23
Figure 29. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound under the moisture barrier. 23
Figure 30. Project 1 Percentages of moisture at different depths. 24

Figure 31. Project 1 Variances at various depths. **24**
Figure 32. Project 1 Standard deviations at various depths. **25**
Figure 33. Project 2 Percentages of moisture at different depths. **25**
Figure 34. Project 2 Variances at various depths. **26**
Figure 35. Project 2 Standard deviations at various depths. **26**

LIST OF TABLES

Table Page

Table 1. Specification Requirements for the Geotextile Fabric. 4
Table 2. Tested values for the Geotextile Fabric. 4
Table 3. Petromat MB II Lot #89-12 118" (3.00 m) rolls. 5
Table 4. Petromat MB II Lot #90-1 144" (3.66 m) rolls. 5
Table 5. Project 1 Summary of values past and under the moisture barriers, data for figures 30, 31, & 32. 27
Table 6. Project 2 Summary of values past and under the moisture barriers, data for figures 33, 34, & 35. 27
Table 7. Project 1 Pavement management condition details eastbound. 28
Table 8. Project 1 Pavement management condition details westbound. 28
Table 9. Project 2 Pavement management condition details eastbound. 29
Table 10. Project 2 Pavement management condition details westbound. 29
Table 11. Project 1 All IRI measurements. 34
Table 12. Project 1 Comparing the IRI values with and without moisture barriers, data for figure 12. 34
Table 13. Project 2 All IRI measurements. 35
Table 14. Project 2 Comparing the IRI values with and without moisture barriers, data for figure 13. 35
Table 15. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound past the moisture barrier, data for figure 14. 37
Table 16. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound under the moisture barrier, data for figure 15. 37
Table 17. Project 1 Percentages of moisture past the moisture barrier at 461+50 (14 + 066.548) westbound, data for figure 16. 38
Table 18. Project 1 Percentages of moisture under the moisture barrier at 461+50 (14 + 066.548) westbound, data for figure 17. 38
Table 19. Project 1 Percentages of moisture past the moisture barrier at 460+50 (14 + 036.068) eastbound, data for figure 18. 39
Table 20. Project 1 Percentages of moisture under the moisture barrier at 460+50 (14 + 036.068) eastbound, data for figure 19. 39
Table 21. Project 1 Percentages of moisture past the moisture barrier at 702+00 (21 + 397.003) eastbound, data for figure 20. 40
Table 22. Project 1 Percentages of moisture under the moisture barrier at 702+00 (21 + 397.003) eastbound, data for figure 21. 40
Table 23. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound past the moisture barrier, data for figure 22. 41
Table 24. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound past the moisture barrier, data for figure 23. 41
Table 25. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound past the moisture barrier, data for figure 24. 42
Table 26. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound past the moisture barrier, data for figure 25. 42
Table 27. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound past the moisture barrier, data for figure 26. 43
Table 28. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound past the moisture barrier, data for figure 27. 43
Table 29. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound past the moisture barrier, data for figure 28. 44
Table 30. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound past the moisture barrier, data for figure 29. 44

Table 31. Project 1 Percent moisture at 704+50 (21 + 473.203) westbound. 45
Table 32. Project 1 Percent moisture at 461+50 (14 + 066.548) westbound. 45
Table 33. Project 1 Percent moisture at 460+50 (14 + 036.068) eastbound. 45
Table 34. Project 1 Percent moisture at 702+00 (21 + 397.003) eastbound. 45
Table 35. Project 2 Percent moisture at 1200+50 (36 + 591.313) westbound. 46
Table 36. Project 2 Percent moisture at 963+00 (29 + 352.299) westbound. 46
Table 37. Project 2 Percent moisture at 969+50 (29 + 550.419) eastbound. 46
Table 38. Project 2 Percent moisture at 1197+50 (36 + 499.873) eastbound. 46
Table 39. Project 1 Percentages of moisture at different depths, past the moisture barrier, data for figure 30. 47
Table 40. Project 1 Percentages of moisture at different depths, under the moisture barrier, data for figure 30. 47
Table 41. Project 2 Percentages of moisture at different depths, past the moisture barrier, data for figure 33. 47
Table 42. Project 2 Percentages of moisture at different depths, under the moisture barrier, data for figure 33. 47
Table 43. Project 1 Variances of moisture at various depths past the moisture barrier, data for figure 31. 48
Table 44. Project 1 Variances of moisture at various depths under the moisture barrier, data for figure 31. 48
Table 45. Project 2 Variances of moisture at various depths past the moisture barrier, data for figure 34. 48
Table 46. Project 2 Variances of moisture at various depths under the moisture barrier, data for figure 34. 48
Table 47. Project 1 Standard deviations of moisture at various depths past the moisture barrier, data for figure 32. 49
Table 48. Project 1 Standard deviations of moisture at various depths under the moisture barrier, data for figure 32. 49
Table 49. Project 2 Standard deviations of moisture at various depths past the moisture barrier, data for figure 35. 49
Table 50. Project 2 Standard deviations of moisture at various depths under the moisture barrier, data for figure 35. 49

CHAPTER 1: INTRODUCTION

BACKGROUND

Pavements built on expansive clay act as a type of shallow foundation. "Terzaghi (1943) defined a shallow foundation as one in which the depth to the bottom of the footing is less than or equal to the least dimension of the footing."[1] The pavements tend to smooth out the roughness in the subgrade that is caused by differential changes in moisture. Under the pavement, pressurized water moves wherever there are cracks and increases the moisture content of the soil near the cracks.[2] When the moisture content of the clay increases, it expands. To prevent the movement of moisture under flexible pavements built on expansive clay to the outside soil, horizontal moisture barriers were tried by the Mississippi Department of Transportation.

The Texas State Department of Highways and Public Transportation used an 8' (2.44-m) vertical moisture barrier at the pavement edges, which prevented rainwater from flowing horizontally under the pavement.[5] The purpose of the moisture barrier was to isolate the subbase soil from seasonal climatic changes.

Pavement roughness was attributed to the presence of shrinkage cracks in the subbase soils. In some cases, the Texas State Department of Highways and Public Transportation noted that the vertical moisture barrier seemed to reduce considerably the rate at which roughness develops. The barrier had somewhat increased the rate of roughness development, in other cases. Some sections with the barrier in Texas experienced a higher rate of roughness development than adjacent control sections. There it looked like sometimes the barrier would actually retain moisture inside rather than keep it outside.[3]

Expansive soils have extremely low permeabiities, and thus absorption of water by soil clods is a very slow process. The depth of a moisture barrier should be chosen based on the expected maximum depth of shrinkage cracks possible at the site. If the moisture barrier is placed on soil that is not already in a stable moisture condition, then the pavement may become rougher than the other pavement. Once a stable moisture condition is reached, future overlays should be more effectual. The moisture barrier will reduce further change of moisture and will preserve the surface profile.

The flow of water in expansive soils is non-Darcy flow. As the soil absorbs water it swells and progressively the cracks close. The bulk of rainwater penetration into cracks moves directly to the tips of cracks instead of being absorbed on the crack walls.[1]

Evapotranspiration removes soil water from the cracks within the soil on the side of the pavement and under the edge of the pavement. Soil evaporation has been proved a very ineffective mechanism of moisture removal. Even small amounts of soil evaporation forms a dry soil crust at the soil surface that prevents any further evaporation from taking place. Soil evaporation might affect only the soil within the upper foot of the soil deposit.[1]

Plant transpiration is a much more effective mechanism. Grasses have maximum rooting depths of 8' to 9' (2.44 m to 2.74 m). However, when shrubs or trees grow near the pavement, much larger rooting depths should be expected. The moisture barrier also acts as a root barrier and by preventing the vegetation root system from the pavement sub soils, moisture losses are lowered. Mowing of roadside grasses reduces exposure of vegetation to the environment and reduces the water removal from the soil mass.[3]

OBJECTIVES

The objective of this investigation was to examine the use of horizontally placed moisture barrier fabric to stabilize moisture variations and reduce the vertical distortion caused by the highly expansive soil (Yazoo Clay).

A horizontal moisture barrier is designed to isolate the subsoil from rainwater. All the rainwater from the pavement centerline to 6’ (1.8 m) beyond the bottom of the ditch should end in the ditch and not permeate into the pavement subsoil.

SCOPE

For Project 1, a 9.6-mile (15.4-km) section of I-20 between SR 481 and Lake in Scott County (figure 1) was rehabilitated under project IR-20-2 (54) 79. The beginning of the project had a station number of 430+00 (13 + 106.426) and ending station number of 952+00 (29 + 017.018). The horizontal moisture barrier was installed at thirteen locations in the eastbound and westbound lanes throughout the project in areas in which there was severe vertical distortion. Four of these sites were used for moisture testing.

For Project 2, a 10.2-mile (16.4-km) section of I-20 from East of MS 35 to east of U.S. 80 in Scott and Newton counties (figure 2) was rehabilitated under project IR-20-2 (54) 79. The starting station was 952+00 (29 + 017.018) in Scott county and the ending station was 225+00 (6 + 858.014) in Newton county. The horizontal moisture barrier was installed at four locations in the eastbound lanes and two locations in the westbound lanes throughout the project in areas of severe vertical distortion. Four of these sites were used for moisture testing.

This arrangement was chosen to provide a good opportunity to quantify the performance of the moisture barrier. The evaluation of performance was based on ride quality as measured with a South Dakota Profiler (SDP) and limited measurement of in-situ moisture content.

Consideration was given to determine the effectiveness of the moisture barrier. After reviewing the literature from several companies, the benefits gained from instrumentation were not cost effective for this application. Soil samples were manually collected for moisture determination over and past the moisture barrier at four locations on the project.

Over the moisture barrier, moisture samples were taken past the shoulder and about 15’ (4.57 m) from the bottom of the ditch. Samples were taken at 2’ (0.61 m), 4’ (1.22 m), 6’ (1.83 m), and 8’ (2.44 m) below the ditch slope.

Samples were also taken on the backslope, 10’ to 13’ (3 to 4 m) past the end of the moisture barrier. This was near the tree line (figure 3) and at the approximate same elevations to determine background moisture contents to serve as a control. This moisture sampling was done semiannually to coincide with the measurement of roadway roughness.

It is acknowledged that this degree of moisture sampling is not accurate enough to measure the performance of the barrier, although it does provide general information on the reasonableness of this design.

CHAPTER 2: DESIGN AND CONSTRUCTION

DESCRIPTION OF MATERIALS

The fabric used was Phillips Fibers Petromat MB II (figure 4) which meets the MDOT specifications for Geotextile Fabric for Moisture Barrier physical property requirements. Petromat MB II is a composite of two layers of nonwoven polypropylene fabric with a polyethylene film bonded between the two nonwoven fabric layers. The fabric came in widths of 144" (3.66 m) and 118" (3.00 m). A total of 142,820 yd^2 (119 416 m^2) of geotextile fabric was used in the moisture barrier. The specification requirements for the Geotextile Fabric for Moisture Barrier are listed below.

Below in Table 1 is a summary of the 80 rolls of 118" (3.00 m) Petromat MB II Lot # 89-12 and 322 rolls of 144" (3.66 m) Petromat MB II Lot #90-1 used in the project. The REQUIREMENT column contains the minimum specification values.

Table 1. Specification Requirements for the Geotextile Fabric.

PHYSICAL PROPERTY	TEST PROCEDURE	REQUIREMENT
FABRIC WT., oz /sq.yd.	ASTM D-3776	6.5
TENSILE STRENGTH, lbs.	ASTM D-4632	150
ELONGATION, PERCENT	ASTM D-4632	20
TRAPEZOIDAL TEAR STRENGTH, lbs.	ASTM D-4533	15

Table 2 lists the MINIMUM VALUE, which is the actual tested values on shipped 118" (3.00 m) and 144" (3.66 m) rolls of fabric.

Table 2. Tested values for the Geotextile Fabric.

PHYSICAL PROPERTY	TEST PROCEDURE	MINIMUM VALUE FOR 118" ROLLS	MINIMUM VALUE FOR 144" ROLLS
FABRIC WT., oz /sq.yd.	ASTM D-3776	10.5	9.72
TENSILE STRENGTH, lbs.	ASTM D-4632	173	116
ELONGATION, PERCENT	ASTM D-4632	61	42
TRAPEZOIDAL TEAR STRENGTH, lbs.	ASTM D-4533	62	57

Table 3 is a summary of the properties of the 80 118" (3.00 m) rolls Petromat MB II. MD is in the machine direction and XMD is in the cross machine direction, or rotated 90^o from the machine direction.

Table 3. Petromat MB II Lot #89-12 118" (3.00 m) rolls.

WT, OZ/YD^2	ELONGATION, %		TENSILE STRENGTH, LBS.		TRAP TEAR, LBS.	
	MD	XMD	MD	XMD	MD	XMD
AVG. 10.5	70	92	201	209	87	78
MAX. 11.0	78	99	244	257	111	100
MIN. 10.0	61	84	175	173	73	62

Table 4 is a summary of the properties of the 322 rolls of 144" (3.66 m) Petromat MB II used in the project.

Table 4. Petromat MB II Lot #90-1 144" (3.66 m) rolls.

WT, OZ/YD^2	ELONGATION, %		TENSILE STRENGTH, LBS.		TRAP TEAR, LBS.	
	MD	XMD	MD	XMD	MD	XMD
AVG. 9.98	46	70	193	181	66	68
MAX. 10.37	52	76	222	196	86	90
MIN. 9.72	42	68	175	161	57	58

The water permeability and abrasion resistance for the fabric was 0.4 oz/yd^2 (9.5 g/m^2), which was less than the maximum permissible of 0.6 oz/yd^2 (14.2 g/m^2).

CONSTRUCTION

The first field inspection was April 24, 1990 for project 1, and the first field inspection was January 13, 1993 for project 2. The moisture barrier extended 9' (2.74 m) from the pavement centerline to 6' (1.83 m) beyond the bottom of the ditch (figure 5). It was placed under a minimum of 18" (0.46 m) of soil, on both sides of the roadway (figure 6). In areas where the moisture barrier fabric was required on both lanes with a common median ditch, the first waterproof lap-seal was 6' (1.83 m) from the centerline of the ditch. An 18" (0.46-m) minimum lap was tacked with SS-1 emulsified asphalt. The lap was shingled down slope both transversely and longitudinally. Any holes cut or punctured in the moisture barrier fabric were sealed using SS-1 emulsified asphalt or equivalent. If the embankment was placed and a guard post, signpost, or delineator post was driven through the moisture barrier fabric, the embankment was removed to the fabric at the post location. The fabric was cut to install the post and sealed with SS-1 emulsified asphalt and the embankment was replaced. A concrete drainage ditch was then installed (figure 7) and finally the grass was re-seeded (figure 8). A completed installation is shown in figure 9.

ECONOMICS

For Project 1, the final cost of the moisture barrier was $2.34/yd^2 ($2.80/m^2). The total cost of the fabric for 142,820 yd^2 (119 459 m^2) was $334,198.80. The cost of the borrow excavation for 52,762 yd^3 (40 333 m^3) was $5.80/yd^3 ($7.59/m^3), for a total of $306,019.60.

For Project 2, the final cost of the moisture barrier fabric for 74,134 yd^2 (61 985 m^2) was $198,679.12 or $2.68/yd^2 ($3.21 per m^2). The borrow excavation for 35,037 yd^3 (26 784 m^3) cost was $5.59/yd^3 ($7.31/m^3), for at total of $195,856.83.

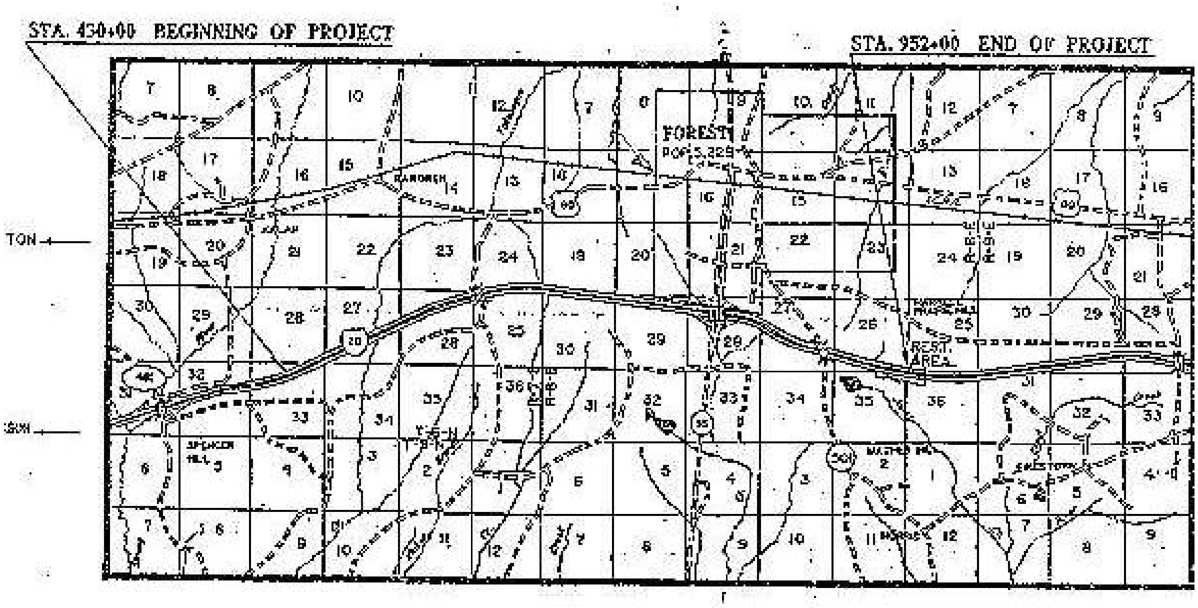

Figure 1. Project 1 location in Scott county.

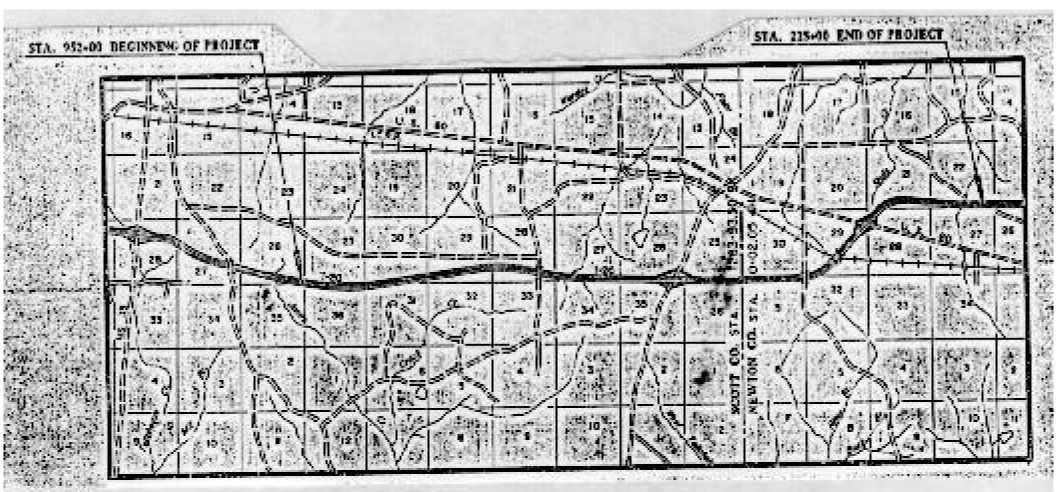

Figure 2. Project 2 location in Scott and Newton counties.

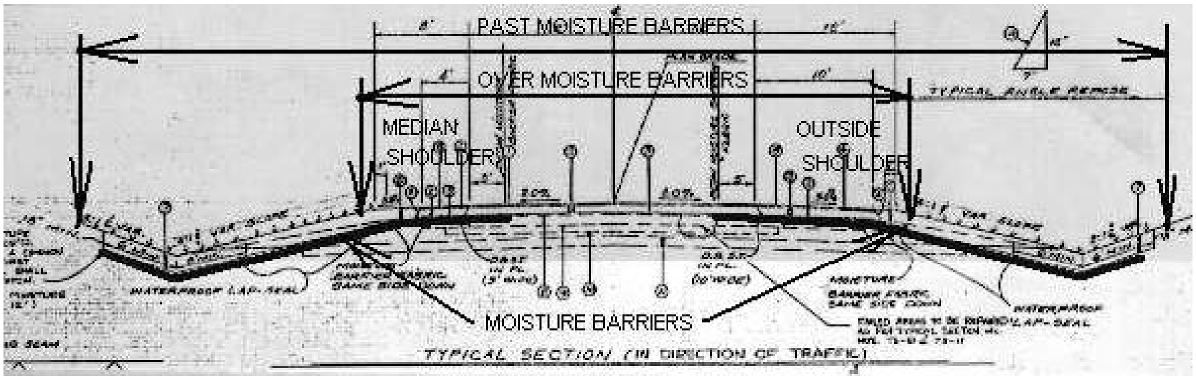

Figure 3. Typical section.

Figure 4. Rolls of moisture barrier fabric.

Figure 5. Fabric installed in median ditch.

Figure 6. Fabric partially covered.

Figure 7. Installing concrete ditch.

Figure 8. Seeding the grass.

Figure 9. A finished ditch.

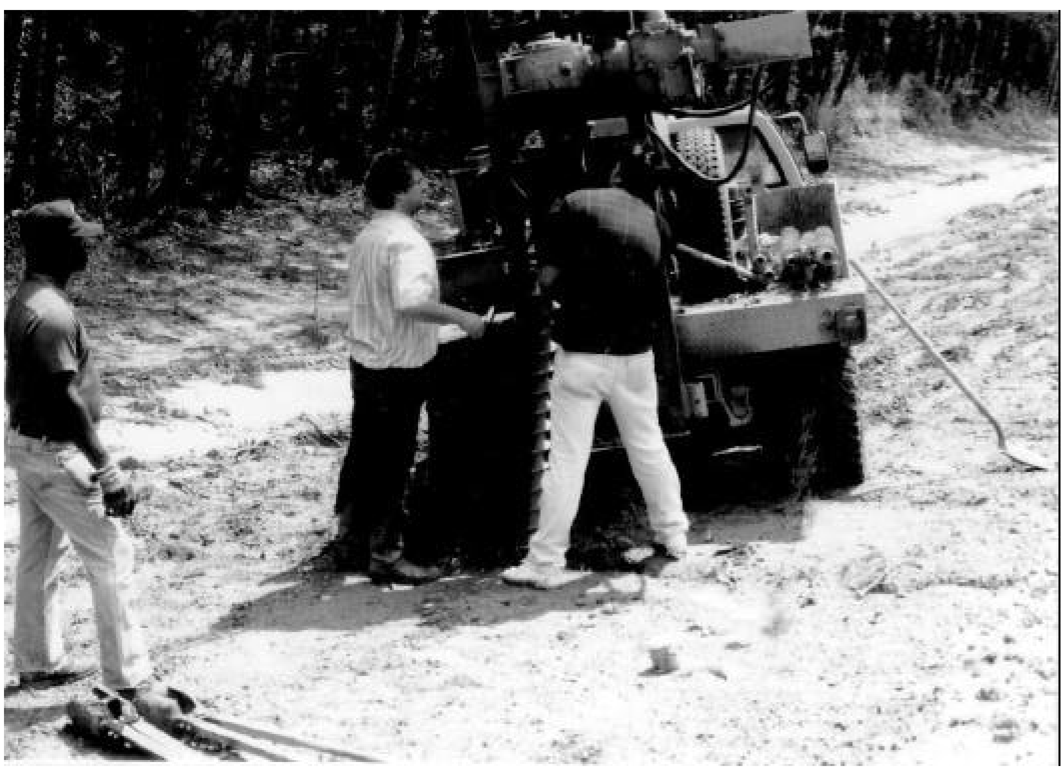

Figure 10. Taking soil samples.

Figure 11. Water standing at moisture barrier.

CHAPTER 3: TEST RESULTS AND DISCUSSION

ROUGHNESS TESTS

The roughness statistic International Roughness Index (IRI) was determined from the roadway profile. The IRI is the ratio of the accumulated suspension motion of a vehicle, divided by the distance traveled during the test at 50 mph (80 km/hr) and the units are meters per kilometer of roughness. A perfectly smooth pavement has an IRI of zero and the roughest pavements in the United States may have an IRI greater than five.

The entire project was surveyed for measurements of roughness with the SDP quarterly for the evaluation period. IRI values were not found before the new overlay because construction on the pavement had the right lane blocked off at some locations. The locations of the moisture barriers were marked in January 1993 with reflective tape. The roughness tests were made at about 50 mph (80 km/hr). Four trips were made on each test date and the location of the moisture barriers was recorded on the computer as they were passed. Measurements of roughness using the SDP are illustrated for project 1 in figure 12 and for project 2 in figure 13.

Usually the SDP computes the IRI over the entire project in increments of 0.1 mile (0.16 km), but for this project, each SDP run was imported into a spreadsheet with the IRI values computed in increments of 50' (15.24 m).

The sections with and without the moisture barriers were marked on the spreadsheet and the averages of the IRI values of pavement with and without the moisture barriers were computed. Roughness data tables are in Appendix A.

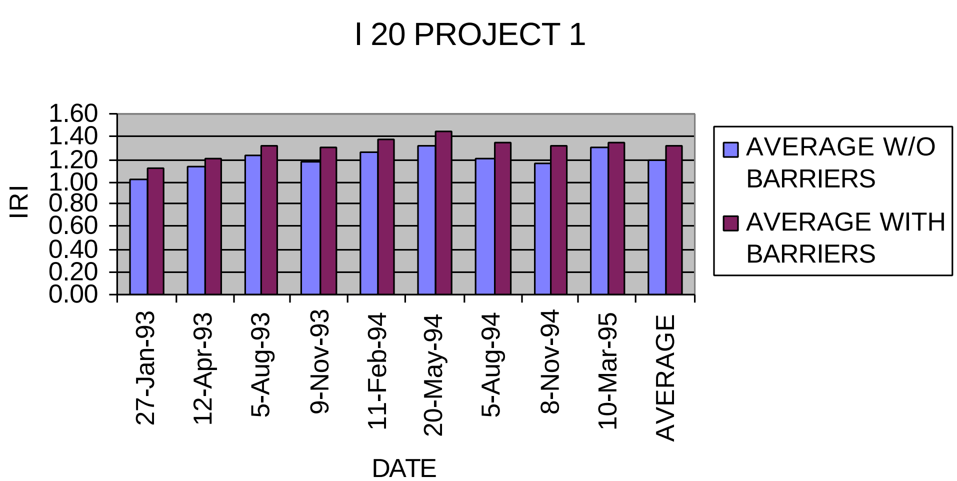

Figure 12. Project 1 IRI values with and without moisture barriers.

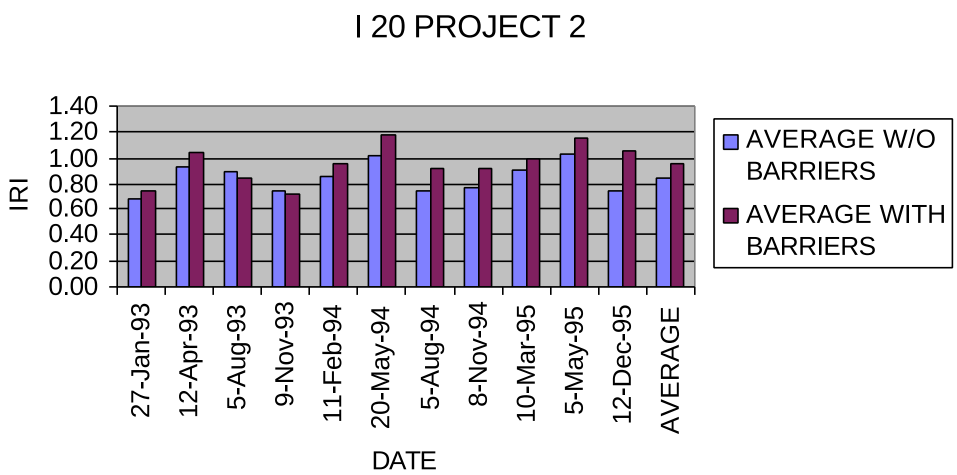

Figure 13. Project 2 IRIs with and without moisture barriers.

MOISTURE TESTS

On project 1, a hand auger was first tried on two test holes to get the soil samples, but this proved to be very slow. Soil samples were finally taken with a 6-wheel drive truck with a power auger from the MDOT Fifth District (figure 10).

Eight holes 8' (2.44 m) deep were drilled at the four chosen sites. At each site, four soil samples at 2' (0.61-m) intervals were taken down to 8' (2.44 m). First, four samples were taken on the slope past the fabric, near the tree line. Then four samples were taken over the fabric at about 15' (4.57 m) from the bottom of the ditch. A post hole digger was used down to the fabric. Sometimes there was standing water at the moisture barrier (figure 11). The fabric was then removed and the first soil sample was taken for the 2' (0.61 m) sample. The drilling rig was used to get samples at 4' (1.22 m), 6' (1.83 m), and 8' (2.44 m) and all of the samples past the moisture barrier. The holes under the fabric were sealed with emulsified asphalt and refilled with soil.

All the sites were very muddy and no grass was growing on them, on May 28, 1991, so these initial moisture samples are of limited value. Samples were never taken in the same hole, but were usually within 10' (3.05 m) of each other. It was sometimes difficult to collect samples off the drill auger at exact depths.

Figures 14 and 15 present the moisture contents for project 1 at 704+50 (21 + 473.203) westbound past and under the moisture barrier.

Figures 16 and 17 present the moisture contents for project 1 at 461+50 (14 + 066.548) westbound past and under the moisture barrier.

Figures 18 and 19 present the moisture contents for project 1 at 460+50 (14 + 036.068) eastbound past and under the moisture barrier.

Figures 20 and 21 present the moisture contents for project 1 at 702+00 (21 + 397.003) eastbound past and under the moisture barrier.

Figures 22 and 23 present the moisture contents for project 2 at 1200+50 (36 + 591.313) westbound past and under the moisture barrier.

Figures 24 and 25 present the moisture contents for project 2 at 963+00 (29 + 352.299) westbound past and under the moisture barrier.

Figures 26 and 27 present the moisture contents for project 2 at 969+50 (29 + 550.419) eastbound past and under the moisture barrier.

Figures 28 and 29 present the moisture contents for project 2 at 1197+50 (36 + 499.873) eastbound past and under the moisture barrier.

For project 1, the samples taken under the moisture barriers had a slightly overall lower average moisture content than the samples taken past the moisture barriers. As can be seen from figure 30 this is due to the much lower moisture content under the moisture barrier at 2' (0.6 m).

The overall averages of the variances and standard deviations of the moisture contents are greater under the moisture barriers. Figures 31 and 32 show that the variance and standard deviation under the moisture barrier at 6' (1.8 m) are less than those past the moisture barrier, but are greater at the other test depths. Moisture data tables are listed in Appendix B and Appendix C.

For project 2, the samples taken under the moisture barriers had a slightly overall higher average moisture content than the samples taken past the moisture barriers. As can be seen from figure 33, the average moisture content under the moisture barrier at 2' (0.6 m) is less than the average moisture content past the moisture barrier. Soil samples taken at 2' (0.6 m) were directly under the moisture barrier.

The overall averages of the variances and standard deviations of the moisture contents are greater under the moisture barriers. Figures 34 and 35 show that the variance and standard deviation under the moisture barrier at 2' (0.6 m) and 6' (1.8 m) are less than those past the moisture barrier are.

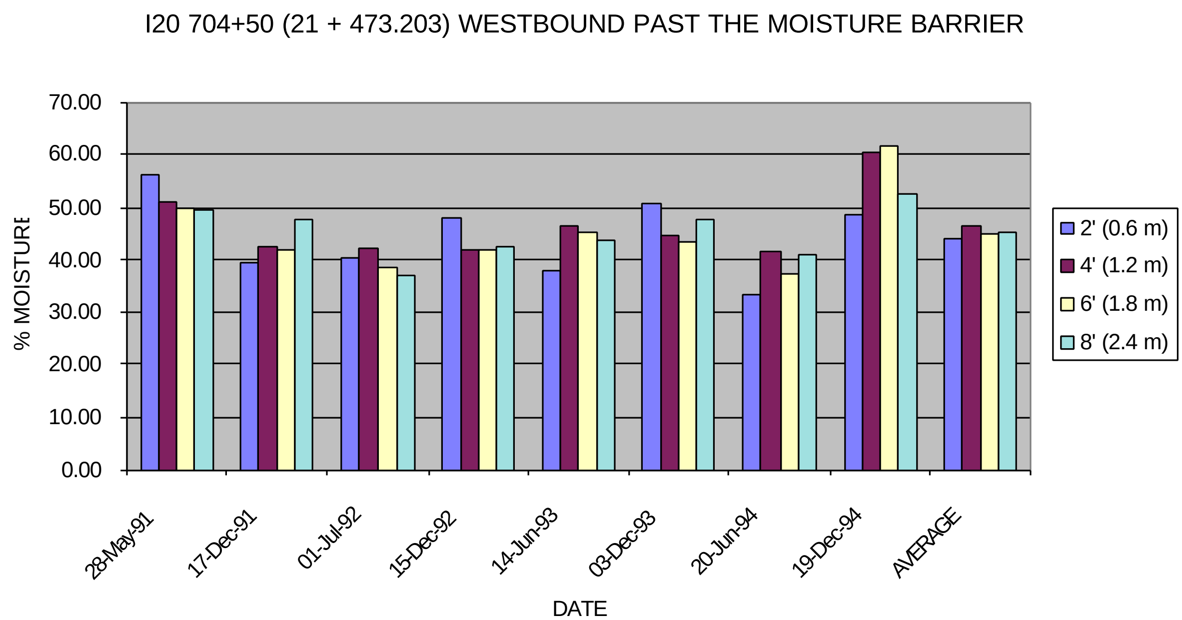

Figure 14. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound past the moisture barrier.

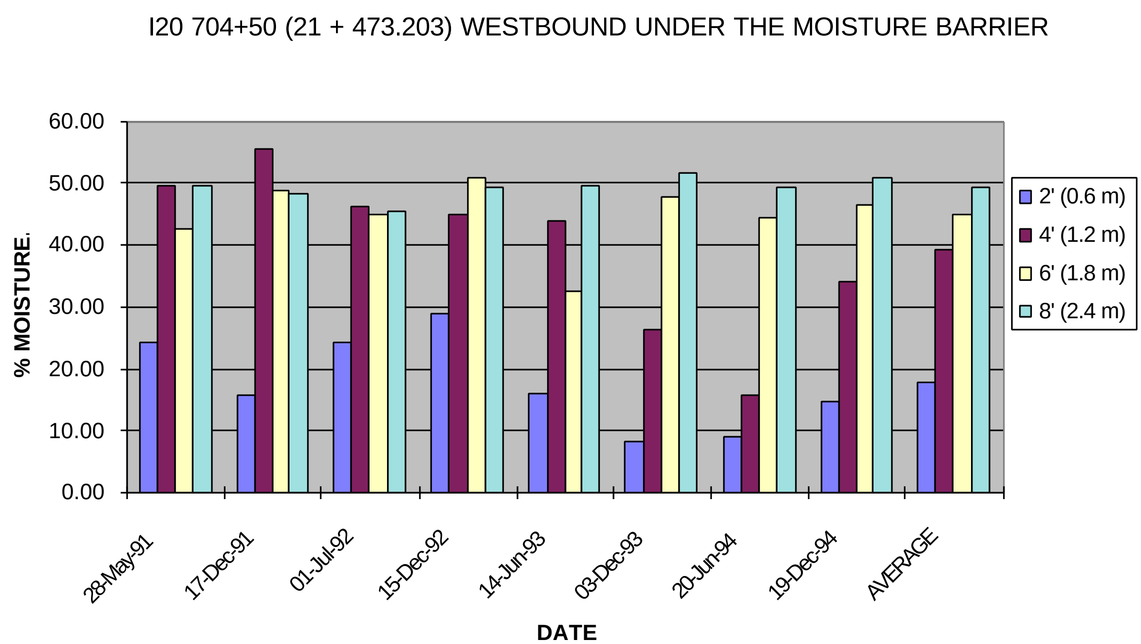

Figure 15. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound under the moisture barrier.

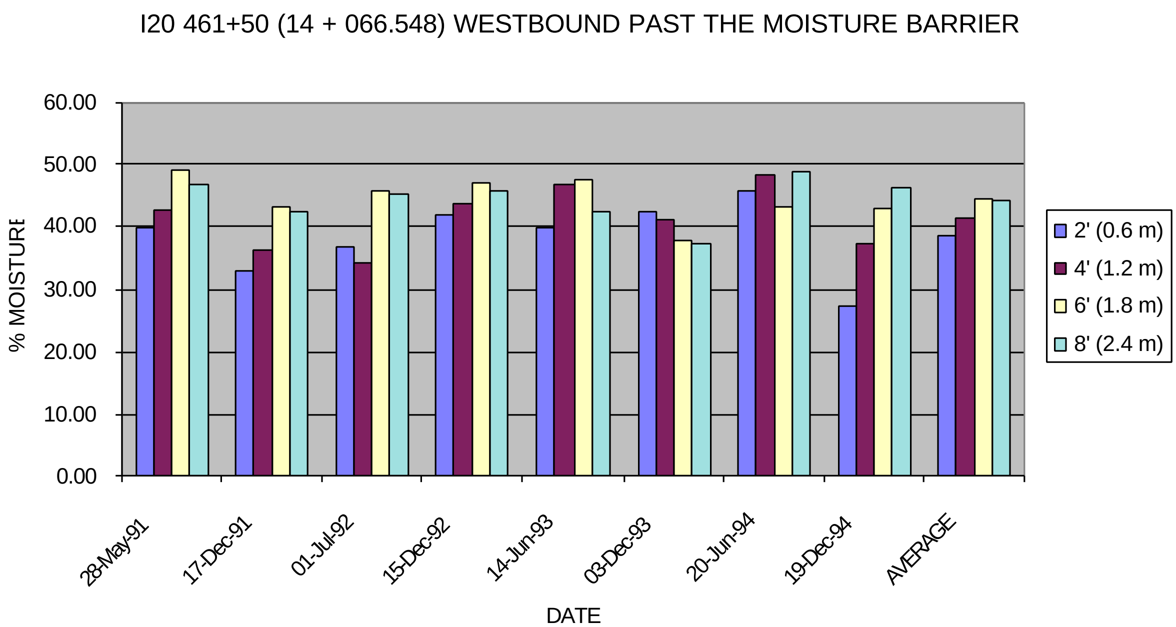

Figure 16. Project 1 Percentages of moisture past the moisture barrier at 461+50 (14 + 066.548) westbound.

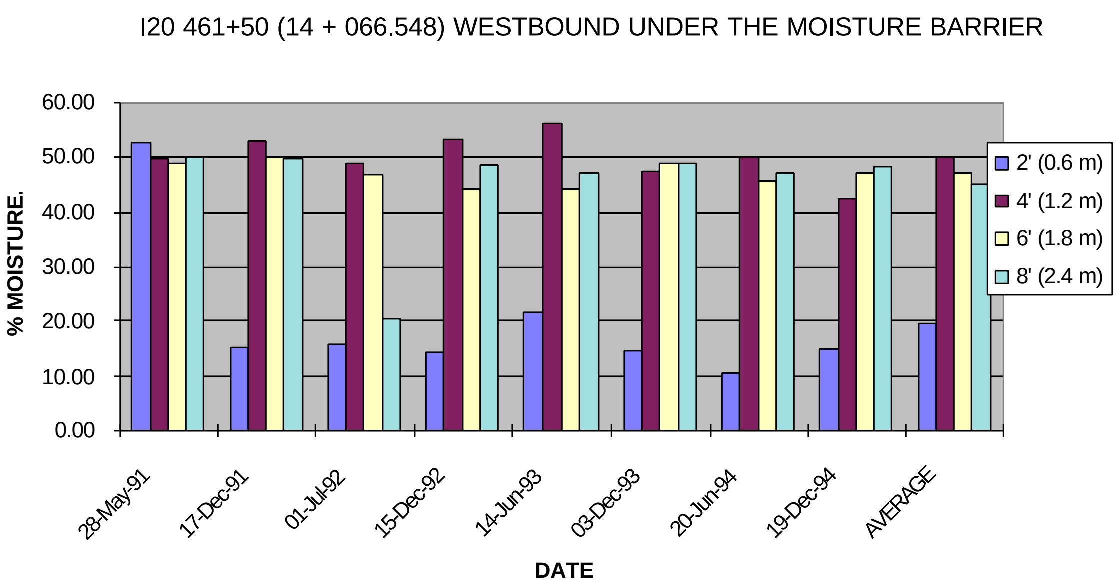

Figure 17. Project 1 Percentages of moisture under the moisture barrier at 461+50 (14 + 066.548) westbound.

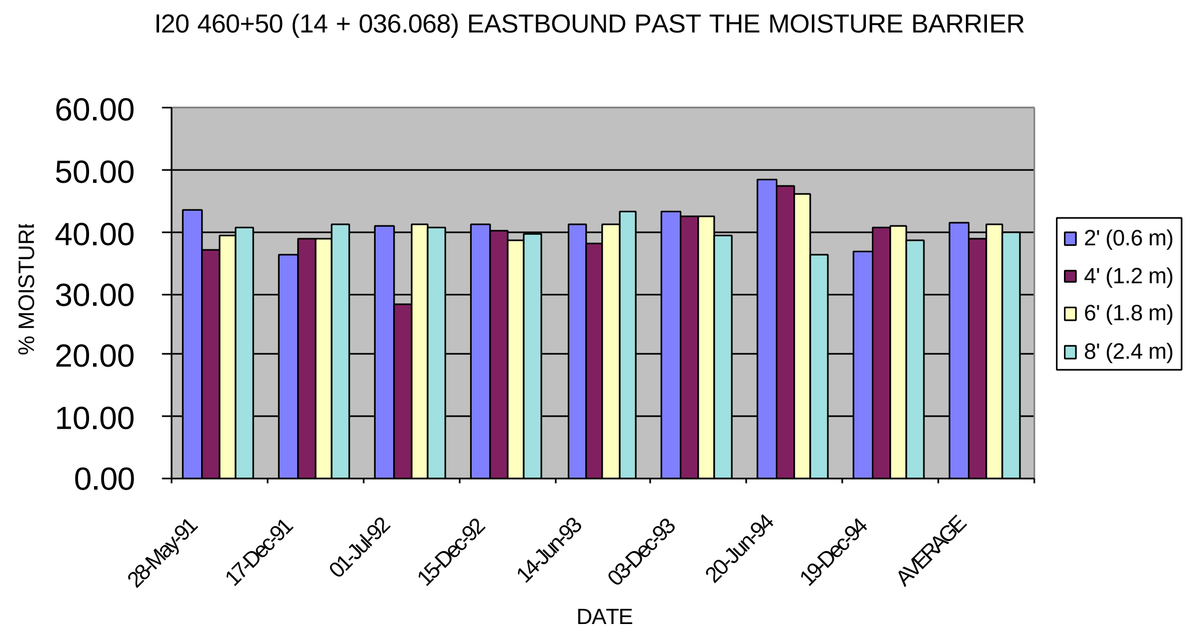

Figure 18. Project 1 Percentages of moisture past the moisture barrier at 460+50 (14 + 036.068) eastbound.

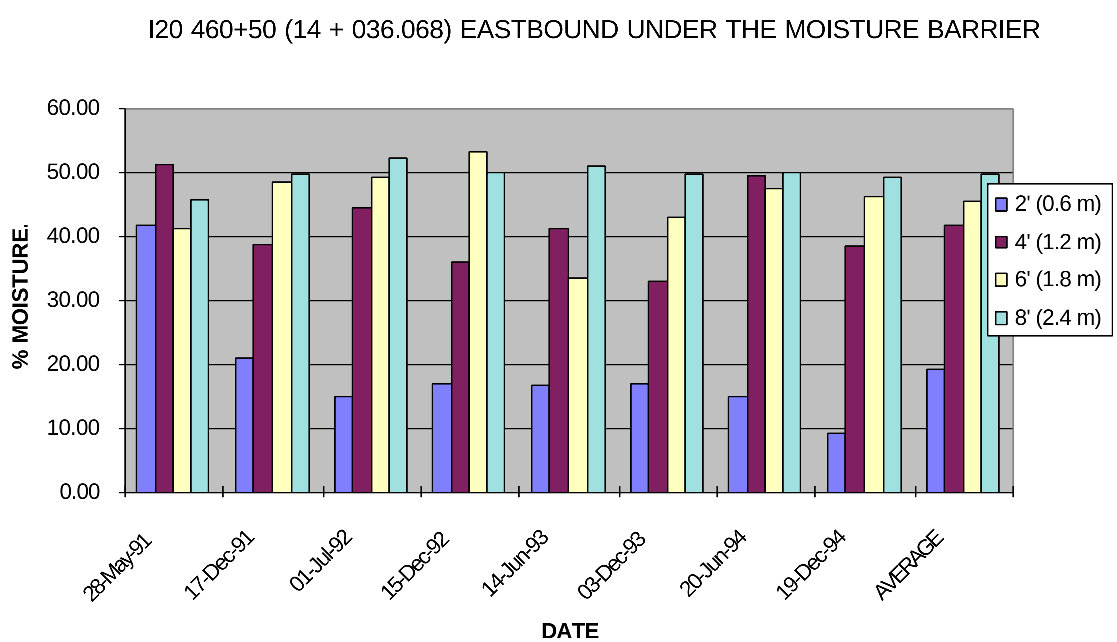

Figure 19. Project 1 Percentages of moisture under the moisture barrier at 460+50 (14 + 036.068) eastbound.

I20 702+00 (21 + 397.003) EASTBOUND PAST THE MOISTURE BARRIER

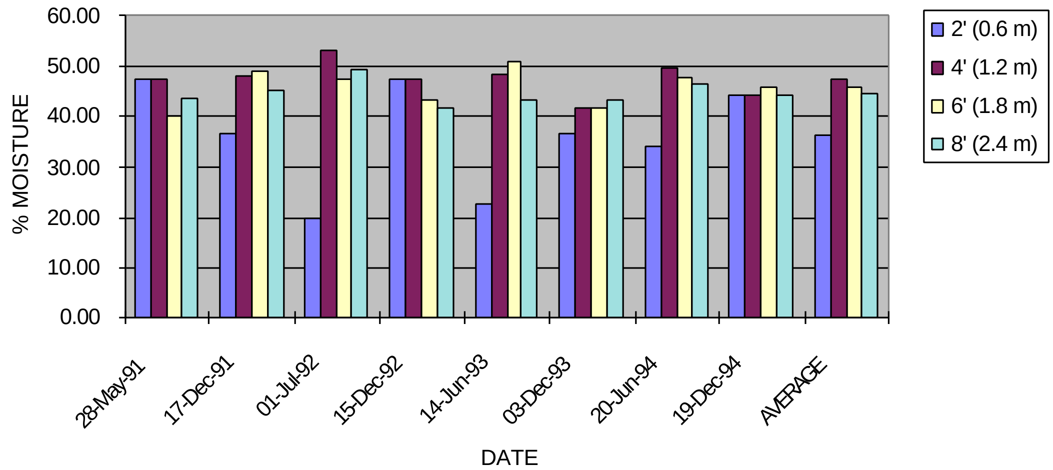

Figure 20. Project 1 Percentages of moisture past the moisture barrier at 702+00 (21 + 397.003) eastbound.

I20 702+00 (21 + 397.003) EASTBOUND UNDER THE MOISTURE BARRIER

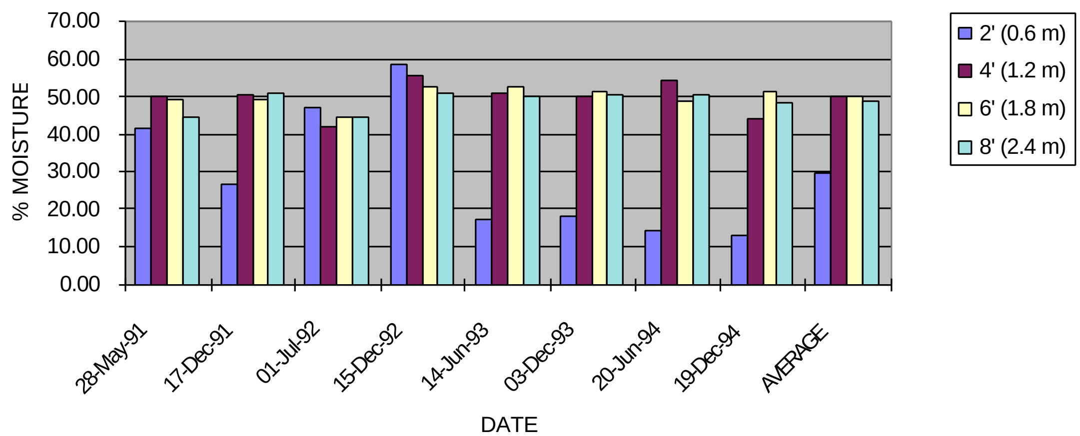

Figure 21. Project 1 Percentages of moisture under the moisture barrier at 702+00 (21 + 397.003) eastbound.

I 20 1200+50 (36 + 591.313) WESTBOUND PAST THE MOISTURE BARRIER

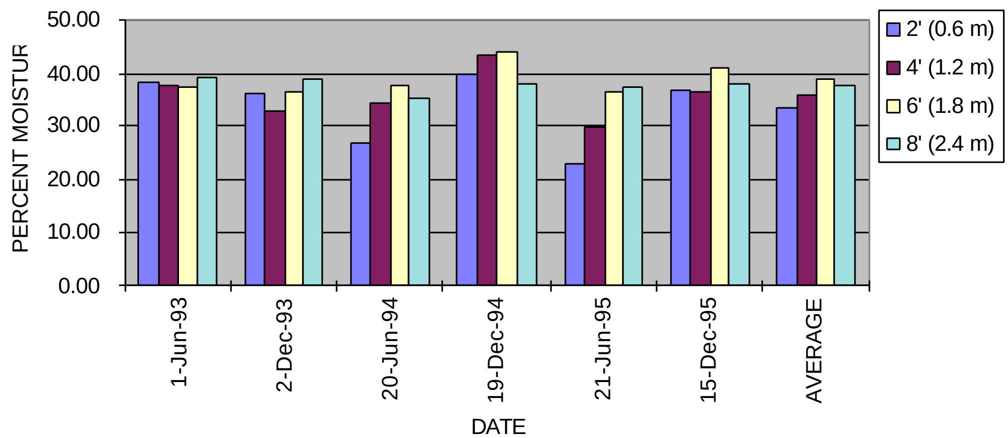

Figure 22. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound past the moisture barrier.

I 20 1200+50 (36 + 591.313) WESTBOUND UNDER THE MOISTURE BARRIER

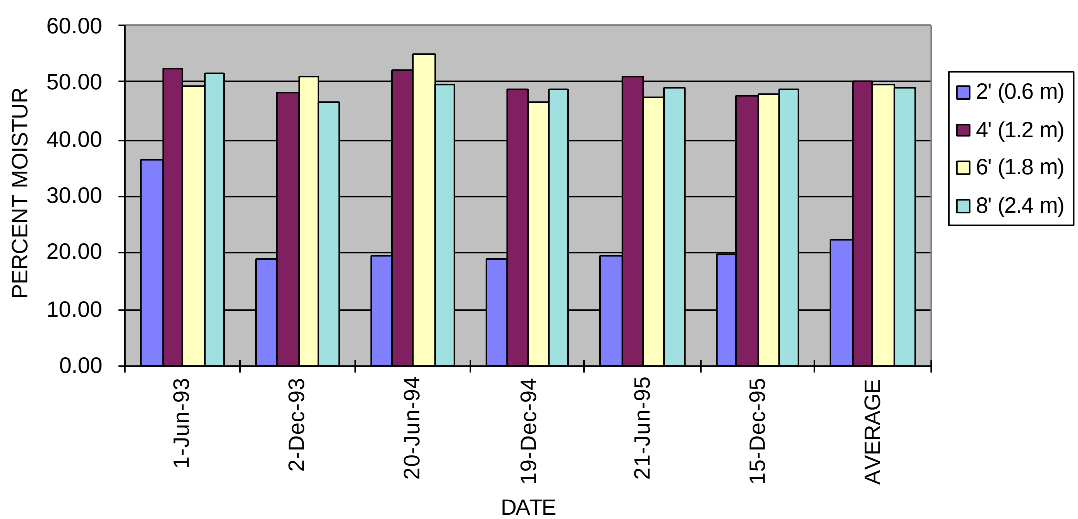

Figure 23. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound under the moisture barrier.

I 20 963+00 (29 + 352.299) WESTBOUND PAST THE MOISTURE BARRIER

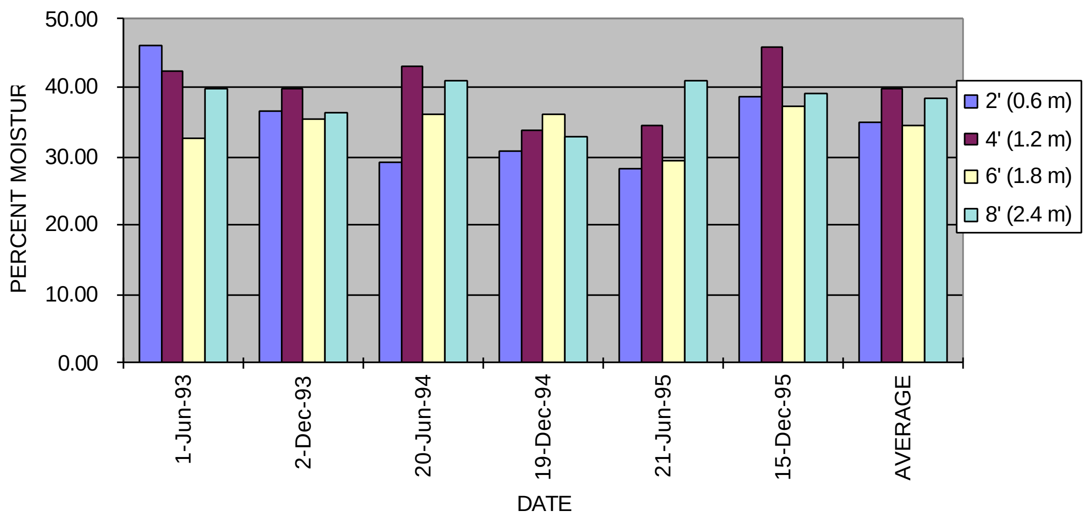

Figure 24. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound past the moisture barrier.

I 20 963+00 (29 + 352.299) WESTBOUND UNDER THE MOISTURE BARRIER

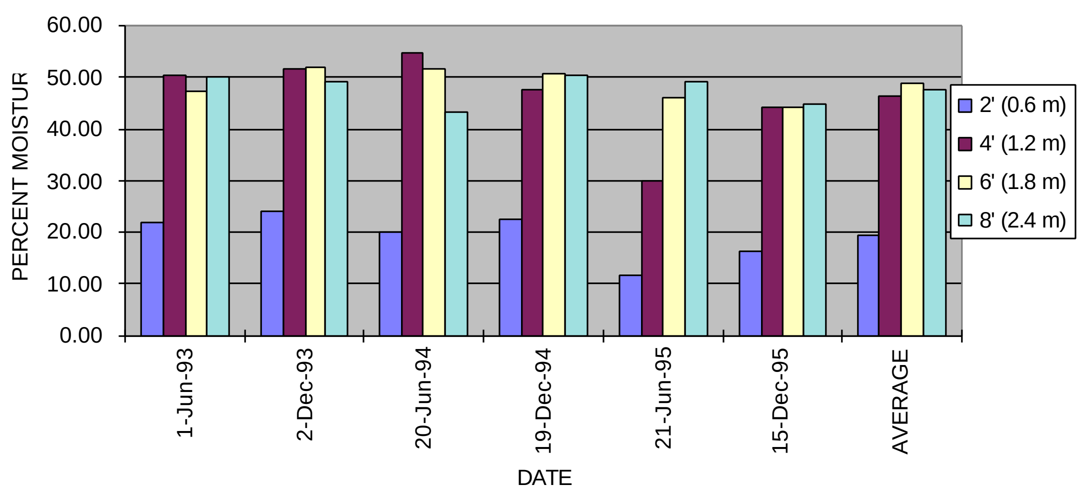

Figure 25. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound under the moisture barrier.

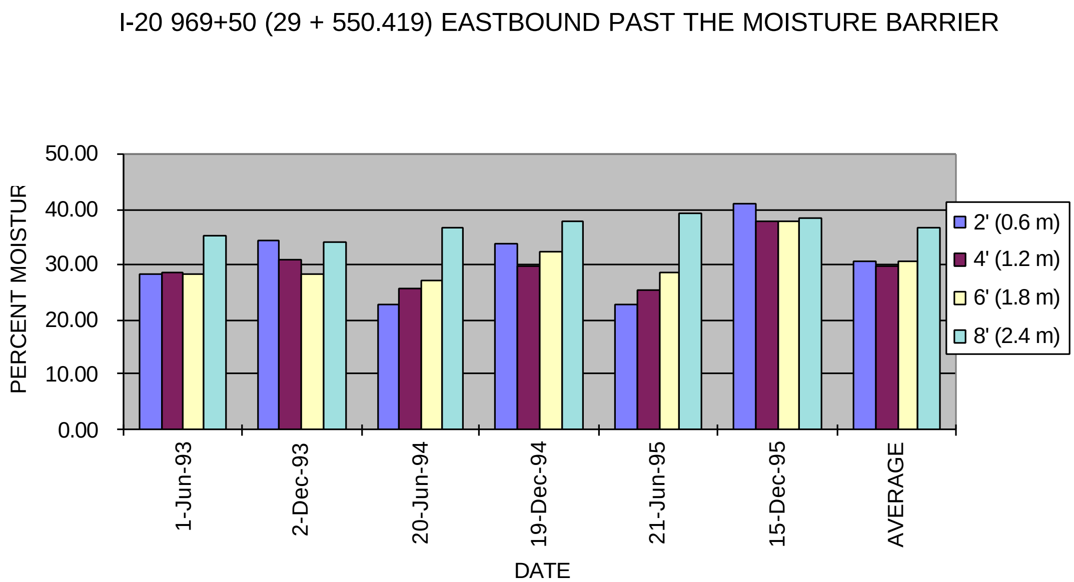

Figure 26. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound past the moisture barrier.

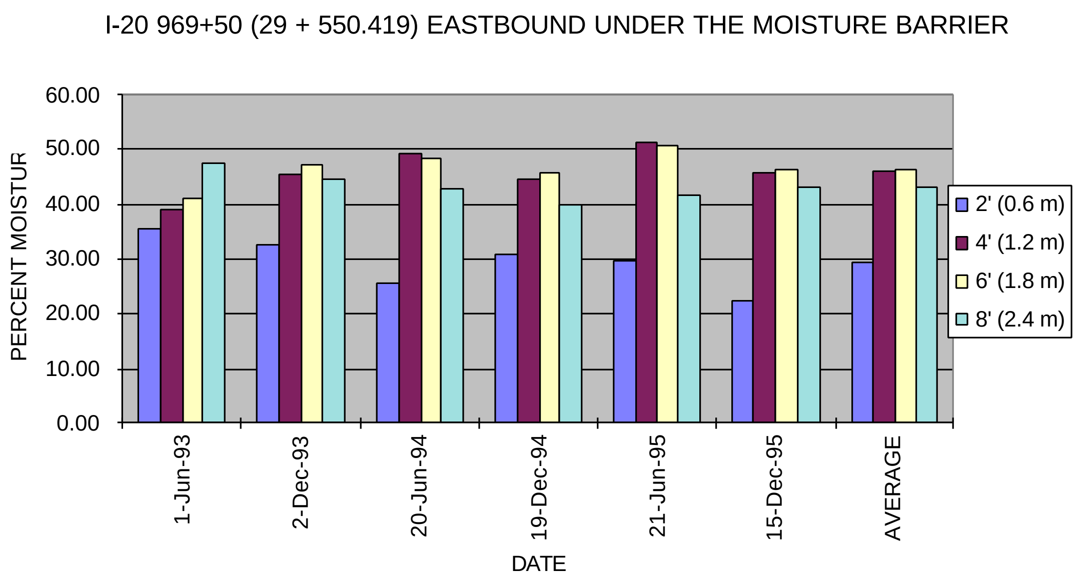

Figure 27. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound under the moisture barrier.

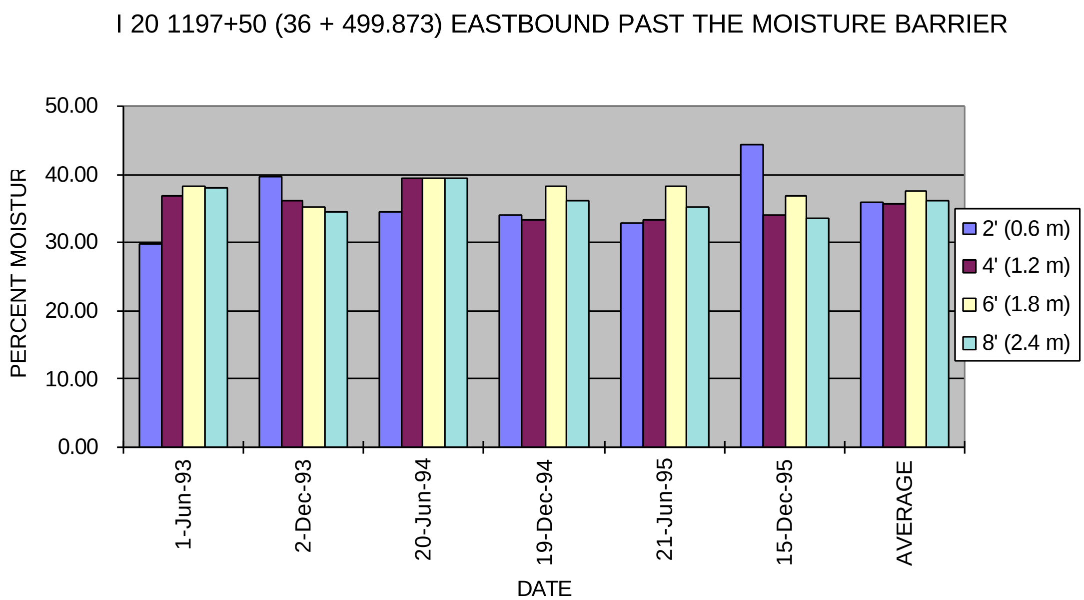

Figure 28. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound past the moisture barrier.

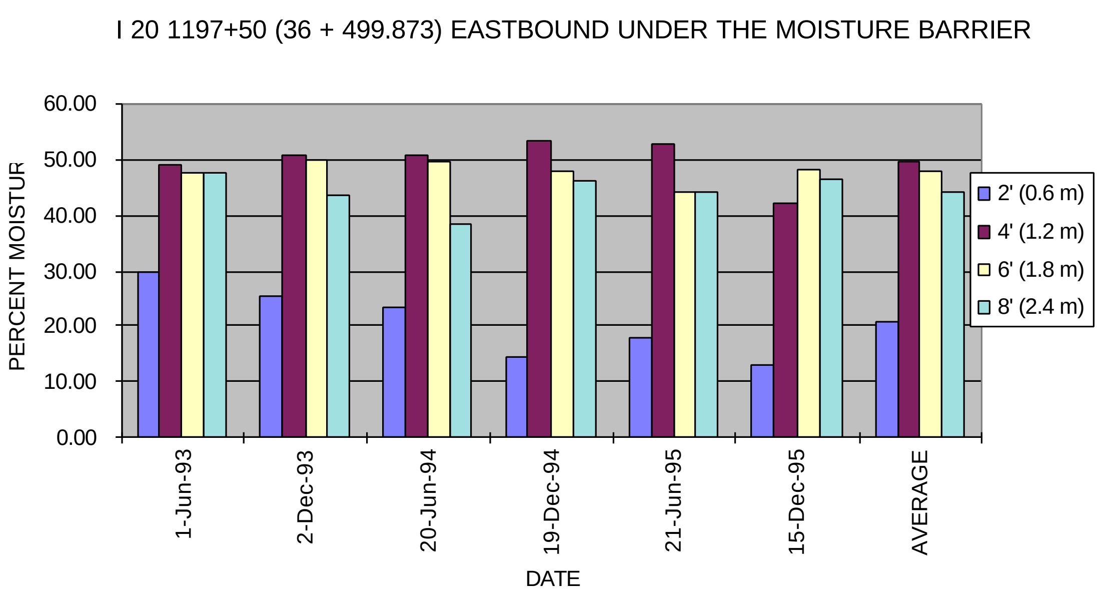

Figure 29. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound under the moisture barrier.

SUMMARY OF AVERAGES, VARIANCES, AND STANDARD DEVIATIONS.

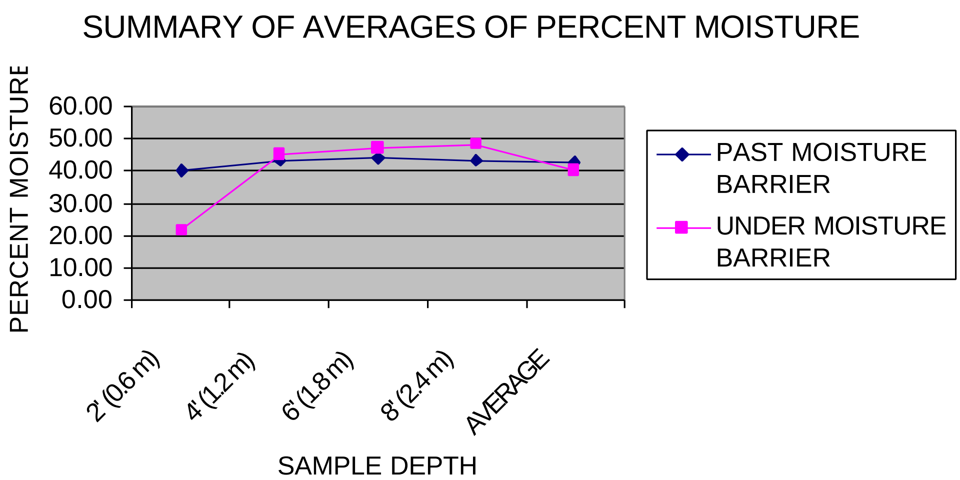

Figure 30. Project 1 Percentages of moisture at different depths.

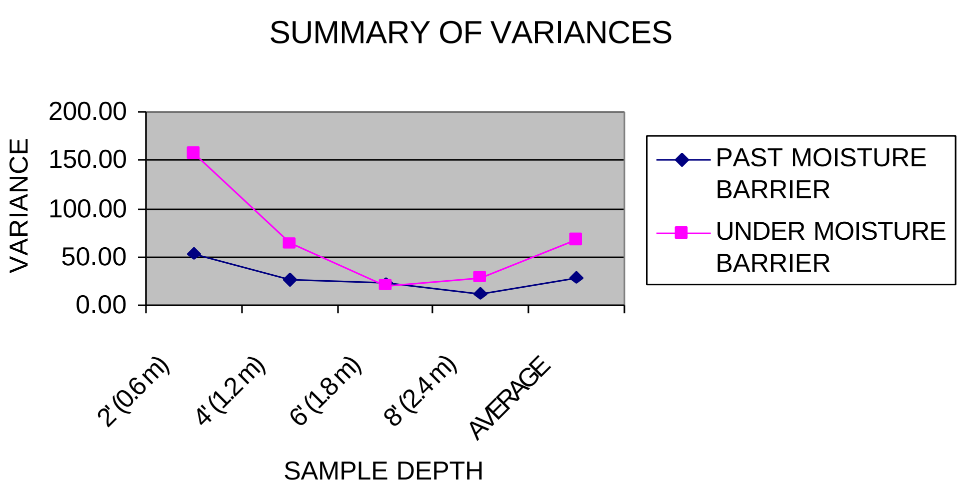

Figure 31. Project 1 Variances at various depths.

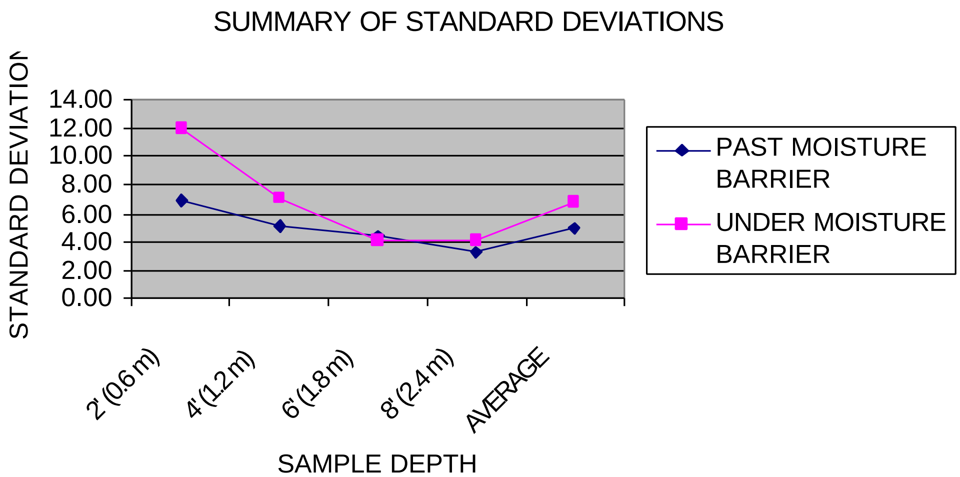

Figure 32. Project 1 Standard deviations at various depths.

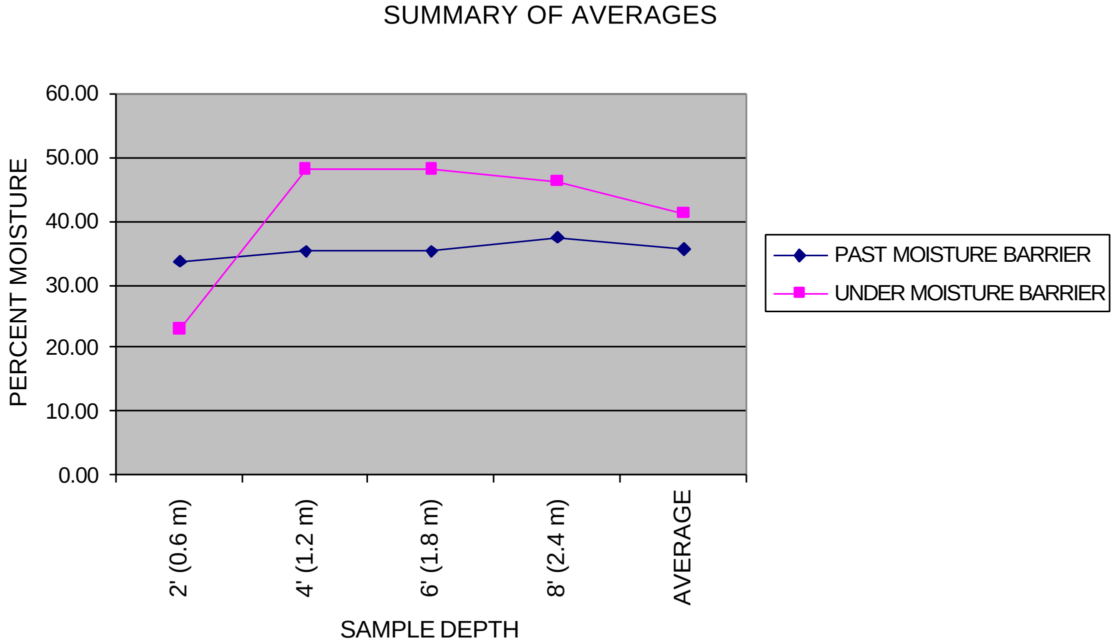

Figure 33. Project 2 Percentages of moisture at different depths.

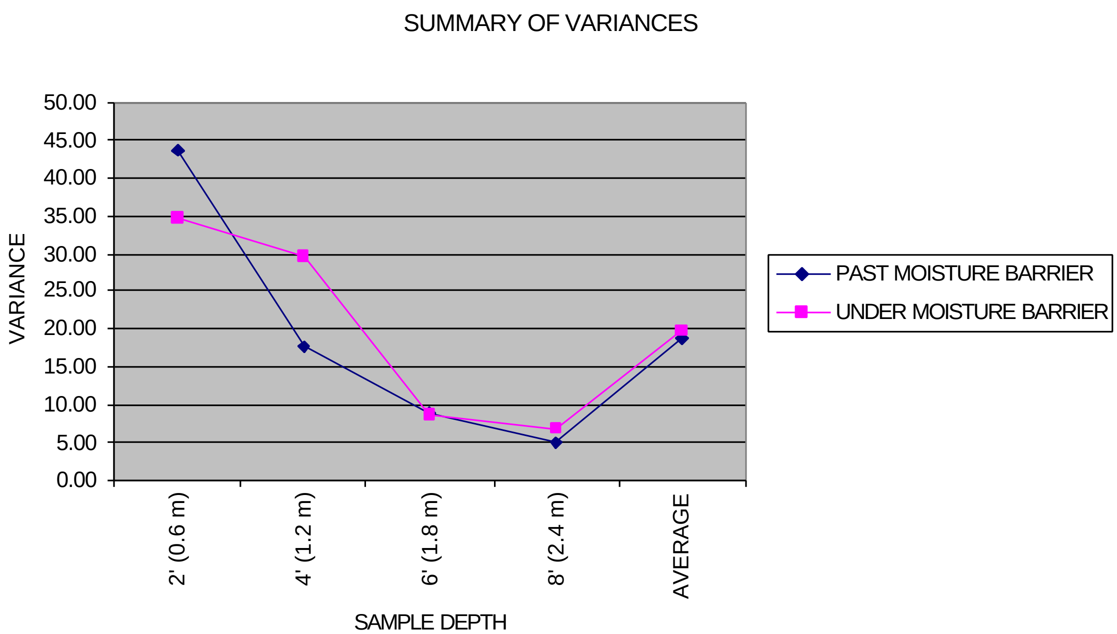

Figure 34. Project 2 Variances at various depths.

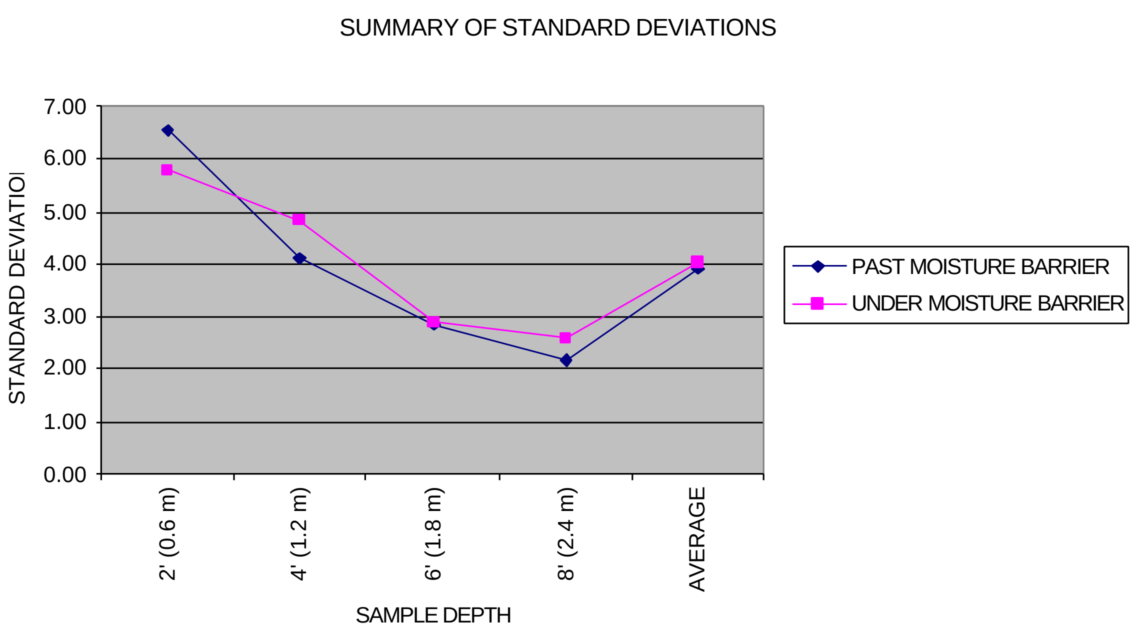

Figure 35. Project 2 Standard deviations at various depths.

Tables 5 and 6 summarize the percent moisture, variance, and standard deviation of the moisture samples taken at the four sites for both projects.

Table 5. Project 1 Summary of values past and under the moisture barriers, data for figures 30, 31, & 32.

	past moisture barrier			under moisture barrier		
	% moisture	variance	standard deviation	% moisture	variance	standard deviation
704+50 (21 + 473.203) wb	45.18	46.62	6.74	37.84	65.65	7.00
461+50 (14 + 066.548) wb	42.15	21.67	4.55	40.58	77.16	7.54
460+50 (14 + 036.068) eb	40.35	13.40	3.41	38.83	43.53	5.99
702+00 (21 + 397.003) eb	43.48	34.63	4.96	44.47	82.73	6.80
average	42.79	29.08	4.91	40.43	67.27	6.83

Table 6. Project 2 Summary of values past and under the moisture barriers, data for figures 33, 34, & 35.

	past moisture barrier			under moisture barrier		
STATION	% moisture	variance	standard deviation	% moisture	variance	standard deviation
1200+50 (36 + 591.313) wb	36.43	20.36	4.02	42.76	16.41	3.46
963+00 (29 + 352.299) wb	36.93	22.40	4.45	40.52	29.79	4.90
969+50 (29 + 550.419) eb	31.83	22.77	4.40	41.27	14.53	3.71
1197+50 (36 + 499.873) eb	36.31	10.00	2.80	40.65	19.08	4.02
average	35.38	18.88	3.92	41.30	19.95	4.02

Tables 7 and 8 list the pavement condition ratings for the project 1. Tables 9 and 10 list the pavement condition ratings for project 2.

The equation for the pavement condition rating is:

$PCR = 100 * ((12-IRI)/12) * ((D_{MAX}-DP)/D_{MAX}))^2$

where IRI = road roughness, express in m/km

D_{MAX} = probable maximum deduct point (MDP) with 205, 230, 185, and 145 respectively, for flexible, composite, jointed, and continuously reinforced concrete pavements.

DP_{MAX} = total deduct point for a pavement section

Table 7. Project 1 Pavement management condition details eastbound.

BEGINNING STATION NUMBER	ENDING STATION NUMBER	PAVEMENT CONDITION RATING
341+20 (12 + 463) EB 0.03 miles (0.048 km) east of SR 481	430+00 (15 + 182) EB 1.659 miles (2.669 km) east of SR 481	68
430+00 (15 + 182) EB 1.659 miles (2.669 km) east of SR 481	782+00 (25 + 370) EB 0.133 miles (0.214 km) east of SR 35	76
782+00 (25 + 370) EB 0.133 mile (0.214 km) east of SR 35	890+00 (29 + 053) EB 2.178 miles (3.505 km) east of SR 35	77

Table 8. Project 1 Pavement management condition details westbound.

BEGINNING STATION NUMBER	ENDING STATION NUMBER	PAVEMENT CONDITION RATING
782+00 (25 + 370) WB 0.133 miles (0.214 km) east of SR 35	890+00 (29 + 053) WB 2.178 miles (3.505 km) east of SR 35	78
430+00 (14 + 980) WB 1.711 miles (2.753 km) east of SR 481	782+00 (25 + 370) WB 0.133 miles (0.214 km) east of SR 35	77
351+00 (12 + 565) WB 0.210 miles (0.338 km) east of SR 481	430+00 (14 + 980) WB 1.711 miles (2.753 km) east of SR 481	69

Table 9. Project 2 Pavement management condition details eastbound.

BEGINNING STATION NUMBER	ENDING STATION NUMBER	PAVEMENT CONDITION RATING
890+00 (29 + 053) EB SCOTT COUNTY 2.178 miles (3.505 km) east of SR 35	950+00 (30 + 881) EB SCOTT COUNTY 3.318 miles (5.340 km) east of SR 35	81
950+00 (30 + 881) EB SCOTT COUNTY 3.318 miles (5.340 km) east of SR 35	1021+00 (33 + 045) EB SCOTT COUNTY 4.663 miles (7.504 km) east of SR 35	87
1021+00 (33 + 045) EB SCOTT COUNTY 4.663 miles (7.504 km) east of SR 35	1036+00 (33 + 502) EB SCOTT COUNTY 4.947 miles (7.961 km) east of SR 35	87
1036+00 (33 + 502) EB SCOTT COUNTY 4.947 miles (7.961 km) east of SR 35	1283+83.63 (40 + 822) EB NEWTON COUNTY LINE	88
0+02.05 (1 + 000) EB SCOTT COUNTY LINE	122+24.14 (4 + 759) EB NEWTON COUNTY East bridge abutment US 80	86
122+24.14 (4 + 759) EB NEWTON COUNTY East bridge abutment US 80	174+50 (6 + 375) EB NEWTON COUNTY 1.03 miles (1.658 km) east of US 80	86
174+50 (6 + 375) EB NEWTON COUNTY 1.03 miles (1.658 km) east of US 80	202+00 (7 + 214) EB NEWTON COUNTY 1.55 miles (2.496 km) east of US 80	89

Table 10. Project 2 Pavement management condition details westbound.

BEGINNING STATION NUMBER	ENDING STATION NUMBER	PAVEMENT CONDITION RATING
121+37.4 (4 + 711) WB NEWTON COUNTY EAST BRIDGE ABUTMENT US 80	202+00 (7 + 169) WB NEWTON COUNTY 1.53 miles (2.457 km) east of US 80	85
0+02.06 (1 + 000) WB SCOTT COUNTY LINE	121+37 (4 + 711) WB NEWTON COUNTY EAST BRIDGE ABUTMENT	83
967+00 (31 + 021) WB SCOTT COUNTY 3.401 miles (5.473 km) east of SR 35	1283+83.63 (40 + 699) WB NEWTON COUNTY LINE	84
950+00 (30 + 881) WB SCOTT COUNTY 3.314 miles (5.333 km) east of SR 35	967+00 (31 + 021) WB SCOTT COUNTY 3.401 miles (5.473 km) east of SR 35	85
890+00 (29 + 053) WB SCOTT COUNTY 2.178 miles (3.505 km) east of SR 35	950+00 (30 + 881) WB SCOTT COUNTY 3.314 miles (5.333 km) east of SR 35	82

DISCUSSION OF RESULTS

Two types of measurements were made: profile measurements and moisture contents.

Ride quality, as measured by the SDP, decreased with time for both the fabric and non-fabric protected soils. This could be caused by the expansive soil's subgrade, but the higher IRI values might be caused by conditions beside the capability of the geomembrane, such as base failure and pavement deterioration. The increasing permeability of the asphalt pavement is also a component.[4]

For project 1, the moisture barrier is under only 18.3 percent of the asphalt for this project:

- Thirteen sites totaling 1.69 miles (2.71 km) of 9.58 miles (15.41 km) in the eastbound direction
- Thirteen sites totaling 1.83 miles (2.94 km) of 9.60 miles (15.45 km) in the westbound direction

For project 2, The moisture barrier is under only 5.7 percent of the asphalt:

- 4 sites totaling 0.80 miles (1.28 km) of 10.22 miles (16.45 km) in the eastbound direction
- 2 sites totaling 0.36 miles (0.58 km) of 10.19 miles (16.41 km) in the westbound direction.

The SDP computes the IRI over the entire project in increments of 0.10 mile (0.16 km), which includes the sections with and without the moisture barriers.

The sections with and without the moisture barriers were marked and the averages of the IRIs of pavement with and without the moisture barriers were computed. For project 1, the IRI values of the pavement over the moisture barriers averaged 9.45 percent more than the rest of the pavement. For project 2, the IRI values of the pavement over the moisture barriers averaged 13.37 percent more than the rest of the pavement.

The samples taken under the moisture barriers had a slightly overall lower average moisture content than the samples taken past the moisture barriers (table 5). As can be seen from figure 20, this is due to the much lower moisture content under the moisture barrier at 2' (0.6 m).

The overall averages of the variances and standard deviations of the moisture contents are greater under the moisture barriers (table 5). Figures 21 and 22 show that the variance and standard deviation under the moisture barrier at 6' (1.8 m) are less than those past the moisture barrier, but are greater at the other test depths.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The following conclusions are based on roughness tests using the SDP and laboratory tests conducted on the soil samples.

- For both projects studied, the IRIs were greater in sections of the pavement where the moisture barriers were present relative to control sections.
- The average moisture variances were greater under the moisture barriers than past the moisture barriers.

RECOMMENDATIONS

It is recommended that future use of this design of horizontal moisture barriers on pavements not be continued. The moisture barrier did not produce a smoother ride than the unprotected pavement in the roughness tests or reduce the moisture variance.

Vertical moisture barriers on both sides of the pavement, along both shoulders, down to the rooting depth of vegetation, about 8' (2.4 m), have been proven to be effective. They isolate the soils beneath the pavement from horizontal flow of rainwater and prevent moisture exchange from soil under the pavement to the soil outside. Vertical moisture barriers would require less fabric than used on this project and could also be used on pavements already constructed.

There is no moisture barrier 9' (2.74 m) on either side of the pavement centerline. If the geomembrane were continuous under the pavement, then the pavement subsoil would be sealed off from moisture entering through cracks in the asphalt. A better moisture barrier design might be using a geomembrane that is continuous under the pavement, to seal off rainwater, and using vertical moisture barriers on both sides at the shoulders to prevent horizontal flow of water.

Permanent moisture sensors should be placed for the length of the study period. The method used on this study was labor intensive, cut holes in the moisture barrier, left tire ruts in the grass on both sides of the ditch, and might not have been very accurate.

Computer programs have been used in other states for over 10 years to simulate the movement of water under a pavement with vertical moisture barriers. Computer analysis simulations on several designs should be done before other moisture barrier projects are built.

REFERENCES

1. Bowles, J. E., 1977, "Foundation Analysis and Design", second edition, McGraw-Hill Book Company, New York, 750 pp. 113.

2. Gay, D. A., and Lytton, R. L., 1988, "Moisture Barrier Effects on Pavement Roughness", in Measured Performance of Shallow Foundations, Geotechnical Special Publication No. 15, American Society of Civil Engineers.

3. Rahim, M. A. B. A., and Picornell, M., 1989, "Moisture Movement under the Pavement Structure", Study 10-8-88-1165, CENTER FOR GEOTECHNICAL & HIGHWAY MATERIALS RESEARCH, The University of Texas at El Paso.

4. Steinberg, M. L. "Controlling Expansive Soils: Twenty Texas Highway Projects", 7th International Conference on Expansive Soils, pp. 392-397.

5. Picornell, M., and Lytton, R. L. "Behavior and Design of Vertical Moisture Barriers", Transportation Research Record 1137, National Research Council, Washington, D.C., pp. 71-82.

6. Ridgeway, H. H., "Infiltration of Water Through the pavement Surface", Transportation Research Record, 616, National Research Council, Washington, D.C., pp. 98-100.

7 George, K. P., "PAVMENENT MANAGEMENT INFORMATION SYSTEM – PHASE II Interim Report on COMPOSITE INDEX FOR PAVEMENT CONDITION RATING", pp. 7-11.

APPENDIX A

ROUGHNESS RESULTS

Table 11. Project 1 All IRI measurements.

		I-20 MOISTURE BARRIER PROJECT				
		EAST	WEST	EAST	WEST	
	DATE	OUTSIDE	OUTSIDE	INSIDE	INSIDE	
1	22-Oct-91	0.98	0.90	1.07	0.99	
2	7-Feb-92	1.07	1.00	1.09	1.03	
3	8-Jun-92	0.96	1.08	1.05	0.99	
4	30-Sep-92	1.08	1.05	1.15	1.10	
5	27-Jan-93	1.03	0.96	1.09	1.00	
6	12-Apr-93	1.11	1.07	1.21	1.20	
7	5-Aug-93	1.24	1.21	1.29	1.21	
8	9-Nov-93	1.21	1.17	1.21	1.12	
9	11-Feb-94	1.20	1.32	1.18	1.33	
10	20-May-94	1.31	1.31	1.36	1.29	
11	5-Aug-94	1.25	1.24	1.24	1.18	
12	8-Nov-94	1.21	1.17	1.20	1.13	
13	10-Mar-95	1.31	1.25	1.28	1.36	
PERCENT	GREATER	33.67	38.89	20.19	37.37	32.53
THAN	BEGINNING					AVERAGE

Table 12. Project 1 Comparing the IRI values with and without moisture barriers, data for figure 12.

DATE	AVERAGE W/O BARRIERS	AVERAGE WITH BARRIERS	PERCENT MORE
27-Jan-93	1.01	1.12	10.42%
12-Apr-93	1.13	1.22	7.29%
5-Aug-93	1.23	1.32	7.59%
9-Nov-93	1.16	1.30	12.05%
11-Feb-94	1.26	1.36	8.16%
20-May-94	1.31	1.44	9.62%
5-Aug-94	1.21	1.35	11.62%
8-Nov-94	1.16	1.31	13.40%
10-Mar-95	1.29	1.35	4.89%
PERCENT GREATER	27.73%	21.34%	9.45%
THAN BEGINNING			AVERAGE

Table 13. Project 2 All IRI measurements.

I-20 EXTENDED MOISTURE BARRIER PROJECT						
	DATE	**EAST OUTSIDE**	**WEST OUTSIDE**	**EAST INSIDE**	**WEST INSIDE**	
BEFORE #1	23-Apr-91	1.98	1.80	1.99	1.77	
BEFORE #2	23-Apr-91	1.99	1.81	2.00	1.81	
	-	-	-	-	-	
AFTER #1	27-Jan-93	0.67	0.69	0.69	0.73	
AFTER #2	12-Apr-93	0.90	0.86	0.87	0.95	
AFTER #3	5-Aug-93	0.85	0.85	0.92	0.91	
AFTER #4	9-Nov-93	0.68	0.69	0.71	0.73	
AFTER #5	11-Feb-94	0.71	0.78	0.80	0.95	
AFTER #6	20-May-94	0.97	1.00	1.04	1.05	
AFTER #7	5-Aug-94	0.71	0.72	0.70	0.74	
AFTER #8	8-Nov-94	0.72	0.77	0.73	0.77	
AFTER #10	10-Mar-95	0.88	0.77	0.95	0.86	
AFTER #11	5-May-95	0.93	0.85	1.20	1.02	
AFTER #12	12-Dec-95	0.80	0.81	0.69	0.74	
PERCENT GREATER		19.40	17.39	0.00	1.37	9.54
AFTER #12 IS THAN AFTER #1						AVERAGE

Table 14. Project 2 Comparing the IRI values with and without moisture barriers, data for figure 13.

DATE	AVERAGE W/O BARRIERS	AVERAGE WITH BARRIERS	PERCENT MORE WITH BARRIERS
27-Jan-93	0.68	0.75	10.95%
12-Apr-93	0.93	1.04	11.04%
5-Aug-93	0.89	0.84	-6.18%
9-Nov-93	0.74	0.71	-4.30%
11-Feb-94	0.85	0.95	12.19%
20-May-94	1.01	1.18	16.66%
5-Aug-94	0.74	0.92	23.04%
8-Nov-94	0.76	0.92	21.25%
10-Mar-95	0.91	1.00	9.75%
5-May-95	1.03	1.15	12.16%
12-Dec-95	0.75	1.05	40.55%
PERCENT GREATER	10.15%	39.54%	13.37%
THAN BEGINNING			AVERAGE

APPENDIX B

MOISTURE RESULTS

MOISTURE TESTS AT THE FOUR -TEST SITES PAST AND UNDER THE MOISTURE BARRIERS.

Table 15. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound past the moisture barrier, data for figure 14.

704+50 (21 + 473.203) westbound on the median shoulder.					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	56.12	50.87	49.65	49.51	
17-Dec-91	39.47	42.68	41.82	47.61	
01-Jul-92	40.33	42.23	38.27	36.88	
15-Dec-92	47.83	41.98	41.76	42.50	
14-Jun-93	38.22	46.41	45.24	43.80	
03-Dec-93	50.66	44.46	43.51	47.70	
20-Jun-94	33.39	41.61	37.23	41.03	
19-Dec-94	48.51	60.44	61.53	52.65	AVERAGES
AVERAGE	44.32	46.33	44.88	45.21	45.18
VARIANCE	57.92	42.07	60.48	26.01	46.62
STANDARD DEVIATION	7.61	6.49	7.78	5.10	6.74

Table 16. Project 1 Percentages of moisture at 704+50 (21 + 473.203) westbound under the moisture barrier, data for figure 15.

704+50 (21 + 473.203) westbound on the median shoulder.					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	24.26	49.55	42.66	49.73	
17-Dec-91	15.96	55.33	48.84	48.37	
01-Jul-92	24.26	46.04	45.00	45.50	
15-Dec-92	29.03	44.75	51.12	49.44	
14-Jun-93	16.02	43.76	32.66	49.62	
03-Dec-93	8.38	26.35	47.72	51.56	
20-Jun-94	9.16	15.72	44.50	49.40	
19-Dec-94	14.85	34.10	46.31	51.00	AVERAGES
AVERAGE	17.74	39.45	44.85	49.33	37.84
VARIANCE	55.42	172.50	31.31	3.38	65.65
STANDARD DEVIATION	7.44	13.13	5.60	1.84	7.00

Table 17. Project 1 Percentages of moisture past the moisture barrier at 461+50 (14 + 066.548) westbound, data for figure 16.

461+50 (14 + 066.548) westbound on the outside shoulder,					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	39.75	42.53	49.05	46.76	
17-Dec-91	32.94	36.32	43.29	42.28	
01-Jul-92	37.04	34.33	45.88	45.18	
15-Dec-92	41.92	43.75	47.13	45.90	
14-Jun-93	39.74	46.81	47.63	42.51	
03-Dec-93	42.33	41.02	37.85	37.10	
20-Jun-94	45.86	48.49	43.27	48.71	
19-Dec-94	27.17	37.07	42.85	46.31	AVERAGES
AVERAGE	38.34	41.29	44.62	44.34	42.15
VARIANCE	34.98	25.84	12.74	13.14	21.67
STANDARD DEVIATION	5.91	5.08	3.57	3.63	4.55

Table 18. Project 1 Percentages of moisture under the moisture barrier at 461+50 (14 + 066.548) westbound, data for figure 17.

461+50 (14 + 066.548) westbound on the outside shoulder.					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	52.75	49.59	49.19	49.98	
17-Dec-91	15.31	52.94	50.21	49.85	
01-Jul-92	15.76	49.09	46.91	20.34	
15-Dec-92	14.14	53.50	44.17	48.73	
14-Jun-93	21.41	56.45	44.28	47.26	
03-Dec-93	14.47	47.65	49.08	49.06	
20-Jun-94	10.74	50.21	45.60	47.25	
19-Dec-94	14.91	42.45	47.06	48.18	AVERAGES
AVERAGE	19.94	50.23	47.06	45.08	40.58
VARIANCE	184.41	17.95	5.25	101.03	77.16
STANDARD DEVIATION	13.58	4.24	2.29	10.05	7.54

Table 19. Project 1 Percentages of moisture past the moisture barrier at 460+50 (14 + 036.068) eastbound, data for figure 18.

460+50 (14 + 036.068) eastbound on the outside shoulder,					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	43.43	36.85	39.38	40.62	
17-Dec-91	36.30	38.96	38.93	41.33	
01-Jul-92	41.02	28.27	41.10	40.66	
15-Dec-92	41.06	40.23	38.50	39.50	
14-Jun-93	41.10	37.91	41.15	43.21	
03-Dec-93	42.99	42.39	42.45	39.10	
20-Jun-94	48.22	47.27	45.98	36.47	
19-Dec-94	36.71	40.61	40.91	38.49	AVERAGES
AVERAGE	41.35	39.06	41.05	39.92	40.35
VARIANCE	14.51	29.28	5.72	4.09	13.40
STANDARD DEVIATION	3.81	5.41	2.39	2.02	3.41

Table 20. Project 1 Percentages of moisture under the moisture barrier at 460+50 (14 + 036.068) eastbound, data for figure 19.

460+50 (14 + 036.068) eastbound on the outside shoulder,					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	41.46	51.37	41.16	45.60	
17-Dec-91	20.83	38.63	48.44	49.78	
01-Jul-92	15.13	44.33	48.95	52.06	
15-Dec-92	16.93	35.94	53.12	49.86	
14-Jun-93	16.58	41.25	33.34	51.05	
03-Dec-93	16.90	32.89	42.74	49.62	
20-Jun-94	15.08	49.23	47.37	50.12	
19-Dec-94	9.10	38.47	46.15	49.12	AVERAGES
AVERAGE	19.00	41.51	45.16	49.65	38.83
VARIANCE	92.93	41.10	36.55	3.53	43.53
STANDARD DEVIATION	9.64	6.41	6.05	1.88	5.99

Table 21. Project 1 Percentages of moisture past the moisture barrier at 702+00 (21 + 397.003) eastbound, data for figure 20.

702+00 (21 + 397.003) eastbound on the median shoulder,					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	47.37	47.22	40.19	43.85	
17-Dec-91	36.69	47.92	48.98	45.34	
01-Jul-92	20.03	53.35	47.22	49.20	
15-Dec-92	47.12	47.48	43.28	41.75	
14-Jun-93	22.78	48.53	50.80	43.45	
03-Dec-93	36.36	41.84	41.79	43.16	
20-Jun-94	33.99	49.57	47.84	46.32	
19-Dec-94	44.11	43.91	45.61	44.26	AVERAGES
AVERAGE	36.06	47.48	45.72	44.67	43.48
VARIANCE	107.57	12.10	13.59	5.26	34.63
STANDARD DEVIATION	10.37	3.48	3.69	2.29	4.96

Table 22. Project 1 Percentages of moisture under the moisture barrier at 702+00 (21 + 397.003) eastbound, data for figure 21.

702+00 (21 + 397.003) eastbound on the median shoulder,					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
28-May-91	41.34	49.94	49.18	44.41	
17-Dec-91	26.26	50.46	49.48	50.86	
01-Jul-92	46.97	42.02	44.75	44.28	
15-Dec-92	58.43	55.51	52.75	51.03	
14-Jun-93	17.40	51.04	52.55	50.07	
03-Dec-93	18.01	49.81	51.37	50.36	
20-Jun-94	14.41	54.25	48.71	50.34	
19-Dec-94	13.18	44.05	51.30	48.39	AVERAGES
AVERAGE	29.50	49.64	50.01	48.72	44.47
VARIANCE	295.08	21.12	6.82	7.91	82.73
STANDARD DEVIATION	17.18	4.60	2.61	2.81	6.80

Table 23. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound past the moisture barrier, data for figure 22.

1200+50 (36 + 591.313) westbound on the outside shoulder.					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	38.51	37.51	37.28	39.18	
2-Dec-93	36.27	32.80	36.34	38.59	
20-Jun-94	26.86	34.35	37.64	35.25	
19-Dec-94	39.80	43.31	44.10	38.10	
21-Jun-95	22.83	29.65	36.38	37.36	
15-Dec-95	36.79	36.60	40.84	38.04	AVERAGES
AVERAGE	33.51	35.70	38.76	37.75	36.43
VARIANCE	48.24	21.77	9.55	1.87	20.36
STANDARD DEVIATION	6.95	4.67	3.09	1.37	4.02

Table 24. Project 2 Percentages of moisture at 1200+50 (36 + 591.313) westbound past the moisture barrier, data for figure 23.

1200+50 (36 + 591.313) westbound on the outside shoulder.					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	36.44	52.44	49.43	51.66	
2-Dec-93	19.22	48.38	51.07	46.72	
20-Jun-94	19.36	52.17	55.17	49.81	
19-Dec-94	19.13	48.59	46.55	48.61	
21-Jun-95	19.28	51.25	47.43	49.19	
15-Dec-95	19.78	47.68	48.06	48.88	AVERAGES
AVERAGE	22.20	50.09	49.62	49.15	42.76
VARIANCE	48.68	4.44	9.92	2.60	16.41
STANDARD DEVIATION	6.98	2.11	3.15	1.61	3.46

Table 25. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound past the moisture barrier, data for figure 24.

963+00 (29 + 352.299) westbound on the median shoulder.					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	46.09	42.36	32.62	39.69	
2-Dec-93	36.55	39.94	35.53	36.47	
20-Jun-94	29.16	43.05	36.17	40.97	
19-Dec-94	30.90	33.71	35.99	32.92	
21-Jun-95	28.08	34.52	29.50	41.13	
15-Dec-95	38.66	45.85	37.17	39.19	AVERAGES
AVERAGE	34.91	39.91	34.50	38.39	36.93
VARIANCE	47.52	23.72	8.34	10.03	22.40
STANDARD DEVIATION	6.89	4.87	2.89	3.17	4.45

Table 26. Project 2 Percentages of moisture at 963+00 (29 + 352.299) westbound past the moisture barrier, data for figure 25.

963+00 (29 + 352.299) westbound on the median shoulder.					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	22.05	50.49	47.30	49.85	
2-Dec-93	23.98	51.53	51.81	48.97	
20-Jun-94	20.18	54.57	51.52	43.29	
19-Dec-94	22.35	47.42	50.57	50.39	
21-Jun-95	11.58	29.67	46.17	49.16	
15-Dec-95	16.15	44.27	44.31	44.91	AVERAGES
AVERAGE	19.38	46.33	48.61	47.76	40.52
VARIANCE	21.82	79.03	9.73	8.57	29.79
STANDARD DEVIATION	4.67	8.89	3.12	2.93	4.90

Table 27. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound past the moisture barrier, data for figure 26.

969+50 (29 + 550.419) eastbound on the outside shoulder.					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	28.31	28.50	28.34	35.18	
2-Dec-93	34.60	30.96	28.10	33.91	
20-Jun-94	22.83	25.56	27.19	36.42	
19-Dec-94	33.85	29.84	32.09	37.68	
21-Jun-95	22.89	25.43	28.69	39.10	
15-Dec-95	40.79	37.52	37.85	38.30	AVERAGES
AVERAGE	30.55	29.63	30.38	36.77	31.83
VARIANCE	51.08	19.92	16.21	3.88	22.77
STANDARD DEVIATION	7.15	4.46	4.03	1.97	4.40

Table 28. Project 2 Percentages of moisture at 969+50 (29 + 550.419) eastbound past the moisture barrier, data for figure 27.

969+50 (29 + 550.419) eastbound on the outside shoulder.					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	35.34	39.06	40.82	47.38	
2-Dec-93	32.72	45.38	47.18	44.50	
20-Jun-94	25.48	49.43	48.11	42.86	
19-Dec-94	30.65	44.55	45.79	39.99	
21-Jun-95	29.80	51.32	50.72	41.75	
15-Dec-95	22.24	45.78	46.42	43.29	AVERAGES
AVERAGE	29.37	45.92	46.51	43.30	41.27
VARIANCE	22.90	18.15	10.73	6.34	14.53
STANDARD DEVIATION	4.79	4.26	3.28	2.52	3.71

Table 29. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound past the moisture barrier, data for figure 28.

1197+50 (36 + 499.873) eastbound on the median shoulder.					
% MOISTURE PAST THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	29.72	36.88	38.18	37.89	
2-Dec-93	39.82	36.08	35.44	34.54	
20-Jun-94	34.39	39.49	39.37	39.34	
19-Dec-94	34.26	33.19	38.13	36.13	
21-Jun-95	32.96	33.36	38.17	35.26	
15-Dec-95	44.29	34.14	36.86	33.58	AVERAGES
AVERAGE	35.91	35.52	37.69	36.12	36.31
VARIANCE	27.52	5.99	1.85	4.65	10.00
STANDARD DEVIATION	5.25	2.45	1.36	2.16	2.80

Table 30. Project 2 Percentages of moisture at 1197+50 (36 + 499.873) eastbound past the moisture barrier, data for figure 29.

1197+50 (36 + 499.873) eastbound on the median shoulder.					
% MOISTURE UNDER THE MOISTURE BARRIER					
DATE	2' (0.6 m)	4' (1.2 m)	6' (1.8 m)	8' (2.4 m)	
1-Jun-93	29.99	49.01	47.58	47.25	
2-Dec-93	25.35	50.60	50.00	43.65	
20-Jun-94	23.41	50.56	49.72	38.31	
19-Dec-94	14.31	53.35	47.76	45.86	
21-Jun-95	18.07	52.76	44.26	44.31	
15-Dec-95	12.83	42.06	47.96	46.52	AVERAGES
AVERAGE	20.66	49.72	47.88	44.32	40.65
VARIANCE	45.03	16.62	4.22	10.46	19.08
STANDARD DEVIATION	6.71	4.08	2.06	3.23	4.02

COMPARING PERCENT MOISTURES AT THE TEST DEPTHS.

Table 31. Project 1 Percent moisture at 704+50 (21 + 473.203) westbound.

704+50 (21 + 473.203) westbound on the median shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
28-May-91	56.12	24.26	50.87	49.55	49.65	42.66	49.51	49.73
17-Dec-91	39.47	15.96	42.68	55.33	41.82	48.84	47.61	48.37
1-Jul-92	40.33	24.26	42.23	46.04	38.27	45.00	36.88	45.50
15-Dec-92	47.83	29.03	41.98	44.75	41.76	51.12	42.50	49.44
14-Jun-93	38.22	16.02	46.41	43.76	45.24	32.66	43.80	49.62
3-Dec-93	50.66	8.38	44.46	26.35	43.51	47.72	47.70	51.56
20-Jun-94	33.39	9.16	41.61	15.72	37.23	44.50	41.03	49.40
19-Dec-94	48.51	14.85	60.44	34.10	61.53	46.31	52.65	51.00
AVERAGE	44.32	17.74	46.33	39.45	44.88	44.85	45.21	49.33
VARIANCE	57.92	55.42	42.07	172.50	60.48	31.31	26.01	3.38
S.D.	7.61	7.44	6.49	13.13	7.78	5.60	5.10	1.84

Table 32. Project 1 Percent moisture at 461+50 (14 + 066.548) westbound.

461+50 (14 + 066.548) westbound on the outside shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
28-May-91	39.75	52.75	42.53	49.59	49.05	49.19	46.76	49.98
17-Dec-91	32.94	15.31	36.32	52.94	43.29	50.21	42.28	49.85
1-Jul-92	37.04	15.76	34.33	49.09	45.88	46.91	45.18	20.34
15-Dec-92	41.92	14.14	43.75	53.50	47.13	44.17	45.90	48.73
14-Jun-93	39.74	21.41	46.81	56.45	47.63	44.28	42.51	47.26
3-Dec-93	42.33	14.47	41.02	47.65	37.85	49.08	37.10	49.06
20-Jun-94	45.86	10.74	48.49	50.21	43.27	45.60	48.71	47.25
19-Dec-94	27.17	14.91	37.07	42.45	42.85	47.06	46.31	48.18
AVERAGE	38.34	19.94	41.29	50.23	44.62	47.06	44.34	45.08
VARIANCE	34.98	184.41	25.84	17.95	12.74	5.25	13.14	101.03
S.D.	5.91	13.58	5.08	4.24	3.57	2.29	3.63	10.05

Table 33. Project 1 Percent moisture at 460+50 (14 + 036.068) eastbound.

460+50 (14 + 036.068) eastbound on the outside shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
28-May-91	43.43	41.46	36.85	51.37	39.38	41.16	40.62	45.60
17-Dec-91	36.30	20.83	38.96	38.63	38.93	48.44	41.33	49.78
1-Jul-92	41.02	15.13	28.27	44.33	41.10	48.95	40.66	52.06
15-Dec-92	41.06	16.93	40.23	35.94	38.50	53.12	39.50	49.86
14-Jun-93	41.10	16.58	37.91	41.25	41.15	33.34	43.21	51.05
3-Dec-93	42.99	16.90	42.39	32.89	42.45	42.74	39.10	49.62
20-Jun-94	48.22	15.08	47.27	49.23	45.98	47.37	36.47	50.12
19-Dec-94	36.71	9.10	40.61	38.47	40.91	46.15	38.49	49.12
AVERAGE	41.35	19.00	39.06	41.51	41.05	45.16	39.92	49.65
VARIANCE	14.51	92.93	29.28	41.10	5.72	36.55	4.09	3.53
S.D.	3.81	9.64	5.41	6.41	2.39	6.05	2.02	1.88

Table 34. Project 1 Percent moisture at 702+00 (21 + 397.003) eastbound.

702+00 (21 + 397.003) eastbound on the median shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
28-May-91	47.37	41.34	47.22	49.94	40.19	49.18	43.85	44.41
17-Dec-91	36.69	26.26	47.92	50.46	48.98	49.48	45.34	50.86
1-Jul-92	20.03	46.97	53.35	42.02	47.22	44.75	49.20	44.28
15-Dec-92	47.12	58.43	47.48	55.51	43.28	52.75	41.75	51.03
14-Jun-93	22.78	17.40	48.53	51.04	50.80	52.55	43.45	50.07
3-Dec-93	36.36	18.01	41.84	49.81	41.79	51.37	43.16	50.36
20-Jun-94	33.99	14.41	49.57	54.25	47.84	48.71	46.32	50.34
19-Dec-94	44.11	13.18	43.91	44.05	45.61	51.30	44.26	48.39
AVERAGE	36.06	29.50	47.48	49.64	45.72	50.01	44.67	48.72
VARIANCE	107.57	295.08	12.10	21.12	13.59	6.82	5.26	7.91
S.D.	10.37	17.18	3.48	4.60	3.69	2.61	2.29	2.81

Table 35. Project 2 Percent moisture at 1200+50 (36 + 591.313) westbound.

1200+50 (36 + 591.313) westbound on the outside shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
1-Jun-93	38.51	36.44	37.51	52.44	37.28	49.43	39.18	51.66
2-Dec-93	36.27	19.22	32.80	48.38	36.34	51.07	38.59	46.72
20-Jun-94	26.86	19.36	34.35	52.17	37.64	55.17	35.25	49.81
19-Dec-94	39.80	19.13	43.31	48.59	44.10	46.55	38.10	48.61
21-Jun-95	22.83	19.28	29.65	51.25	36.38	47.43	37.36	49.19
15-Dec-95	36.79	19.78	36.60	47.68	40.84	48.06	38.04	48.88
AVERAGE	33.51	22.20	35.70	50.09	38.76	49.62	37.75	49.15
VARIANCE	48.24	48.68	21.77	4.44	9.55	9.92	1.87	2.60
S.D.	6.95	6.98	4.67	2.11	3.09	3.15	1.37	1.61

Table 36. Project 2 Percent moisture at 963+00 (29 + 352.299) westbound.

963+00 (29 + 352.299) westbound on the median shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
1-Jun-93	46.09	22.05	42.36	50.49	32.62	47.30	39.69	49.85
2-Dec-93	36.55	23.98	39.94	51.53	35.53	51.81	36.47	48.97
20-Jun-94	29.16	20.18	43.05	54.57	36.17	51.52	40.97	43.29
19-Dec-94	30.90	22.35	33.71	47.42	35.99	50.57	32.92	50.39
21-Jun-95	28.08	11.58	34.52	29.67	29.50	46.17	41.13	49.16
15-Dec-95	38.66	16.15	45.85	44.27	37.17	44.31	39.19	44.91
AVERAGE	34.91	19.38	39.91	46.33	34.50	48.61	38.39	47.76
VARIANCE	47.52	21.82	23.72	79.03	8.34	9.73	10.03	8.57
S.D.	6.89	4.67	4.87	8.89	2.89	3.12	3.17	2.93

Table 37. Project 2 Percent moisture at 969+50 (29 + 550.419) eastbound.

969+50 (29 + 550.419) eastbound on the outside shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
1-Jun-93	28.31	35.34	28.50	39.06	28.34	40.82	35.18	47.38
2-Dec-93	34.60	32.72	30.96	45.38	28.10	47.18	33.91	44.50
20-Jun-94	22.83	25.48	25.56	49.43	27.19	48.11	36.42	42.86
19-Dec-94	33.85	30.65	29.84	44.55	32.09	45.79	37.68	39.99
21-Jun-95	22.89	29.80	25.43	51.32	28.69	50.72	39.10	41.75
15-Dec-95	40.79	22.24	37.52	45.78	37.85	46.42	38.30	43.29
AVERAGE	30.55	29.37	29.63	45.92	30.38	46.51	36.77	43.30
VARIANCE	51.08	22.90	19.92	18.15	16.21	10.73	3.88	6.34
S.D.	7.15	4.79	4.46	4.26	4.03	3.28	1.97	2.52

Table 38. Project 2 Percent moisture at 1197+50 (36 + 499.873) eastbound.

1197+50 (36 + 499.873) eastbound on the median shoulder,								
DATE	2' (0.6 m) past	2' (0.6 m) under	4' (1.2 m) past	4' (1.2 m) under	6' (1.8 m) past	6' (1.8 m) under	8' (2.4 m) past	8' (2.4 m) under
1-Jun-93	29.72	29.99	36.88	49.01	38.18	47.58	37.89	47.25
2-Dec-93	39.82	25.35	36.08	50.60	35.44	50.00	34.54	43.65
20-Jun-94	34.39	23.41	39.49	50.56	39.37	49.72	39.34	38.31
19-Dec-94	34.26	14.31	33.19	53.35	38.13	47.76	36.13	45.86
21-Jun-95	32.96	18.07	33.36	52.76	38.17	44.26	35.26	44.31
15-Dec-95	44.29	12.83	34.14	42.06	36.86	47.96	33.58	46.52
AVERAGE	35.91	20.66	35.52	49.72	37.69	47.88	36.12	44.32
VARIANCE	27.52	45.03	5.99	16.62	1.85	4.22	4.65	10.46
S.D.	5.25	6.71	2.45	4.08	1.36	2.06	2.16	3.23

MOISTURE CONCLUSIONS

Table 39. Project 1 Percentages of moisture at different depths, past the moisture barrier, data for figure 30.

	2' (0.6 m) past	4' (1.2 m) past	6' (1.8 m) past	8' (2.4 m) past	AVERAGE
Average % @ 704+50 (21 + 473.203) wb	44.32	46.33	44.88	45.21	45.18
Average % @ 461+50 (14 + 066.548) wb	38.34	41.29	44.62	44.34	42.15
Average % @ 460+50 (14 + 036.068) eb	41.35	39.06	41.05	39.92	40.35
Average % @ 702+00 (21 + 397.003) eb	36.06	47.48	45.72	44.67	43.48
AVERAGE	40.02	43.54	44.07	43.53	42.79

Table 40. Project 1 Percentages of moisture at different depths, under the moisture barrier, data for figure 30.

	2' (0.6 m) under	4' (1.2 m) under	6' (1.8 m) under	8' (2.4 m) under	AVERAGE
Average % @ 704+50 (21 + 473.203) wb	17.74	39.45	44.85	49.33	37.84
Average % @ 461+50 (14 + 066.548) wb	19.94	50.23	47.06	45.08	40.58
Average % @ 460+50 (14 + 036.068) eb	19.00	41.51	45.16	49.65	38.83
Average % @ 702+00 (21 + 397.003) eb	29.50	49.64	50.01	48.72	44.47
AVERAGE	21.54	45.21	46.77	48.19	40.43

Table 41. Project 2 Percentages of moisture at different depths, past the moisture barrier, data for figure 33.

	2' (0.6 m) past	4' (1.2 m) past	6' (1.8 m) past	8' (2.4 m) past	AVERAGE
1200+50 (36 + 591.313) wb	33.51	35.70	38.76	37.75	36.43
963+00 (29 + 352.299) wb	34.91	39.91	34.50	38.39	36.93
969+50 (29 + 550.419) eb	30.55	29.63	30.38	36.77	31.83
1197+50 (36 + 499.873) eb	35.91	35.52	37.69	36.12	36.31
AVERAGE	33.72	35.19	35.33	37.26	35.38

Table 42. Project 2 Percentages of moisture at different depths, under the moisture barrier, data for figure 33.

	2' (0.6 m) under	4' (1.2 m) under	6' (1.8 m) under	8' (2.4 m) under	AVERAGE
1200+50 (36 + 591.313) wb	22.20	50.09	49.62	49.15	42.76
963+00 (29 + 352.299) wb	19.38	46.33	48.61	47.76	40.52
969+50 (29 + 550.419) eb	29.37	45.92	46.51	43.30	41.27
1197+50 (36 + 499.873) eb	20.66	49.72	47.88	44.32	40.65
AVERAGE	22.90	48.01	48.15	46.13	41.30

Table 43. Project 1 Variances of moisture at various depths past the moisture barrier, data for figure 31.

	2' (0.6 m) past	4' (1.2 m) past	6' (1.8 m) past	8' (2.4 m) past	AVERAGE
Average % @ 704+50 (21 + 473.203) wb	57.92	42.07	60.48	26.01	46.62
Average % @ 461+50 (14 + 066.548) wb	34.98	25.84	12.74	13.14	21.67
Average % @ 460+50 (14 + 036.068) eb	14.51	29.28	5.72	4.09	13.40
Average % @ 702+00 (21 + 397.003) eb	107.57	12.10	13.59	5.26	34.63
AVERAGE	53.74	27.32	23.13	12.12	29.08

Table 44. Project 1 Variances of moisture at various depths under the moisture barrier, data for figure 31.

	2' (0.6 m) under	4' (1.2 m) under	6' (1.8 m) under	8' (2.4 m) under	AVERAGE
Average % @ 704+50 (21 + 473.203) wb	55.42	172.50	31.31	3.38	65.65
Average % @ 461+50 (14 + 066.548) wb	184.41	17.95	5.25	101.03	77.16
Average % @ 460+50 (14 + 036.068) eb	92.93	41.10	36.55	3.53	43.53
Average % @ 702+00 (21 + 397.003) eb	295.08	21.12	6.82	7.91	82.73
AVERAGE	156.96	63.17	19.98	28.96	67.27

Table 45. Project 2 Variances of moisture at various depths past the moisture barrier, data for figure 34.

	2' (0.6 m) past	4' (1.2 m) past	6' (1.8 m) past	8' (2.4 m) past	AVERAGE
1200+50 (36 + 591.313) wb	48.24	21.77	9.55	1.87	20.36
963+00 (29 + 352.299) wb	47.52	23.72	8.34	10.03	22.40
969+50 (29 + 550.419) eb	51.08	19.92	16.21	3.88	22.77
1197+50 (36 + 499.873) eb	27.52	5.99	1.85	4.65	10.00
AVERAGE	43.59	17.85	8.99	5.11	18.88

Table 46. Project 2 Variances of moisture at various depths under the moisture barrier, data for figure 34.

	2' (0.6 m) under	4' (1.2 m) under	6' (1.8 m) under	8' (2.4 m) under	AVERAGE
1200+50 (36 + 591.313) wb	48.68	4.44	9.92	2.60	16.41
963+00 (29 + 352.299) wb	21.82	79.03	9.73	8.57	29.79
969+50 (29 + 550.419) eb	22.90	18.15	10.73	6.34	14.53
1197+50 (36 + 499.873) eb	45.03	16.62	4.22	10.46	19.08
	34.61	29.56	8.65	6.99	19.95

Table 47. Project 1 Standard deviations of moisture at various depths past the moisture barrier, data for figure 32.

	2' (0.6 m) past	4' (1.2 m) past	6' (1.8 m) past	8' (2.4 m) past	AVERAGE
Average % @ 704+50 (21 + 473.203) wb	7.61	6.49	7.78	5.10	6.74
Average % @ 461+50 (14 + 066.548) wb	5.91	5.08	3.57	3.63	4.55
Average % @ 460+50 (14 + 036.068) eb	3.81	5.41	2.39	2.02	3.41
Average % @ 702+00 (21 + 397.003) eb	10.37	3.48	3.69	2.29	4.96
AVERAGE	6.93	5.12	4.36	3.26	4.91

Table 48. Project 1 Standard deviations of moisture at various depths under the moisture barrier, data for figure 32.

	2' (0.6 m) under	4' (1.2 m) under	6' (1.8 m) under	8' (2.4 m) under	AVERAGE
Average % @ 704+50 (21 + 473.203) wb	7.44	13.13	5.60	1.84	7.00
Average % @ 461+50 (14 + 066.548) wb	13.58	4.24	2.29	10.05	7.54
Average % @ 460+50 (14 + 036.068) eb	9.64	6.41	6.05	1.88	5.99
Average % @ 702+00 (21 + 397.003) eb	17.18	4.60	2.61	2.81	6.80
AVERAGE	11.96	7.09	4.14	4.15	6.83

Table 49. Project 2 Standard deviations of moisture at various depths past the moisture barrier, data for figure 35.

	2' (0.6 m) past	4' (1.2 m) past	6' (1.8 m) past	8' (2.4 m) past	AVERAGE
1200+50 (36 + 591.313) wb	6.95	4.67	3.09	1.37	4.02
963+00 (29 + 352.299) wb	6.89	4.87	2.89	3.17	4.45
969+50 (29 + 550.419) eb	7.15	4.46	4.03	1.97	4.40
1197+50 (36 + 499.873) eb	5.25	2.45	1.36	2.16	2.80
AVERAGE	6.56	4.11	2.84	2.17	3.92

Table 50. Project 2 Standard deviations of moisture at various depths under the moisture barrier, data for figure 35.

	2' (0.6 m) under	4' (1.2 m) under	6' (1.8 m) under	8' (2.4 m) under	AVERAGE
1200+50 (36 + 591.313) wb	6.98	2.11	3.15	1.61	3.46
963+00 (29 + 352.299) wb	4.67	8.89	3.12	2.93	4.90
969+50 (29 + 550.419) eb	4.79	4.26	3.28	2.52	3.71
1197+50 (36 + 499.873) eb	6.71	4.08	2.06	3.23	4.02
AVERAGE	5.79	4.83	2.90	2.57	4.02

APPENDIX C

SPECIFICATIONS

MISSISSIPPI STATE HIGHWAY DEPARTMENT

SPECIAL PROVISION NO. 907-486-23 CODE: (SP)

DATE: 8/11/89

SUBJECT: Geotextile Fabric for Moisture Barrier

Section 907-486, Pavement Fabric, is added to the 1976 Standard Specifications for Road and Bridge Construction as follows

SECTION 907-486 PAVEMENT FABRIC

907-486.01--Description. This work shall consist of furnishing and installing a geotextile fabric in accordance with details show on the plans and requirements of the contract.

907-486.02--Material. The fabric for this work shall meet the requirements of Subsection 907-714.14.

907-486.03--Equipment. The Contractor shall provide equipment necessary for placing the fabric on a smooth subgrade and in the position and location set out in the plans.

907-486.04--Construction Details. The area shall be prepared to establish a relatively smooth surface. If required by the Engineer sand may be placed over these areas to cushion the fabric. The fabric shall be placed as smooth as possible. Wrinkles and folds in the fabric shall be removed by stretching and staking as required.

The strips of the fabric shall be overlapped a minimum of 18 inches for each joint. Securing pins with washers shall be inserted through both strips of overlapped cloth along a line through the mid-point of the overlap at intervals required by the Engineer to prevent movement of the fabric until covered.

The subsequent courses of material shall be back-dumped in such a manner as to avoid damage to the underlying fabric.

907-486.05--Method of Measurement. The accepted fabric placed in accordance with these specifications and as directed will be measured by the square yard. Laps will not be measured for payment.

907-486.06--Basis of Payment. The fabric will be paid for at the contract unit price per square yard. This price shall be full compensation for furnishing and placing the fabric, pins, lapping and maintaining the fabric until covered, and satisfactorily completing the work specified.

Payment will be made under:

Pay Item No. 907-486-C: Geotextile Fabric for Moisture Barrier - per sq. yd.

MISSISSIPPI STATE HIGHWAY DEPARTMENT

SPECIAL PROVISION NO. 907-714-27 CODE: (SP)

DATE: 4/17/89

SUBJECT: Geotextile Fabric for Moisture Barrier

Section 714, Miscellaneous Materials, of the Standard Specifications is amended as follows:

Add Subsection 907-714.14

907-714.14--Geotextile Fabric for Moisture Barrier.

907-714.14.1--General. The geotextile fabric for moisture barrier shall consist of sheeting, coated fabric or a fabric sheeting laminate constructed exclusively of man-made materials. Sheeting shall be of single-layered construction. Coated fabric shall be made of woven or non-woven polyester or polypropylene. The fabric shall be furnished precoated on one or both sides or impregnated so as to make the fabric impermeable to water or moisture. Fabric-sheeting laminate shall consist of fabric fused or heat-sealed to sheeting so as to form an integral geotextile membrane.

The geotextile fabric shall be able to withstand normal handling and placement at material temperatures from 20^{o}F to 145^{o}F without endangering the serviceability of the material in the intended application. If the geotextile evidences de-lamination, such de-lamination may serve as grounds for rejection. The geotextile fabric shall be mildew, abrasion, and puncture resistant and suitable for long term burial in the presence of water and/or moisture in the intended construction application. It shall be packaged in rolls of the length and width specified on the plans or directed by the Engineer.

907-714.14.2--Physical Requirements. The geotextile fabric shall meet the following additional requirements when sampled and tested in accordance with the methods specified.

Original Physical Properties	Test Method	Requirements
Fabric weight, oz/sq.yd. (air-dried tension-free sample)	Texas Test Method Tex-616-J "Testing Construction Fabrics"	6.5 minimum
Water permeability expressed as weight of water in oz/sq.yd. Fabric is subjected to the equivalent of a ten foot column of water for a period of two hours. Moisture passing through the fabric is determined by weight gain of desiccant.	Tex-616-J	0.6 maximum

Test	Method	Requirements
Original Physical Properties		
Abrasion Resistance expressed as weight of water in oz/sq.yd. After prescribed sandblast, the fabric shall meet the requirement for water permeability.	Texas Test Method Tex-851-B "METHOD FOR EVALUATING THE ABRASION RESISTANCE OF PAVEMENT MARKING MATERIALS" modified as follows: six-inch sample distance, 40 psig regulated blast pressure and one kilogram of blast medium with a blast time of two minutes plus or minus 15 seconds per one kilogram of blast medium.	0.6 maximum
Load characteristics at break or 100% elongation whichever occurs first. Material shall meet specified minimum in both machine direction and cross-machine direction. Test values to be expressed in pounds.	ASTM D 1682, Grab Test G with 1" x 2" jaws and constant time to break rate of extension of 20 plus or minus three seconds, as specified.	150 minimum
Apparent elongation break or rupture, expressed in percent	See above Grab Test G	20% minimum
Tear strength determined by the tongue (single rip) method on specimens pre-pared from "as-received" samples. Specimens are to be tested at a cross-head speed of twelve plus or minus 0.5 inches/minute. Test results are to be calculated by the "average of five highest peaks" method. Both the average	ASTM D 751	
	15 minimum	

of five specimens cut with the longer dimension parallel to the machine direction and the average of five specimens cut in the cross-machine direction shall meet the specified minimum expressed in pounds.

907-714.14.3--Packaging Requirements. The geotextile fabric shall be packaged in rolls of the length and width specified on the plans or directed by the Engineer. The material shall be uniformly wound onto suitable cylindrical forms or cores to aid in handing and unrolling. Each roll shall be packaged individually in a suitable sheath, wrapper, or container to protect from ultraviolet light and moisture damage during normal storage and handling.

907-714.14.4--Identification. Each roll of fabric or container shall be visibly labeled with the name of the manufacturer, type of geomembrane or trade name, date, lot number and length, width and quantity of material.

907-714.14.5--Sampling. A sample of five square yards of the fabric shall be furnished to the State from each shipment for verification testing. The samples shall be provided at no cost to the State.

907-714.14.6--Certification. The Contractor shall furnish to the Engineer three copies of the manufacturer's certified test report(s) showing results of all required tests and certification that the material meets the specifications. Certification shall be furnished for each lot in a shipment.

MISSISSIPPI STATE HIGHWAY DEPARTMENT

SPECIAL PROVISION NO. 907-714-32 (CODE: (IS)

DATE: 12/1/89

SUBJECT: Geotextile Fabric

Section 714, Miscellaneous Materials, of the Standard Specification is amended as follows:

Delete Subsection 714.13, page 859, and substitute:

907-714.13--Geotextile Fabrics.

907-714.13.1--General. Unless specified otherwise, the fabric may be woven or nonwoven. The fabric shall consist only of long chain polymeric yarns or filaments such as polypropylene, polyethylene, polyester, polyamide, or polyvinylidene-chloride and shall be formed into a stable network such that the yarns or filaments retain their relative position. The fabric shall be mildew resistant and inert to biological degradation and naturally encountered chemicals, alkalis and acids. Fabric, which is not protected from sunlight after installation, shall contain stabilizers and/or inhibitors to make it resistant to deterioration from direct sunlight, ultraviolet rays, and heat.

The edges of the fabric shall be selvaged or finished in such a manner to prevent the outer yarn or filaments from raveling. The fabric shall be free of defects or flaws, which affect the required physical properties.

Fabric for silt fence shall be manufactured in widths of not less than three feet and fabric for other applications shall be manufactured in widths of not less than six feet. Sheets of fabric may be sewn or bonded together at the factory or other approved locations but deviation from the physical requirements will not be permitted.

Tests for manufacturer's certification shall be conducted with fabric as shipped by the manufacturer and acceptance testing will be conducted with fabric from the project.

907-714.13.2--Geotextile Fabric for Silt Fence. The fabric shall conform to the physical requirements of Type I or II as shown in Table I. Unless a Specific type is specified in the plans or contract documents, the Contractor may select Type I or II.

907-714.13.2.1--Woven Wire Backing. Except as provided herein, silt fence shall be reinforced with woven wire backing. The wire backing shall be at least 32 inches high and have no less than six horizontal wires. Vertical wires shall be spaced no more than 12 inches apart. The top and bottom wire shall be 10 gage or larger. All other wire shall be no smaller than 12-½ gage.

Type II fabric may be installed without the wire backing provided:

A. Post spacing reduced to six feet of less.

B. The fabric manufacturer recommends its use without the wire backing.

C. The fence posts are inclined toward the run-off source but not more than 20^o from vertical.

D. The fabric shall be attached to the posts as recommended by the manufacturer.

907-714.13.2.2--Posts. Wood or steel posts may be used. Wood posts shall have a minimum diameter of three inches and length of five feet and shall be straight enough to provide a fence without noticeable misalignment. Steel tee posts shall be five feet long, approximate 1 3/8 inches wide, 1 3/8 inches deep and 1/8 inch thick with a nominal weight of 1.33 pounds per foot prior to fabrication. The posts shall have projections, notches, or holes for fastening the wire backing or fabric to the posts.

907-714.13.2.3--Staples. Staples shall be made of nine-gage wire with a minimum length of one inch after bending.

907-714.13.3--Geotextile Fabric for Subsurface Drainage. Unless otherwise specified, the fabric shall conform to the physical requirements of Type III as shown in Table I.

907-714.13.4--Geotextile Fabric Undersell. The fabric shall be nonwoven polyester or polypropylene, which is satisfactory for use with asphalt cements. Unless otherwise specified, the fabric shall conform to the physical requirements of Type IV in Table I.

907-714.13.5--Geotextile Fabric for Use under Riprap. Unless otherwise specified, the fabric shall conform to the physical requirements of Type V in Table I. The requirements for tensile, bursting, puncture and trapezoidal tear strengths may be reduced 50 percent when the fabric is cushioned from rock placement by a 6 inch minimum layer of sand.

907-714.13.6--Geotextile Fabric Stabilization. The fabric shall meet the physical requirements as shown in TABLE I for the type specified in the plans or contract documents.

907-714.13.7--Securing Pins. Steel pins used for anchoring the fabric shall be three-sixteenth inch in diameter, minimum length of 15 inches, pointed at one end and fabricated with a head for retaining a steel washer. A minimum one and one-half inch washer shall be installed on each pin.

907-714.13.8--Identification. Each roll of fabric or container shall be visibly labeled with the name of the manufacturer, type of fabric or trade name, lot number and quantity of material.

907-714.13.9--Shipment and Storage. During shipment and storage, the fabric shall be protected from direct sunlight, ultraviolet rays, temperatures greater than 140°F, mud, dirt, dust and debris. The fabric shall be wrapped and maintained in a heavy-duty protective covering.

907-714.13.10--Manufacturer's Certification. The contractor shall furnish to the Engineer three copies of the manufacturer's certified test reports and certification that each lot in a shipment complies with requirements of the contract. All fabric, steel pins, washers, fence posts, woven wire and wire staples are subject to approval by the Engineer upon delivery to the work site and prior to incorporating in the work.

907-714.13.11--Acceptance Sampling and Testing. Final acceptance of each shipment will be based on results of tests performed by the Department on verification samples submitted from the project. The Engineer shall select one roll at random from each shipment for sampling. A sample extending full width of the randomly selected roll and containing at least five square yards of fabric shall be obtained and submitted by the Engineer. The sample from each shipment shall be provided at no cost to the State.

Table I
GEOTEXTILE FABRICS

MINIMUM AVERAGE ROLL VALUE

Physical Properties	Type Designation I	II	III	IV	V	VI	VII	Test Method
Tensile Strength, lbs. (weaker principal direction)	50	90	90	90	200	280	450	ASTM D 4632 (CRC) (See Note 1).
Elongation at required strength, percent.	-	- (Max.)	50	20	50	-	-	ASTM D 4632 (CRC) (See Note 1).
Bursting Strength, psi.	100	180	140	-	300	450	700	ASTM D 3786 Diaphragm Bursting Tester
Puncture Strength, psi	-	-	35	-	80	110	180	ASTM D 3787, Tension Testing Machine with Ring Clamp; Steel Ball replaced with a 5/16 inch hemi-spherical tip
Trapezoidal Tear. lbs.	-	-	35	-	65	100	150	ASTM D 4533 (CRE) (See Note 1).
Retained Strength when wet, percent.	100	100	100	-	100	100	100	ASTM D 4632 (CRE) and ASTM D 3786 and 3787, as above. (See Note 1)

`

Physical Properties	Type Designation I	II	III	IV	V	VI	VII	Test Method
Thickness, mils.	-	-	-	40	-	-	-	ASTM D 1777
Weight, oz./sq.yd.	-	-	-	4-9	-	-	-	ASTM D 3776, Option A or B
Asphalt Retention, oz./sq.ft.	-	-	-	3.0	-	-	-	Miss. Test Method MT 64
Maximum Change in Area, percent.	-	-	-	15	-	-	-	Miss. Test Method MT 64
Permeability, cm/sec. (see Note 2)	-	-	0.01	-	0.01	0.01	0.01	AASHTO M 288 (Appendix)
Flow Rate, gal./min./sq.ft. (see Note 2)	-	-	30	-	30	30	30	AASHTO M 288 (Appendix)
Equivalent Opening Size (EOS) (see Notes 2 & 3)								Miss. Test Method: MT 60
Woven Fabric	20-100	20-100	40-100	-	70-100	70-100	70-100	
Nonwoven Fabric	20+	20+	40+	-	70+	70+	70+	
Tensile Strength after Ultraviolet exposure, lbs.	40	80	-	-	-	-	-	ASTM D 4632 (CRE) after 500 hours exposure on xenon arc weatherometer as detailed in ASTM G 26. (see Note 1)

Note 1: A test result shall be the average of the test values of five specimens.
Note 2: Unless designated otherwise in the plays or contract documents.
Note 3: The EOS test for nonwoven fabric may be waived by the Testing Engineer.
Note 4: All of the above strength tests except "retained strength" are to be conducted in a dry condition.