COMMONWEALTH OF KENTUCKY
DEPARTMENT OF HIGHWAYS
FRANKFORT

HENRY WARD
COMMISSIONER OF HIGHWAYS

ADDRESS REPLY TO
DEPARTMENT OF HIGHWAYS
DIVISION OF RESEARCH
132 GRAHAM AVENUE
LEXINGTON, KENTUCKY 40506

September 19, 1966

H-2-18

MEMORANDUM

TO: W. B. Drake, Assistant Project Management Engineer
Chairman, Kentucky Highway Research Committee

SUBJECT: Research Report;"Interim Performance Report, Experimental Use of Thermoplastic Pavement-Striping Materials;" KYHPR-64-18, HPR 1(1), Part II.

The report attached is the fourth issuing from a study concerning the application and long-range performance of thermoplastic pavement-striping materials. It embodies four years of performance record and offers significant, cost histories and comparisons between thermoplastic lines and painted lines. The study was originally programmed under P.P.M. 60-2 of the Bureau of Public Roads--which provides for cooperative financing of experimental construction for study purposes. Later, the surveillance and reporting phase was incorporated into the cooperative HPS-HPR program as authorized by P.P.M. 50-1.1. The format of this report is styled according to P.P.M. 60-2.

Test Sites 5 through 9 were added to the study in 1965 and have not been reported on previously. The Department elected to proceed with service-life testing of thermoplastic lines applied over an epoxy-type adhesive primer. Theretofore, loss of adhesive bond or loosening from portland cement concrete pavements had proven to be ignominious failing of the striping system. Test Sites 1 and

3 remain a reproving record of such performance. A study similar to this one is being conducted by the New York Department of Public Works (Project 22), and a report (RR 64-4) issued in December, 1964 indicated that more favorable results were being realized where the epoxy adhesive had been employed. Test Sites 5 through 9, after 1 year of service, have exhibited significant tendencies for the lines to spall away.

The cost of thermoplastic lines remains disproportionate to the level of service realized in comparison to traffic paint. Losses of service and investment through premature failure of the lines have not been sufficiently requitable or recoupable under warranty provisions offered voluntarily by the striping contractors. It is suggested that a limiting, feasible cost can be estimated on the basis of anticipated renewals of traffic paint lines during a reasonable period--not exceeding the tenure of the particular pavement surface and not exceeding eight to ten years in the extreme. It appears that losses of more than 1 percent per year (or less than 90 percent terminal retention) in footage of line are intolerable. It appears also that greater opportunity to amortize the investment exists where the frequency of paint renewal would be extremely high.

Since the writing of this report, the edge- and center-lines of Catatherm and Perma-Line in Test Site 3 have been over-striped with paint by State forces; and future repaintings of these lines will be made as needed. Edge-lines in the control section at this site have been renewed also.

Observations on existing installations are continuing, and additional reports will be forthcoming.

Respectfully submitted,

Jas. H. Havens, Director
Division of Research
Secretary, Research Committee

JHH:em
Attachment
cc: Research Committee
A. O. Neiser
R. O. Beauchamp
T. J. Hopgood
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W. G. Galloway

Research Report

INTERIM PERFORMANCE REPORT EXPERIMENTAL USE OF THERMOPLASTIC PAVEMENT-STRIPING MATERIALS

Report No. 4

KYHPR-64-18*; HPR-1(2), Part II

by

John W. Scott
Research Engineer

Division of Research
DEPARTMENT OF HIGHWAYS
Commonwealth of Kentucky

September, 1966

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PROJECT NUMBERS, TERMINI, STATION NUMBERS AND MILEAGES

TEST SITE 1

Jefferson County; I 264-1(25)20, SP 56-898; Watterson Expressway; north end of US 60 Interchange, extending northwardly, Sta. 28+00, 1.458 miles; PCC pavement.

**	Subsection 1; Sta. 28+00 to Sta. 53+67; 0.486 mi.
***	Subsection 2; Sta. 53+67 to Sta. 79+33; 0.486 mi.
*	Subsection 3; Sta. 79+33 to Sta.105+00; 0.486 mi.

TEST SITE 2

Jefferson County; I 264-1(24)16, SP 56-898; Watterson Expressway; 1.231 miles (net); BC pavement.

Section A - East end of Bardstown Road Interchange, extending eastwardly, Sta. 515+00 to Sta. 547+00, 0.606 miles; BC Pavement.

*	Subsection 1; Sta. 515+00 to Sta. 525+67; 0.202 mi.
**	Subsection 2; Sta. 525+67 to Sta. 536+34; 0.202 mi.
***	Subsection 3; Sta. 536+34 to Sta. 547+00; 0.202 mi.

(Subsections 1 & 2, 1067 ft. ea.; Subsection 3, 1066 ft.)

Section B - East end of Taylorsville Road Interchange, extending eastwardly, Sta. 585+00 to Sta. 603+00, 0.341 miles; BC pavement.

*	Subsection 4; Sta. 585+00 to Sta. 591+00; 0.1137 mi.
**	Subsection 5; Sta. 591+00 to Sta. 597+00; 0.1137 mi.
***	Subsection 6; Sta. 597+00 to Sta. 603+00; 0.1137 mi.

(Subsections 4, 5, & 6, 600 ft. ea.)

Section C - East end of Breckenridge Lane Interchange, extending eastwardly, Sta. 633+00 to Sta. 648+00, 0.284 miles; BC pavement.

*	Subsection 7; Sta. 633+00 to Sta. 638+00; 0.0947 mi.
**	Subsection 8; Sta. 638+00 to Sta. 643+00; 0.0947 mi.
***	Subsection 9; Sta. 643+00 to Sta. 648+00; 0.0947 mi.

(Subsections 7, 8, & 9, 500 ft. ea.)

TEST SITE 3

Franklin-Shelby Counties; I 64-3(14)34, SP 37-905, SP 106-806; Louisville-Lexington Road; east end of KY 53 Interchange, extending eastwardly, Sta. 1418+00 to Sta. 2081+00; 11.965 miles (net); PCC pavement.

*** Subsection 1; Sta. 1418+00 to Sta. 1628+63; 3.99 mi.
* Subsection 2; Sta. 1628+63 to Sta. 1839+36; 3.99 mi.
** Subsection 3; Sta. 1839+36 to Sta. 2081+00; 3.99 mi.

(Sta. 1989+04 BK, EB = Sta. 1988+40 BK, WB = Sta. 2020+00 AH)

TEST SITE 4

Clark-Montgomery Counties; I 64-5(16)93, SP 25-422, SP 87-557; Lexington-Catlettsburg Road; EKTP Interchange, extending eastwardly, Sta. 430+00 to Sta. 1053+00; 11.80 miles; BC pavement.

* Subsection 1; Sta. 430+00 to Sta. 637+67; 3.933 mi.
** Subsection 2; Sta. 637+67 to Sta. 845+34; 3.933 mi.
*** Subsection 3; Sta. 845+34 to Sta. 1053+00; 3.933 mi.

ADDITIONAL PERMA-LINE THERMOPLASTIC LINE NOT PART OF ORIGINAL EXPERIMENTAL PROJECT BUT INCLUDED IN THIS STUDY FOR COMPLETENESS.

TEST SITE 5

Franklin-Woodford Counties; US 60, SP 37-45, SP 120-15; Frankfort-Versailles Road; Eastern Junction US 421, extending eastwardly for 3.6 miles; Sta. 7+00 to Sta. 198+50; 3.63 miles; PCC pavement.

* Center-Line of WB Line
*** Center-Line of EB Line

TEST SITE 6

Franklin County; I 64; SP 37-905, Louisville-Lexington Road; US 127 extending eastwardly to US 60; Sta. 2385+00 to Sta. 2620+00; 4.45 miles; PCC Pavement.

* Center-Line of WB Lane
*** Center-Line of EB Lane

TEST SITE 7

Jefferson County; I 64; SP 56-273; Louisville-Lexington Road; From Watterson Expressway, I 264, extending eastwardly to Jefferson Freeway, KY 841; Sta. 190+00 to 520+00; 6.25 miles; PCC Pavement.

* Center-Line of WB Lane
*** Center-Line of EB Lane

TEST SITE 8

Jefferson County; I 65; SP 56-798; North-South Expressway; From south end of Watterson Expressway Interchange extending northwardly to north end of Ohio River Bridge; Sta. 2155+00 to Sta. 100+00; 7.53 miles; PCC pavement.

*** Center-Lines and Edge-Lines

TEST SITE 9

Jefferson County; I 264; SP 56-898, Watterson Expressway; From Junction US 31W at Shively to north end of US 60 Interchange excluding Test Sites 1 and 2; Sta. 0+29.6 to Sta. 28+00; 12.66 miles; BC pavement.

*** Center-Lines and Edge-Lines

ALLOCATIONS OF SUBSECTIONS

* Control-Kentucky Paint
** Catatherm
*** Perma-Line

A. NATURE AND OBJECTIVES OF EXPERIMENT

The purposes and objectives of this study are: 1) to evaluate the application and performance characteristics of hot-melt plastic, pavement-striping materials which are presently prominent and known commercially as "Catatherm" and "Perma-Line"; 2) to compare the performance of these materials with the performance of painted stripes applied and renewed according to the current practices of the Kentucky Department of Highways; and 3) to evaluate the economics of these striping materials in terms of cost per mile per day of useful life. The project is described more fully in the "Proposal..." (approved by Division Engineer, September 7, 1962) and in Report No. 1 (pre-Construction Report) submitted September 19, 1962. Report No. 2 (Interim Construction Report) was submitted in April, 1963; and Report No. 3 (Final Construction and Interim Performance Report) was submitted May 15, 1964. Attachment No. 1 shows the location of the test sites.

B. CONSTRUCTION METHODS, QUANTITIES, AND COSTS FOR TEST SITES 5, 6, 7, 8, AND 9

1. Description of Test Sites

Sites 5, 6, and 7 were added to this study to evaluate the recent development of epoxy resin for use as a primer on portland cement concrete pavements. These sites are rural, four-lane, divided, portland cement concrete pavements that have been opened to traffic for different lengths of time. Site 5 has been opened to traffic for 5 1/2 years, Site 6 for 3 1/2 years, and Site 7 for 7 months. The location of the thermoplastic material at each site is in the eastbound lanes, and the location of the control sections of Kentucky paint is in the westbound lanes of each test site.

Sites 8 and 9 represent additional installations of thermoplastic material utilizing epoxy as a binder. Both sites are urban, four-lane, divided highways; the pavement at Site 8 is portland cement concrete; whereas the pavement at site 9 is bituminous concrete. There are no control sections of Kentucky paint for these two projects, but the performance of these sites will be documented for a thorough evaluation of thermoplastic striping material.

2. Prosecution of Work

Bids for Sites 5, 6, and 7 were received on December 16, 1964, and bids for Sites 8 and 9 were received on March 26, 1965. Both contracts were awarded to the Perma-Line Company, and work began on May 18, 1965, at Test Site 8. Thermoplastics were applied to Test Sites 5, 6, and 7 on June 25, 1965. On June 30, 1965, all work was completed and became subject to final inspection. A summary of the quantities and costs of the thermoplastic installations is included as Table 1, Attachment 2. Excerpts from the Department's Final Construction Inspection Report for Test Sites 8 and 9 are included as Attachment 3.

The control sections of Kentucky paint were applied by Department personnel using paint drawn from stock supplies on hand. The westbound lane of Test Site 5 was painted on May 3, 1965, and the westbound lanes of Test Sites 6 and 7 were painted during April, 1965.

3. Perma-Line's Operations

The major portion of Perma-Line's thermoplastic was applied by one crew operating an automatic, truck-mounted applicator (see Figure 1, Attachment 4). In front of and attached to this unit was a strong, air blower that was capable of removing dust, small rocks, and light debris from the surface prior to priming and striping. Directly behind the blower was a spray nozzle which applied epoxy primer to the pavement. The two-component epoxy system which consisted of two parts liquid epoxy and one part liquid catalyst was made by the Adhesive Products Corporation of New York. The system contained a large amount of retarder (methyl ethyl ketone or a similar solvent) which prolonged the pot life to 16 hours. The application rate was such that good coverage of the pavement was obtained; and the width of the primer coat ranged from 9 to 10 inches (see Figure 2, Attachment 5). Just prior to the overlaying of the stripe, the primer was very tacky; and between the time the primer was applied and the overlaying thermoplastic stripe was placed, a period of approximately 20 seconds elapsed. Heat from the newly applied thermoplastic line greatly accelerated the time-of-set of the primer. Laboratory tests indicated that when the primer was heated to 315°F, the time-of-set was reduced to 15-20 minutes.

The thermoplastic material was applied by means of a die that was fed from two heating kettles which were maintained at 425°F. The operator could control the location of the die by a steering system which permitted 6 feet of maneuverability. The operating speed of the truck was 130 to 140 feet per minute, but the daily applied footage was limited by the production output of the kettles. The footage applied in a 6-hour day averaged 25,000 feet.

Drop-on beads, for initial reflectivity, were applied to the hot thermoplastic about 12 inches behind the applicating die. Good coverage and distribution of the beads were obtained by the dispensing equipment. The beads were manufactured by the Flex-O-Lite Corporation of St. Louis.

The length of time required for the thermoplastic line to harden was 3 minutes. The width of the edge- and centerline was 4 inches, and the thickness ranged from 0.12 to 0.13 inches.

A handliner that was fed from a truck-mounted, heating kettle was used to apply the 8-inch markings.

The blower was not effective on bridge decks where heavy debris was present or in areas covered by mud; and hand-brooming was used in these areas. Occasionally the spray nozzle would clog, and the spray pattern would be erratic. In some cases which were more prevalent on ramps and skip-dash center-lines, the stripe was not placed directly over the primer because of misalignment of the primer. Occasionally rocks were drug by the die causing lengthy scars in the line.

The general workmanship of the thermoplastic installations at Test Sites 8 and 9 was considered to be very poor. The alignment of the edge-lines was quite irregular; and, in some instances, large bulges were present (see Figure 3, Attachment 6). The contractor did not shape up a number of places where excess material was allowed to flow out of the die. A number of unsightly white stains were present on the pavement (see Figure 4, Attachment 7), and drippings on the pavement were common. Before acceptance, the contractor was required to remove and correct all large bulges, remove splotches and stains, and correct a number of skip-dash lines. The general appearance of the thermoplastic installations at Test Sites 5, 6, and 7 were satisfactory. Only one area of drippings was noted.

4. Control Operations: Kentucky Paint

The paints and beads were drawn from stock supplies and applied by the Department's striping machine. The normal application rate of Kentucky paint was 15 gallons per mile, and drop-on beads were added at the rate of 2 pounds per gallon of paint.

The control sections of Kentucky paint will be repainted as needed to retain visibility comparable to that of the thermoplastics.

C. CONDITION OF PROJECT

Test Site 1

I 264-1(25)20; PCC Pavement

Transverse Lines

These lines were applied November 2, 1962. The Kentucky paint lines have been repainted twice--during the spring of 1963 and spring of 1964 (see Table 2, Attachment 8 for repainting history and costs). These lines were inspected on July 7, 1966 (see Figure 5, Attachment 9), and notations of the condition of each line follows:

Line 1: White Kentucky Paint (3 applications of paint and drop-on beads at 3-day intervals). Approximately 15 percent of line has spalled, and the bond of the remainder ranges from good to poor. Line needs repainting.

Line 2: White Kentucky Paint (2 applications of paint and drop-on beads at 3-day intervals). Spalling of 25 percent of the line had occurred. A large portion of the drop-on beads was missing; and the line needs repainting.

Line 3: White Kentucky Paint (1 application of paint and no drop-on beads). This line was completely missing except for a three-foot portion in the outer lane. Line needs repainting.

Line 4: Yellow Kentucky Paint (3 applications of paint and drop-on beads at 3-day intervals). The reflectance of the line was good, but 10 percent of the line was missing. Bond of the remaining portions appeared to be poor, and the line needs repainting.

Line 5: Yellow Kentucky Paint (2 applications of paint and drop-on beads at 3-day intervals). Extensive spalling of 40 percent of the line had occurred. Repainting of the line is necessary at this time.

Line 6: Yellow Kentucky Paint (1 application of paint and no drop-on beads). Except for a 3-foot portion in the outer lane, this line was completely missing and needs repainting.

Line 7: White Perma-Line Thermoplastic. The condition of this line was good. A few, small, bubble-craters were present. Bonding was excellent; reflectance was good; and no visible wear or damage was noted except for 3 1-inch spalled areas.

Line 8: Yellow Perma-Line Thermoplastic. Large bubble-craters imparted a splotchy appearance to the line. Reflectance and bonding was good; and the line was rated as fair.

Line 9: White Catatherm Termoplastic. The appearance of this line was good. A large number of small bubble-craters were present, and alligator cracking had occurred in the center of the right lane. Bonding was excellent, and no spalled or chipped portions were noted.

Line 10: Yellow Catatherm Thermoplastic. The appearance of this line was fair. This line had an extreme number of transverse and alligator cracks over the entire length, and a large number of large bubble-craters were present. There were no missing portions, and the bond was good.

Subsection 1, Catatherm Thermoplastic

These lines were applied November 1, 1962. On April 9, 1963, 65 feet or 0.5 percent of the line in this subsection was either missing or badly spalled and considered to be unsatisfactory. On July 17, 1963, Cataphote repaired not only the above-mentioned 65 feet but all other lines that did not appear to be performing satisfactorily. Approximately 1,259 feet, or 10.3 percent, of line were reworked.

On March 25, 1964, 119 feet or 1.0 percent of the line in this subsection was adjudged to the unsatisfactory, and this reflects the damage incurred during the winter of 1963-64. Cataphote's warranty did not apply in this particular instance, but on July 28, 1964, Cataphote voluntarily repaired all substandard line which amounted to 317 feet, or 2.6 percent.

On April 13, 1965, a total of 912 feet or 7.5 percent of the line in this subsection was adjudged to the unsatisfactory, and this represents the damage incurred during the winter of 1964-65. Cataphote guaranteed 60 percent of a unit for 3 years--a unit being defined as "any length of highway having installed thereon 2,000 lineal feet of line of specified width in any combination or pattern." A roadway 842 feet in length and having a dashed center-line and two edge-lines represents 2,000 lineal feet of line. Due to the small amount of footage considered to be unsatisfactory in 1965, Cataphote's warranty did not apply and no repairs were made.

On July 7, 1966, this subsection was inspected and the appearance was fair. A large number of bubble-craters were present, and portions of line ranging from 1 to 6 inches were missing at expansion joints. Some edge-spalling was noted, but the bond and reflectance were good. A total of 1,550 feet or 12.7 percent of the line in this subsection was unacceptable at this time.

Cataphote's warranty has expired, and repair of the missing footage with thermoplastic at the Department's expense is not recommended. When repairs are deemed to be necessary, all missing thermoplastic will be replaced with Kentucky paint. At the present time, the appearance of this subsection is not too distracting, and it is recommended that repainting be postponed until next year.

A summary of the performance and repair history of Catatherm in this subsection is given in Table 3, Attachment 10.

Subsection 2, Perma-Line Thermoplastic

These lines were applied November 1, 1962. On April 9, 1963, 117 feet or 1.0 percent of line was considered unsatisfactory, and this was repaired by Perma-Line on May 6, 1963.

On March 25, 1964, 13 feet or 0.1 percent of the line in this subsection was considered to be unsatisfactory. Perma-Line's warranty did not apply, and consequently, no repairs were made.

On April 13, 1965, a total of 333 feet or 2.7 percent of line in this subsection was considered to be substandard. This line was not covered by Perma-Line's warranty, and no repairs were made.

On July 7, 1966, the over-all condition of this subsection was good. There was some spalling along the edges, and portions up to 6 inches in length were missing at joints. Small craters were present, but no alligator or transverse cracking was noted. The bonding of all portions was good. A total of 813 feet or 6.7 percent of line in this subsection was considered unsatisfactory.

Perma-Line guaranteed at least 50 percent of the line at each location to remain in place at least 4 years for center-lines and 3 years for edge-lines. The warranty for the edge-lines has expired, and only that portion dealing with the center-lines remains in effect. Repairs can not be made under the provisions of the warranty; and inasmuch as the missing footage of line does not give a disordered appearance, it is recommended that no repairs be made at this time.

A summary of the performance and repair history of Perma-Line in this subsection is given in Table 4, Attachment 11.

Subsection 3, Kentucky Paint

These lines were applied by the Traffic Division of the Kentucky Department of Highways on October 24, 1962. The center-lines were repainted during 1963, 1964, and 1965; and the edge-lines were repainted in 1964 and 1965 (see Table 2, Attachment 8 for costs).

During inspections on July 7, 1966, the appearance of the center-lines was good, but the edge-lines were very dim and need repainting.

TEST SITE 2

I 264-1(24)16; BC Pavement

Transverse Lines

The transverse lines in this subsection were applied November 2, 1962. The transverse lines of Kentucky paint have not been repainted. These lines were inspected July 7, 1966 (see Figure 6, Attachment 12), and notations of the condition of each line follows:

Line 1: White Kentucky Paint (1 application of paint, and drop-on beads). This line was completely devoid of paint and needs repainting.

Line 2: White Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads). The left-lane portion of this line was visible but badly worn, and the right-lane portion was devoid of paint. Repainting is recommended for this line.

Line 3: White Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads). The paint in the right-lane portion was missing, and the paint in the left-lane portion was badly worn. This line should be repainted.

Line 4: Yellow Kentucky Paint (1 application of paint, and drop-on beads). This line was completely devoid of paint and needs repainting.

Line 5: Yellow Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads). The paint was completely missing except for a small portion in the left lane. This line will have to be repainted.

Line 6: Yellow Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads). Paint in the inner lane was very dim, and the paint in the outer lane was missing. Repainting is recommended.

Line 7: White Perma-Line Thermoplastic. This line was in fair condition. The bond and reflectance were good, but the line was worn in the outer-lane wheel tracks.

Line 8: Yellow Perma-Line Thermoplastic. This line had a good over-all appearance. The bond was good, but a small amount of spalling had occurred in the outer lane.

Line 9: White Catatherm Thermoplastic. This line was in poor condition. Some cracking was noted; and the line was badly worn in the outer lane.

Line 10: Yellow Catatherm Thermoplastic. Some transverse cracking was present, and the line was worn in the outer-lane wheel tracks. The bond and reflectance were good; but the general condition of the line was poor.

Subsections 1, 4, and 7; Kentucky Paint

These lines were applied on October 22-23, 1962. The center-lines were repainted during the spring of 1963, and the edge-lines were repainted December, 1964 (see Table 2, Attachment 8 for costs).

On July 7, 1966, the over-all appearance of these subsections was fair. Both the center-lines and edge-lines need repainting.

Subsections 2, 5, and 8; Catatherm Thermoplastic

These lines were applied on October 22-23, 1962. All lines in these subsections were considered to be performing satisfactorily when inspections were made on April 8, 1963; on March 25, 1964; and on April 13, 1965.

On July 7, 1966, the over-all appearance of these subsections was fair. Transverse cracking appeared along all lines of all subsections with the exception of the left edge-line of the westbound lane of Subsection 5. The transverse cracks averaging 1/32 inch in width extended entirely across the line and were spaced from 1-1/2 to 10 inches apart. The bond was generally good; although Subsections 2 and 5 had areas of extreme edge spalling. Snow-plow damage was noted, and the reflectivity of the scraped areas was poor. Footage totaling 1,712 feet or 16.6 percent was considered unacceptable.

Cataphote's warranty has expired, and needed repairs will have to be made at the Department's expense. With this in mind, it is recommended that the spalled thermoplastic edge-lines be restriped with Kentucky paint.

A summary of the performance and repair history of Catatherm in these subsections is given in Table 3, Attachment 10.

Subsections 3, 6, and 9; Perma-Line Thermoplastic

These lines were applied on October 22-23, 1962. On April 8,1963, 2 feet of line in these subsections were considered to be unsatisfactory. On May 6, 1963, all lines that did not appear to be performing satisfactorily were repaired by Perma-Line, and a total of 202 feet or 2.0 percent of line was reworked.

During inspections on March 25, 1964, and on April 13, 1965, 1 foot of line was missing, and no repairs were made in these subsections during these years.

On July 7, 1966, the appearance of these subsections was excellent. No cracking was noted but Subsections 3 and 6 exhibited some edge spalling. The bonding quality and reflectivity were good. One foot of line was scraped during snow and ice removal and considered to be unsatisfactory. A summary of the performance and repair history of Perma-Line in these subsections is given in Table 4, Attachment 11.

TEST SITE 3

I 64-3(14)34; PCC Pavement

Transverse Lines

The transverse lines in this test site were applied on October 19, 1962. The Kentucky paint lines were repainted during the spring of 1963 and 1964 (see Table 2, Attachment 8 for repainting history and costs). These lines were inspected on June 29, 1966 (see Figure 7, Attachment 13), and notations of the condition of each line follows:

Line 1: White Kentucky Paint (1 application of paint, and drop-on beads). During the past year, extensive spalling over 50 percent of the line has occurred; and repainting is needed.

Line 2: White Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads). At the present time, 50 percent of the line has spalled and this line needs repainting.

Line 3. White Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads). Over one-half of the line has spalled and repainting is needed.

Line 4: Yellow Kentucky Paint (1 application of paint, and drop-on beads). The line was worn over its entire length, and repainting of the line is necessary.

Line 5: Yellow Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads). The general condition of this line was good except for a small amount of spalling. Repainting of this line is recommended.

Line 6: Yellow Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads). Extensive spalling of the outside lane has occurred, and repainting is necessary.

Line 7: White Perma-Line Thermoplastic. Extensive spalling of over 35 percent of the line had occurred, and the appearance of the line was poor. A close examination revealed small alligator cracks and numerous small craters. The bond of the line varied from poor to good.

Line 8: Yellow Perma-Line Thermoplastic. The left-lane portion had spalled extensively and the bond of this portion was poor. The bond and appearance of the right lane was satisfactory. A few craters were present. The over-all appearance of this line was very poor, and of all the thermoplastic transverse lines, this line was in the worst condition.

Line 9: White Catatherm Thermoplastic. A large number of craters and alligator cracks were present. In the left-lane portion, the bond was poor and excessive spalling had occurred. The appearance of the line was very poor.

Line 10: Yellow Catatherm Thermoplastic. The over-all condition of this line was very poor. Very wide alligator cracks were present. Due to poor bonding, this line had edge spalling in the left lane.

Subsection 1, Perma-Line Thermoplastic

These lines were applied during October and November of 1962. On April 10, 1963, a total of 6,178 feet or 6.2 percent of the line in this subsection was considered to be unsatisfactory. This footage, along with all other lines that did not appear to be performing satisfactorily, was repaired by Perma-Line during early May of 1963. Approximately 18,145 feet or 18.1 percent of line was reworked.

On April 7, 1964, a total of 1,534 feet or 1.5 percent of line was considered to be unacceptable. Perma-Line's warranty did not apply and consequently no repairs were made.

On April 15, 1965, footage totaling 17,179 feet or 17.2 percent was unacceptable, and the subsection was rated as substandard in over-all appearance (see Figure 8, Attachment 14). This footage was not covered by warranty provisions, and no repairs were made.

On June 29, 1966, the appearance of this subsection was poor. Many areas showed very poor bonding and this seemed to predominate in areas receiving drainage--e.g., the inside of super-elevated curves. In many areas, it was possible to pull up large portions of line (see Figure 9, Attachment 15). Large portions of line had spalled onto the recently paved bituminous shoulders, and it is possible that the spalled thermoplastic might fuse to the asphalt and create a hazardous condition (see Figure 10, Attachment 16). A total of 34,846 feet or 34.8 percent of line was considered to be unsatisfactory.

Inasmuch as the above unsatisfactory footage cannot be replaced under the warranty provisions, replacement with thermoplastic at the Department's expense is not recommended. The attrition rate the past two winters has been very great, and it would be uneconomical to replace the missing footage with thermoplastic. The missing portions have reached the point where they are becoming distracting to the passing public, and repainting of the thermoplastic with Kentucky paint is scheduled for this summer.

A summary of the performance and repair history of Perma-Line in this subsection is given in Table 4, Attachment 11.

Subsection 2, Kentucky Paint

These lines were applied on October 12, and October 15, 1962. The center-lines were repainted during the springs of 1963, 1964, 1965 and 1966 (see Table 2, Attachment 8 for costs). The edge-lines were scheduled for repainting in 1964, but because of the poor alignment of the original application, repainting was postponed to allow additional time for the edge-lines to wear out.

On June 29, 1966, the over-all appearance of this sub-section was fair. The center-lines had just been repainted and had an excellent appearance, but the edge-lines were completely devoid of paint in many areas. In other areas, the edge-lines were in excellent condition; and their appearance was superior to the appearance of the thermoplastics (see Figure 11, Attachment 17). Repainting of the edge-lines was postponed in 1965 until the shoulders of the pavement were paved with bituminous concrete. The shoulders were paved during the spring of 1966, and the edge-lines are scheduled for repainting this year.

Subsection 3, Catatherm Thermoplastic

These lines were applied October, 1962. On April 10, 1963, a total of 9,383 feet or 9.4 percent of line was considered to be unsatisfactory. This line was reworked during July, 1963, when Cataphote, in connection with their warranty provisions, repaired or replaced all lines in this subsection that did not appear to be performing satisfactorily. A total of 36,196 feet or 36.2 percent of line was reworked.

On April 8, 1964, a total of 17,602 feet or 17.6 percent of line was considered to be unacceptable; and of this, 3,831 feet was covered by Cataphote's warranty. Cataphote volunteered to repair all unsatisfactory footage; and when repairs were completed, 29,506 feet or 29.5 percent of line had been reworked.

On April 15, 1965, this subsection ranked poor in over-all appearance (see Figure 12, Attachment 18). A total of 27,656 feet or 27.6 percent of line was considered to be unsatisfactory; and this reflects the damage that occurred during the winter of 1964-65. Cataphote was allowed to have 800 lineal feet of unsatisfactory line for any selected 2,000 lineal feet of line or 842 feet of roadway length (ref. to warranty provisions, Test Site 1, Subsection 1). There were 15 areas in this subsection that exceeded this allowable tolerance, and the excess over 800 feet for each area, according to the guarantee, had to be replaced at no cost to the Department. According to inspection notes of the Division of Research, the Cataphote Corporation was committed to replace or make restitution for 3,176 lineal feet of line in this subsection; and on November 11, 1965, Cataphote satisfied the warranty provisions by repairing 3,302 feet of line. This left 24,354 feet or 24.3 percent of line in an unsatisfactory condition at the beginning of the 1965-66 winter.

On June 28, 1966, this subsection was inspected and the over-all appearance was rated as very poor. The bond was generally poor, expecially in the left-edge and center-lines. A large amount of line-footage was missing; and in many places, it was possible to pull up large portions of line (see Figure 9, Attachment 15). Transverse cracks and large craters were present, and extensive edge-spalling had occured. Portions of spalled lines were strewn on the recently paved shoulder creating a hazardous condition (see Figure 10, Attachment 16). Footage totaling 64,961 feet or 64.9 percent was unacceptable; and of this, none is covered by warranty provisions.

Such a large amount of missing footage imparts a disordered and unsightly appearance to the roadway; and, for all practical purposes, this subsection may be considered a complete failure. Cataphote's warranty does not apply; and, according to past performances of Catatherm in this subsection, it would be uneconomical to restore the remaining unsatisfactory footage with a thermoplastic at the Department's expense. Plans have been made to restripe this thermoplastic subsection with Kentucky paint this season.

A summary of the performance and repair history of Catatherm in this subsection is given in Table 3, Attachment 10.

TEST SITE 4

I 64-5(16)93; BC Pavement

Transverse Lines

These lines were applied on November 27, 1962. The transverse lines of Kentucky paint have not been re-striped. These lines were inspected on April 20, 1966 (see Figure 13, Attachment 19) and notations of the condition of each line follows:

Line 1: White Catatherm Thermoplastic. A large number of alligator and transverse cracks were present, and the line was rated as fair. The bond and reflectivity were good.

Line 2: Yellow Catatherm Thermoplastic. The reflectance and bond quality were good, and no spalling was noted. A large number of large craters were present, and alligator and transverse cracking had occurred over the entire line. The appearance of this line was fair.

Line 3: White Perma-Line Thermoplastic. This line was in an excellent condition. The bond and reflectance were good; no spalling was noted; and no cracks were present.

Line 4: Yellow Perma-Line Thermoplastic. The bond quality and reflectance were good, and no cracking had occurred. The over-all appearance of this line was excellent.

Line 5: White Kentucky Paint (1 application of paint, and drop-on beads). This line was worn and dim and needs repainting.

Line 6: Yellow Kentucky Paint (1 application of paint, and drop-on beads). This line was worn and needs repainting.

Line 7: White Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads). The portion of line in the outside lane was worn

and needs repainting; and the portion on the inside lane was in good condition except for some cracking and edge-spalling.

Line 8: Yellow Kentucky Paint (2 applications of paint at 3-day intervals, and drop-on beads). This line was in an excellent condition even though some edge-spalling had occurred. The line does not need repainting.

Line 9: White Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads). Large portions of the second and third application of paint had flaked off--exposing the first application. The over-all condition of the line was excellent, and the line does not need re-striping.

Line 10: Yellow Kentucky Paint (3 applications of paint at 3-day intervals, and drop-on beads). No flaking had occurred, and the over-all appearance of the line was excellent.

Subsection 1, Kentucky Paint

These lines were applied on November 15-16, 1962. The edge-lines have not been repainted, and the center-lines were repainted during spring, 1964, (see Table 2, Attachment 8 for costs).

On June 30, 1966, the appearance of the center-lines and edge-lines was poor, and the lines need repainting.

Subsection 2, Catatherm Thermoplastic

These lines were applied during November, 1962. On April 12, 1963, a total of 635 feet, or 0.6 percent of line, was considered to be unsatisfactory. On July 18-19, 1963, Cataphote, in connection with their warranty provisions, repaired or replaced all lines in this subsection that did not appear to be performing satisfactorily. A total of 1,471 feet or 1.5 percent of line was repaired, but his included 380 feet or 0.4 percent of new line that was applied over a recently installed, full-width patch. Included in these repairs was the 635 feet referred to above.

On April 10, 1964, an inspection was made and 977 feet or 1.0 percent of the line was considered to be unsatisfactory, and of this, 170 feet were covered by Cataphote's guarantee. Cataphote volunteered to repair all substandard footage, and 1,247 feet or 1.3 percent of line were reworked.

On April 20, 1965, 924 feet or 0.9 percent of line were considered unacceptable; and almost all of this occurred on bridge decks. None of the unsatisfactory footage was covered by Cataphote's warranty; and consequently, no repairs were made.

On June 30, 1966, the bonding was excellent except on bridge decks, and the condition of this subsection was considered to be good. The shoulders of the roadway have recently been paved with bituminous concrete, and portions of the edge-markings have been covered with asphalt. Transverse cracks from 2 to 6 inches apart were noted over a majority of the surface. Longitudinal cracking of a large number of center-lines was noted, and this cracking was caused by the separation of the underlying construction joint. Approximately 12 center-line strips were spalled in the west-bound lane. The amount of line considered to be unacceptable was 1,944 feet of 2.0 percent; and almost all of this occurred on bridge decks, except for 472 feet that had been covered with full-width patches.

Cataphote's guarantee does not apply in this particular instance, and it is felt that no repairs of any kind should be made in this subsection at the Department's expense because the missing footage does not give a disordered appearance.

A summary of the performance and repair history of Catatherm in this subsection is given in Table 3, Attachment 10.

Subsection 3, Perma-Line Thermoplastic

Perma-Line started work on this subsection on November 15, 1962, but because of menacing weather, received permission to postpone further work until the spring of 1963. Perma-Line resumed work on this subsection on April 15, 1963, and all work was completed on April 26, 1963. Of the line that was placed in 1962, 41 feet were reworked during April of 1963. In addition, 150 feet of line were re-applied over a bridge deck patch.

On April 10, 1964, the amount of line considered to be unsatisfactory was 809 feet or 0.8 percent but this included 534 feet or 0.5 percent of line that were covered by an overlay patch on the pavement. Inasmuch as Perma-Line's warranty did not apply, no repairs were made.

On April 20, 1965, a total of 1,441 feet or 1.5 percent of line was adjudged to be unsatisfactory; but this included 982 feet or 1.0 percent of line covered by an overlay patch on the pavement. The missing footage was not covered by Perma-Line's warranty, and no repairs were made.

An inspection of this subsection was made on June 30, 1966, and the over-all appearance was excellent. The bond on the bridge decks was only fair, but the bond elsewhere was good. While recently paving the shoulders with bituminous concrete, portions of the edge-lines were covered with asphalt. Footage totaling 2,266 feet or 2.3 percent of line was unacceptable, but this included 1,606 feet or 1.6 percent of line covered with full-width pavement patches.

The missing footage does not impart a disordered appearance to this subsection; and, inasmuch as Perma-Line's warranty does not cover the replacement of these lines, it is recommended that no repairs be made.

A summary of the performance and repair history of Perma-Line in this subsection is given in Table 4, Attachment 11.

TEST SITE 5

U. S. 60; SP 37-45, SP 120-15; PCC Pavement

Center-Line of Eastbound Lane, Perma-Line Thermoplastic

These lines were applied on June 25, 1965, under HCT 02444. On June 29, 1966, the appearance of these lines was good except for the spalling of 76 center-line stripes which represented 16 percent of the total. These spalled lines seemed to predominate at interchanges.

Center-Line of Westbound Lane, Kentucky Paint

These lines were painted in May, 1965, and they have been repainted during October, 1965 and June, 1966. The appearance of these lines on June 29, 1966 was excellent.

TEST SITE 6

I 64, SP 37-905, PCC Pavement

Center-Line of Eastbound Lane, Perma-Line Thermoplastic

These lines were installed on June 25, 1965, under HCT 02444. During inspections on June 29, 1966 some spalling was noted at the ends of several skip-dash lines, and three lines were extremely spalled. The over-all condition of these lines was excellent.

Center-Line of Westbound Lane, Kentucky Paint

These lines were applied during May, 1965, and were repainted during October, 1965 and June, 1966. On June 29, 1966, the appearance of these lines was excellent.

TEST SITE 7

I 64; SP 56-273, PCC Pavement

Center-Line of Eastbound Lane, Perma-Line Thermoplastic

The lines were applied on June 25, 1965, under HCT 02444. On July 7, 1966, very little spalling was noted; and the over-all condition was excellent.

Center-Line of Westbound Lane, Kentucky Paint

The original application of paint was applied in May, 1965, and the lines have received additional repaintings during October, 1965 and June, 1966. The appearance of these lines on July 7, 1966, was excellent.

TEST SITE 8

I 65; SP 56-798, PCC Pavement

Perma-Line Thermoplastic

These lines were applied during May-June, 1965. During inspection on July 7, 1966, 11 center stripes were missing at one location, and spalling of several other center stripes was noted. This site was considered to have an excellent over-all appearance.

TEST SITE 9

I 264; SP 56-898, BC Pavement

Perma-Line Thermoplastic

These lines were applied during May-June, 1965. During inspections on July 7, 1966, longitudinal cracking of a number of skip-dash lines caused by the separation of the underlying construction joint was noted. Spalling of the thermoplastic was noted at the concrete ramps and where the thermoplastic was installed over existing paint. The over-all condition of these lines was excellent.

D. COST ANALYSIS

Perhaps the simplest method for cost analysis is to calculate the annual outlay for each type of variable and compare these graphically by plotting the accumulative annual cost verses the year the additional expense was incurred. The first-year cost would be the installation cost plus any maintenance incurred within that year. The accumulative cost for the second and successive years would be the total cost from the preceeding year plus any maintenance outlays. Such a plot gives a pictorial account of capital outlays over the years involved, and a rational conclusion as to the most economical alternate can be reached. One aspect which is neglected in this type of analysis is potential interest return on capital lumped into construction. Even though funds might be available and borrowing is unnecessary, interest must still be considered because a loss in potential interest income reflects idle capital or unrewarding investment. For comparison purposes, interest would not be significant if all items had similar initial costs; nevertheless, this type of analysis will be used at this time even though the initial cost of the thermoplastics exceed that of the paint by some 25 times.

The accumulative annual expenditures in cents per foot for each test site, from the original date of installation to the present, are shown in Figure 14, Attachment 20 . Annual expenditures for 1962 consisted of the initial costs of installation; and the annual expenditures for succeeding years consisted of maintenance costs which were computed from data obtained from records maintained by the Division of Research. Data for annual expenditures for maintaining the Kentucky paint,control lines are contained in Table 2. These are based on the costs of 1963 painting program and includes expenditures for paint, beads, personnel, and equipment rental. In regard to the thermoplastics, no actual maintenance expenditures have been incurred because the Department has not elected to have repairs made. There exists, at the present time, a large amount of unsatisfactory footage that is not covered by warranty provisions and even though the Department has no plans to make repairs in kind, this represents a maintenance liability that must be considered. In addition, both contractors have, in the past, voluntarily

made repairs, to varying degrees, of unacceptable footage not covered by warranty provisions; and inasmuch as the contractors were under no obligations, the cost of such replacement must be considered as maintenance expenditures. In view of this, thermoplastic line which has been repaired or adjudged to be unsatisfactory but not covered by warranty has been assumed to have been replaced at a unit cost equal to original cost per foot. Expenditures were calculated from the data in Tables 3 and 4--Annual Performance and Repair History of Catatherm and Perma-Line Thermoplastics.

E. GENERAL DISCUSSION

The original experimental test sites were installed in 1962, and the initial cost of the thermoplastics was 39 cents per foot or 25 times the cost of the control sections of traffic paint. Kentucky regularly (then) used 15 gallons of paint with intermixed beads per mile and 2 pounds of drop-on beads per gallon of paint; and the cost of the painting program averaged $49.72 per mile or 0.9 per foot of line. For the original installations, the over-all rate of application of Kentucky paint was 25 gallons per mile which is somewhat greater than that normally used; and, from place-to-place, the rate may have varied between 18 and 35 gallons per mile. The cost of applying the paint lines averaged 1.6 cents per foot.

During both daytime and nighttime, thermoplastics have; better visibility than freshly applied paint;but the difference is only slight. In comparison to newly installed lines, there is a slight reduction in the visibility of thermoplastics after 6 months of service; but if the lines remain in place, no further reduction occurs. Paint, on the other hand, gradually decreases in visibility with age, and repainting is required at intervals from one to three years-- depending on line location, type of pavement, and traffic volume.

Experience gained thus far in this study indicates that center-lines require repainting yearly for PCC pavements and every 2 years for BC pavements. Edge-lines require repainting every 2 years for PCC pavements and every 3 years for BC pavements. Exceptions do exist as in the case of portions of the edge-lines at Test Site 3 which have never been repainted and which have visibilities comparable to the thermoplastics.

The attrition of high-quality paint is usually brought about by wear, flaking, and fading--flaking occurs predominately on PCC pavements, and fading is more noticeable on BC pavements. Poorer permanence of traffic paints on PCC pavements is obtained on the inside of horizontal curves. This decrease in performance could be caused by the surface drainage passing over the lines, or it could be related to the concentration of laitance on the low side of the pavement when it was built.

Multi-applications of paint were installed transversely at each test site, and comparisons between these lines and single-application lines were made. Somewhat greater wear-resistance was obtained from the multi-application lines, but this did not offset the increased flaking that was experienced with the thicker applications.

In the original installation of thermoplastics in 1962 and for all subsequent repair work, bonding agents, referred to as Permaseal and Pliobond were used exclusively. Pliobond is manufactured by the Goodyear Tire and Rubber Company and is sold as a flexible adhesive for bonding porous and non-porous materials. Pliobond is composed of phenolic resin and synthetic nitrile rubber in a toluene and methyl-ethyl-ketone solution. It is manufactured at solids contents of 20, 30, and 40 percent; and prior to use, methyl-ethyl-ketone is added to reduce the mixture to a 10 percent level.

Better performance of both thermoplastic and paint stripes has been obtained on bituminous surfaces than on PCC pavement. It should be noted that most of the unsatisfactory lines in the bituminous sections occurred on concrete bridge decks. Thermoplastics applied on bituminous surfaces soften and fuse to the asphaltic surface, thereby insuring a good bond. This unique quality, on the other hand, cannot be achieved when thermoplastics are applied to portland cement concrete surfaces, and the bond obtained is somewhat less favorable.

The ability of thermoplastics to permanently adhere to PCC pavements is dependent on the bonding properties of the primer, the climatic conditions, and the condition of the pavement. Little, if any, bond would be attained if thermoplastics were installed on PCC pavements without primers. The primers perform the functions of an adhesive which glues the stripe in place; and, if a pavement has a considerable amount of laitance, the ability of any primer, including epoxy, to penetrate this weak strata and firmly affix both the stripe and the laitance to sound concrete is doubtful.

Performance data indicates that Pliobond is effective in affixing thermoplastics to PCC pavements in areas where no surface laitance is present. On the other hand, experience at Test Site 3 indicates that Pliobond is incapable of penetrating surface laitance to an effective depth for

adequate bonding. An examination of the bottom surface of thermoplastic line that had spalled revealed a thin layer of laitance (see Figure 15, Attachment 21). Another factor which no doubt decreases the life of thermoplastics is the retention of water underneath of the stripe. Figure 16 (Attachment 22) shows a poorly bonded stripe that had been pulled up, and the trapped moisture can be readily seen. Upon freezing of this moisture, sufficient pressure could be exerted to dislodge the stripe.

Catatherm and Perma-Line thermoplastic appear to be very similar in composition. Both contain spherical glass beads, but Perma-Line contains a coarse calcitic filler which is not present in Catatherm.

The performance of Perma-Line has been superior to that of Catatherm, and perhaps this superiority in performance is due to the greater application rate of Pliobond that was used by Perma-Line.

Following a rain, the thermoplastic edge-lines impounded water which, in many cases, extended onto the roadway as much as 18 inches and persisted along the entire edge-line long after the center portion of the roadway had dried (see Figure 17, Attachment 22). This condition caused an accumulation of de-icing salts along the edge of the roadway; and in some instances, caused water to drain across the pavement--creating an icing hazard. Drainage outlets were cut by Department personnel to alleviate this condition.

Each thermoplastic stripe which crossed an expansion joint had developed one, and in some cases more, cracks transverse to the line and parallel to the joint. The foregoing was true for both center-stripes and edge-lines. Later observations of these cracks revealed that the thermoplastics in the immediate vicinity of the cracks had spalled.

At times, portions of spalled, thermoplastic lines as long as 6 feet were observed on the shoulders of Test Site 3. This was very distracting and gave the roadway a cluttered appearance. In fact, the spalled material could be classed as hazardous for nighttime drivers; and the removal of this line by State forces would have been time consuming and costly. In time, the material broke into small pieces of 1/4-inch and was less noticeable on the dense-graded shoulders.

The shoulders at Test Site 3 have been recently paved with bituminous concrete; and, since completion, additional thermoplastic has spalled onto the shoulders. This material is very noticeable (see Figure 10, Attachment 16) and it is possible for this material to fuse to the asphaltic shoulders and create a continuous distraction.

In cases such as Test Site 3, large amounts of Catatherm and Perma-Line that are not covered by warranty provisions are missing and replacement with some type of pavement marking will have to be made this year. The Department has plans to replace these missing portions with traffic paint inasmuch as past performance indicates that replacement in kind would be uneconomical. Thus, badly spalled lines will be repainted, and the future maintenance of these paint and thermoplastic combinations may present problems for years to come. The guarantee currently and heretofore provided by the thermoplastic companies is not sufficient to adequately maintain the lines in a presentable manner. The restoration of unsatisfactory line to a 80 to 90 percent level, as provided by the thermoplastics warranty, is not acceptable inasmuch as the roadway appears unsightly when as much as 10 percent of line is missing.

Thermoplastics have been claimed to be less interfering with traffic because renewal applications are not required. This would be true if almost all the footage is retained from year to year and repairs were not necessary. Another aspect seldom mentioned is the amount of time and inconvenience to traffic required to install the thermoplastics. The daily production of thermoplastic machines does not approach the production of paint-striping machines, and the time required for thermoplastic installation may exceed that of paint installation by as much as three times.

In summary, both traffic paint and thermoplastics bonded with Pliobond will adhere to PCC pavements if surface laitance is not present. Thus, in areas where paints perform poorly and a longer lasting stripe is needed, thermoplastics applied with Pliobond have not performed satisfactorily either.

The initial cost of thermoplastics is high in comparison to paint, and this factor alone is sufficient to deter use of the material. By reviewing Figure 13, which ignores interest factors, it is quite evident that paint is the more

economical inasmuch as the higher initial capital outlay for thermoplastics can never be fully amortized. It is unrealistic to expect the life of a traffic marking to exceed the life of the pavement surface or the life of reflectorizing beads. With continued traffic, beads wear flat, and this reduces the reflectivity to the point where the lines are practically worthless. In time, bituminous pavements require sealing or resurfacing, and such treatments would obliterate pavement markings. Such a loss of low-priced paint would be insignificant, but the loss of expensive thermoplastic markings would be economically intolerable.

At the present, thermoplastics cost about 32 cents per foot when used in large quantities. A heavier-than-usual initial application of paint could be installed for 2 cents per foot, and this would leave 30 cents per foot unobligated. Assuming capital to be worth 4 percent interest, the initial-cost savings if invested would yield a perpetual annual return of 1.2 cents per foot or enough to repaint all lines yearly. Experience has shown that not all paint lines require yearly renewal, and additional savings would thus be realized.

Further improvements in thermoplastic products and other so-called permanent striping may yet be forthcoming. Epoxy type coatings, other types of melts, and tapes are becoming available. All such developments remain subject to rational economic evaluation by the user. None, as yet, is wholly worthy of supporting conventional paint in the Department's striping programs.

Inspection and performance surveys of the thermoplastic installations in Kentucky will continue on a yearly basis, and evaluations will be continuously updated.

F. ATTACHMENTS

1. Map Showing Location of Experimental Projects.

2. Table 1: Summary of Quantities and Costs of 1965 Perma-Line Thermoplastic Installations.

3. Excerpts from Department's Final Construction Inspection Report of Test Sites 8 and 9 (Perma-Line).

4. Figure 1: Photograph Showing Perma-Line's Automatic Striping Equipment.

5. Figure 2: Photograph Showing Epoxy Primer under Thermoplastic Line, Test Site 7.

6. Figure 3: Photograph of Portion of Test Site 8, Showing Irregular Alignment of Edge-Lines.

7. Figure 4: Photograph Showing Thermoplastic Drippings on Pavement at Test Site 8.

8. Table 2: Repainting History and Estimated Costs for Kentucky Paint.

9. Figure 5: Photograph Showing Transverse Test Lines, Test Site 1.

10. Table 3: Performance and Repair History of Catatherm.

11. Table 4: Performance and Repair History of Perma-Line.

12. Figure 6: Photograph Showing Transverse Test Lines, Test Site 2.

13. Figure 7: Photograph Showing Transverse Test Lines, Test Site 3.

14. Figure 8: Photograph Showing a Portion of Test Site 3, Subsection 1, Perma-Line.

15. Figure 9: Photograph Showing Poor Bond of Thermoplastics in Test Site 3.

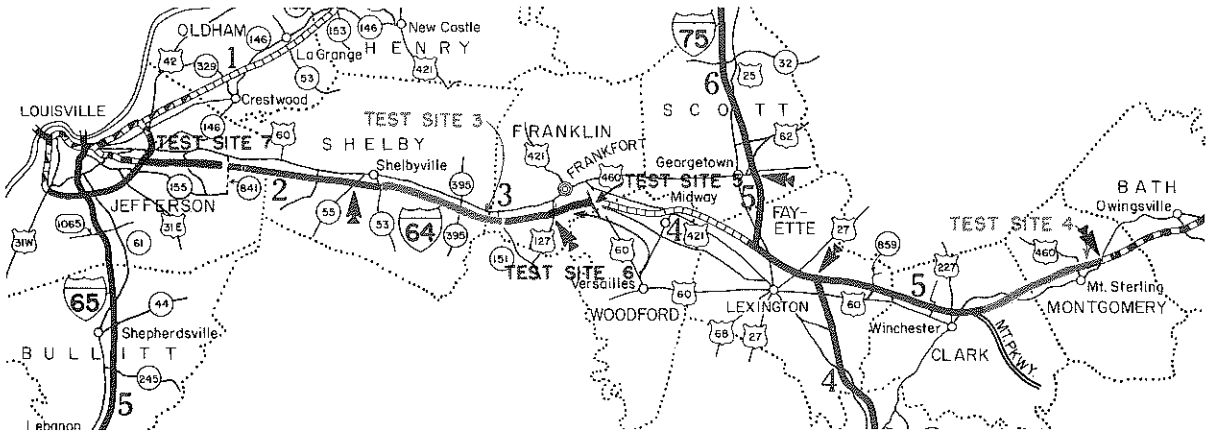
16. Figure 10: Photograph Showing Spalled Thermoplastics on Shoulders of Test Site 3.

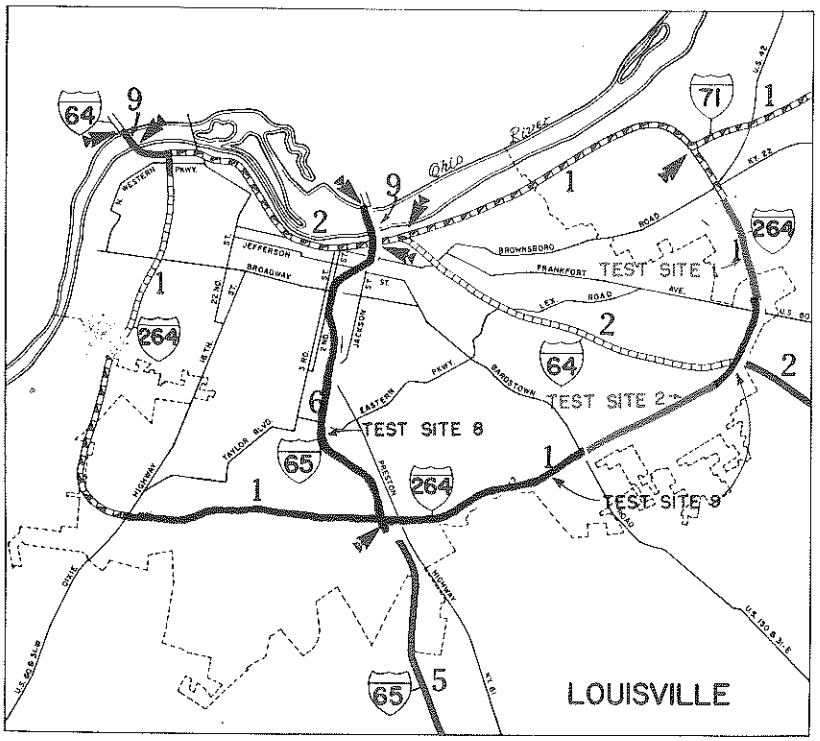
ATTACHMENT 1

TEST SITES

Experimental, Thermoplastic, Pavement-striping Materials

Blue, Installed in 1962
Red, Installed in 1965





ATTACHMENT 2

TABLE 1
SUMMARY OF QUANTITIES AND COSTS OF
1965 PERMA-LINE THERMOPLASTIC INSTALLATIONS

Test Site	Item Description	Lineal Feet	Unit Cost	Cost	Total Cost
5	4-inch Skip Center-Line	7,170	$0.315	$ 2,258.55	$ 2,258.55
6	4-inch Skip Center-Line	8,835	0.315	2,783.03	2,783.03
7	4-inch Skip Center-Line	12,375	0.315	3,898.13	3,898.13
8	4-inch Skip Center-Line	39,495	0.320	12,638.40	
	4-inch Solid Edge-Line	143,153	0.315	45,093.20	59,704.37
	8-inch Solid Edge-Line	3,461	0.570	1,972.77	
9	4-inch Skip Center-Line	50,730	0.320	16,233.60	
	4-inch Solid Edge-Line	250,056	0.315	78,767.64	100,103.31
	8-inch Solid Edge-Line	8,951	0.570	5,102.07	

ATTACHMENT 3

FINAL CONSTRUCTION INSPECTION REPORT

The following is a compilation of remaks from the Final Construction Inspection Report for the thermoplastic installations listed below.

Test Sites 8 and 9

Perma-Line Date of Report: August 3, 1965

Satisfactorily completed with the following work required.

Remove and replace line right hand gore I-65 and 264 east entrance ramp 4' solid. Remove splotch where material ran out of alignment of lines-Remove stains of material which are in the lanes. Correct skip line in southbound lane, Jefferson Exit. Remove all large bows and replace lines.

Plan Sheet 2 - Specifications Section III-E Warranty:

The successful bidder shall guarantee to replace, without cost to the customer, that part of the pavement markings, installed under this contract which, in the opinion of the Engineer in charge, have not remained to perform useful services as follows: 90 percent of a unit for 1 year; 80 percent of a unit for 2 years; 60 percent of a unit for 3 years; 50 percent of a unit for 4 years. A unit is defined as any length of highway having installed thereon 2000 lineal feet of line of specified width in any combination or pattern. The replacement material installed under this guarantee shall be guaranteed the same as the original material, from the date of the original installation. A maintenance bond in the amount of 10 percent of this contract should accompany the final estimate.

ATTACHMENT 4

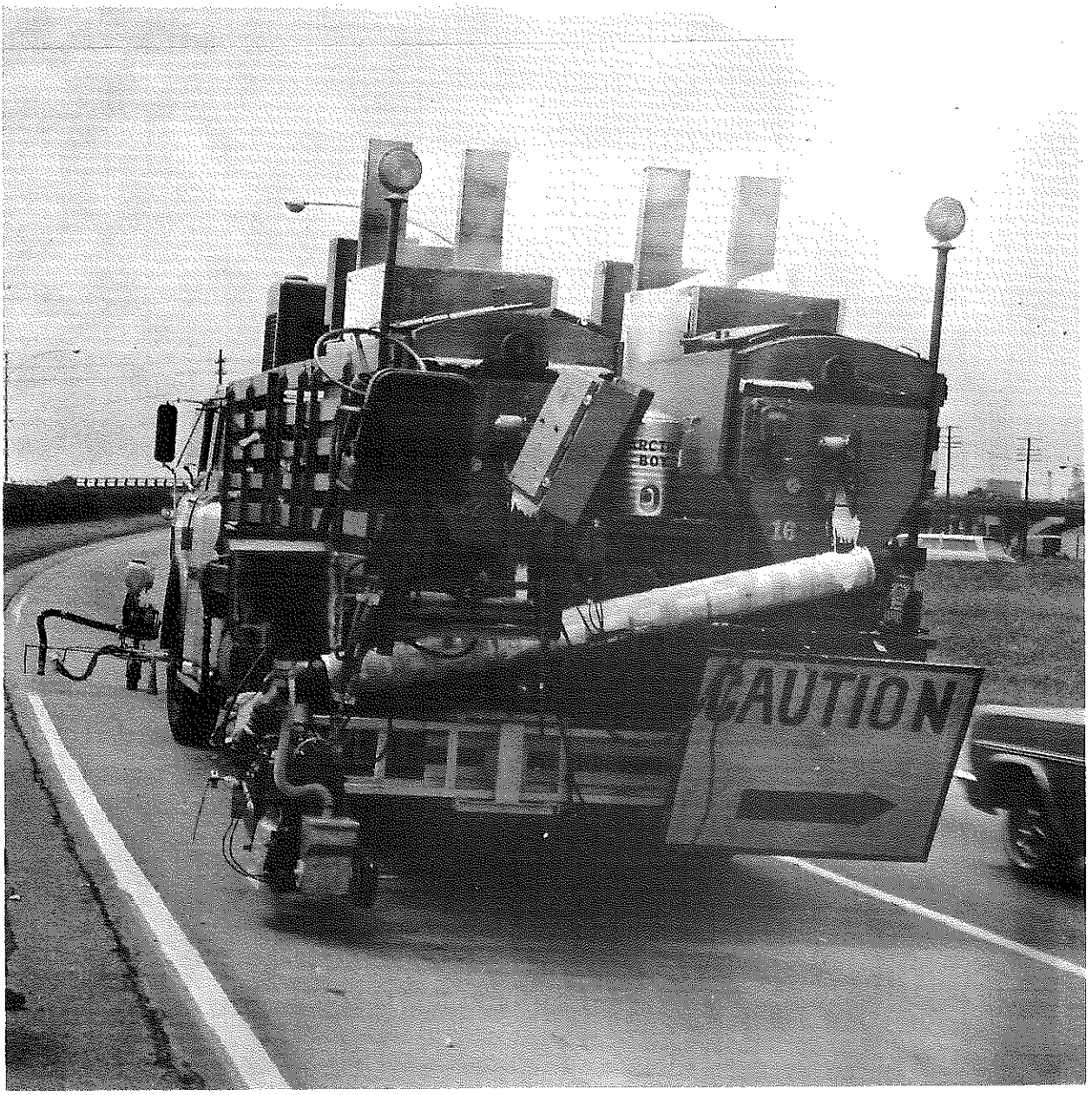


Figure 1. Perma-Line's Automatic Striping Equipment.

ATTACHMENT 5

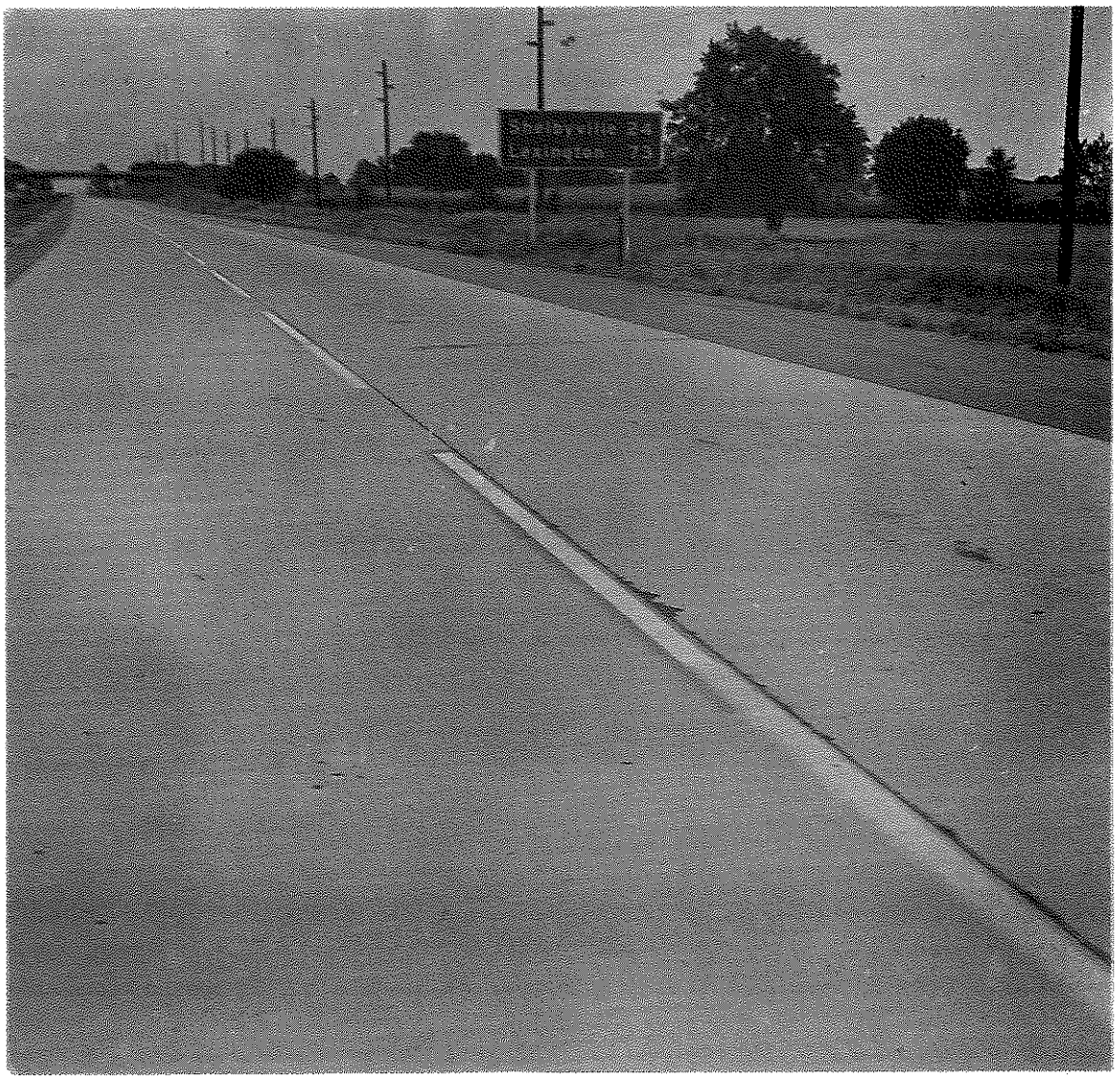


Figure 2. Portion of Test Site 7 Showing Epoxy Primer under Thermoplastic Line.

ATTACHMENT 6

Figure 3. Portion of Test Site 8 Showing Irregular Alignment of Edge-Lines.

ATTACHMENT 7

Figure 4. View of Test Site 8 Showing Unsightly Thermoplastic Drippings on Pavement.

ATTACHMENT 8

TABLE 2
REPAINTING HISTORY AND ESTIMATED* COSTS
FOR KENTUCKY PAINT

County And Project	Test Site	Subsection And Pavement Type	Line Location	Cost Per Repainting					Dates Repainted	Total Cost To Date
				Paint	Beads	Labor	Equipment	Total Cost		
Jefferson I 264-1(25)20 SP 56-898	1	3 PCC	Center	12.90	1.16	3.47	.58	18.11	Spring, 1963 Spring, 1964 Summer, 1965	54.33
			Edge	68.79	6.16	18.48	3.08	96.51	December, 1964 Summer, 1965	193.02
			Transverse	8.40	.88	10.32	4.05	23.65	Spring, 1963 Spring, 1964	47.30
Jefferson I 264-1(24)16 SP 56-898	2	1, 4, & 7 BC	Center	10.89	.98	2.93	.49	15.29	Spring, 1963	15.29
			Edge	58.07	5.20	15.60	2.60	81.47	December, 1964	81.47
			Transverse	8.40	.88	10.32	4.05	23.65	---	23.65**
Franklin-Shelby I 64-3(14)34 SP 37-905 SP 106-806	3	2 PCC	Center	105.81	9.48	28.43	4.74	148.46	Spring, 1963 April, 1964 April, 1965 June, 1966	593.84
			Edge	564.33	50.54	151.61	25.27	791.75	---	791.75**
			Transverse	8.40	.88	10.32	4.05	23.65	Spring, 1963 Spring, 1964	47.30
Clark-Montgomery I 64-5(16)93 SP 25-422 SP 87-557	4	1 BC	Center	104.35	9.34	28.04	4.67	146.40	Spring, 1964	146.40
			Edge	556.56	49.84	149.52	24.92	780.84	---	780.84**
			Transverse	8.40	.88	10.32	4.05	23.65	---	---

* Cost Estimates based on costs of 1963 painting program which is the latest and most accurate information available (K. B. Johns Memorandum of January 9, 1964, Research File P.2.3.1).

** These lines have not been repainted, but costs are indicated inasmuch as painting was needed in 1965.

ATTACHMENT 9

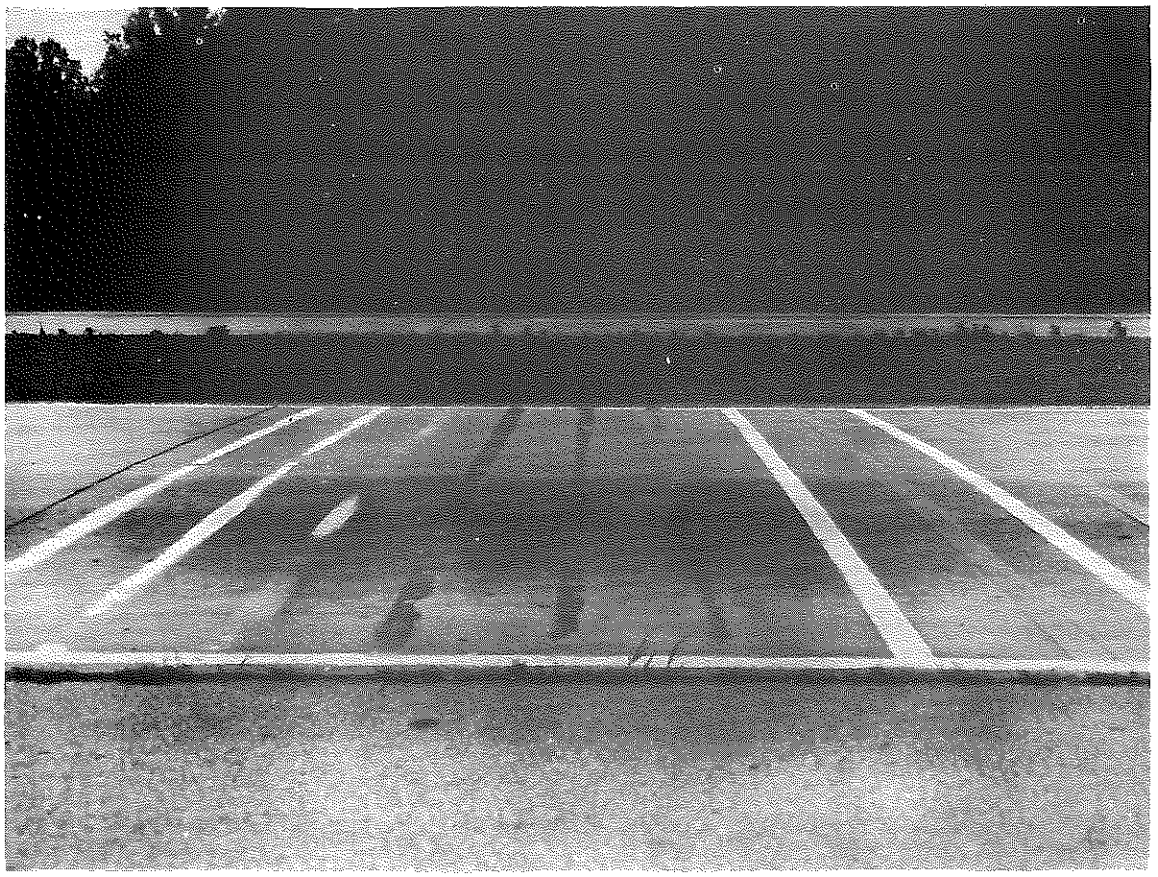


Figure 5. Transverse Lines on Portland Cement Concrete Pavement in Test Site 1, I 264, Jefferson County. Note comparative wear of Kentucky paint lines which received multiple applications. Lines were placed in November, 1962, Kentucky paint lines were repainted in the springs of 1963 and 1964, and photograph was taken during July, 1966. First 6 lines are Kentucky white and yellow paint--3, 2 and 1 applications, respectively; lines 7 and 8 are Perma-Line; and lines 9 and 10 are Catatherm.

ATTACHMENT 10

TABLE 3
PERFORMANCE AND REPAIR HISTORY OF CATATHERM THERMOPLASTIC

Test Site	Pavement Type	Footage of Line	1963						1964						1965						1966					
			Line Adjudged to be Unsatisfactory		Line Covered by Warranty*		Line Repaired		Line Adjudged to by Unsatisfactory		Line Covered by Warranty		Line Repaired		Line Adjudged to be Unsatisfactory		Line Covered by Warranty		Line Repaired		Line Adjudged to be Unsatisfactory		Line Covered by Warranty		Line Repaired	
			Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent
1	PCC	12,192	65	0.5	0	0.0	1,259	10.3	119	1.0	0	0.0	317	2.6	912	7.5	0	0.0	0	0.0	1,550	12.7	0	0.0	0	0.0
2	BC	10,292	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1,712	16.6	0	0.0	0	0.0
3	PCC	100,022	9,383	9.4	5,354	5.4	36,196	36.2	17,602	17.6	3,831	3.8	29,506	29.5	27,656	27.6	3,176	3.2	3,302	3.3	64,961	64.9	0	0.0	0	0.0
4	BC	98,643	635	0.6	245	0.2	1,091	1.1	977	1.0	170	0.2	1,247	1.3	924	0.9	0	0.0	0	0.0	1,472	1.5	0	0.0	0	0.0
	TOTAL	221,149	10,083	4.6	5,599	2.5	38,546	17.4	18,698	8.4	4,001	1.8	31,070	14.0	29,492	13.3	3,176	1.4	3,302	0.1	69,695	31.5	0	0.0	0	0.0

* Assuming original guarantee in effect.
Original warranty guaranteed 90 percent of a unit for one year, 80 percent of a unit for two years, and 60 percent of a unit for three years--a unit defined as any length of a roadway having installed thereon 2,000 lineal feet of line. During construction, Department officials became concerned over the seemingly poor bonding characteristics of Catatherm, and Cataphote agreed to provide a 100 percent warranty for one year if the Department would permit continuation of work.

ATTACHMENT 11

TABLE 4
PERFORMANCE AND REPAIR HISTORY OF PERMA-LINE THERMOPLASTIC

Test Site	Pavement Type	Footage of Line	1963						1964						1965						1966					
			Line Adjudged to be Unsatisfactory		Line Covered by Warranty*		Line Repaired		Line Adjudged to be Unsatisfactory		Line Covered by Warranty		Line Repaired		Line Adjudged to be Unsatisfactory		Line Covered by Warranty		Line Repaired		Line Adjudged to be Unsatisfactory		Line Covered by Warranty		Line Repaired	
			Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent	Footage	Percent
1	PCC	12,192	117	1.0	0	0.0	117	1.0	13	0.1	0	0.0	0	0.0	333	2.7	0	0.0	0	0.0	813	6.7	0	0.0	0	0.0
2	BC	10,292	2	0.0	0	0.0	202	2.0	1	0.0	0	0.0	0	0.0	1	0.0	0	0.0	0	0.0	1	0.0	0	0.0	0	0.0
3	PCC	100,022	6,178	6.2	0	0.0	18,145	18.1	1,534	1.5	0	0.0	0	0.0	17,179	17.2	0	0.0	0	0.0	34,846	34.8	0	0.0	0	0.0
4	BC	98,643	41	0.0	0	0.0	41	0.0	275	0.3	0	0.0	0	0.0	459	0.5	0	0.0	0	0.0	660	0.7	0	0.0	0	0.0
	TOTAL	221,149	6,338	2.9	0	0.0	18,505	8.4	1,823	0.8	0	0.0	0	0.0	17,972	8.1	0	0.0	0	0.0	36,320	16.4	0	0.0	0	0.0

* Assuming original guarantee in effect.
Original warranty guaranteed 50 percent of footage to remain in place for four years for center-lines and three years for edge-lines. In consideration of a change which lowered the minimum temperature for application from 50°F to 40°F for Test Site 4, Perma-Line agreed to provide a 100 percent warranty for one year at Site 4.

ATTACHMENT 12

Figure 6. Transverse Lines on Bituminous Concrete Pavement in Test Site 2, I 264, Jefferson County. Lines were placed in November, 1962, and photograph was taken during July 1966. The Kentucky paint lines have not been repainted. Some minor edge spalling can be seen in lines 9 and 10. First 6 lines are Kentucky white and yellow paint--1, 2, and 3 applications, respectively; lines 7 and 8 are Perma-Line; and lines 9 and 10 are Catatherm.

ATTACHMENT 13

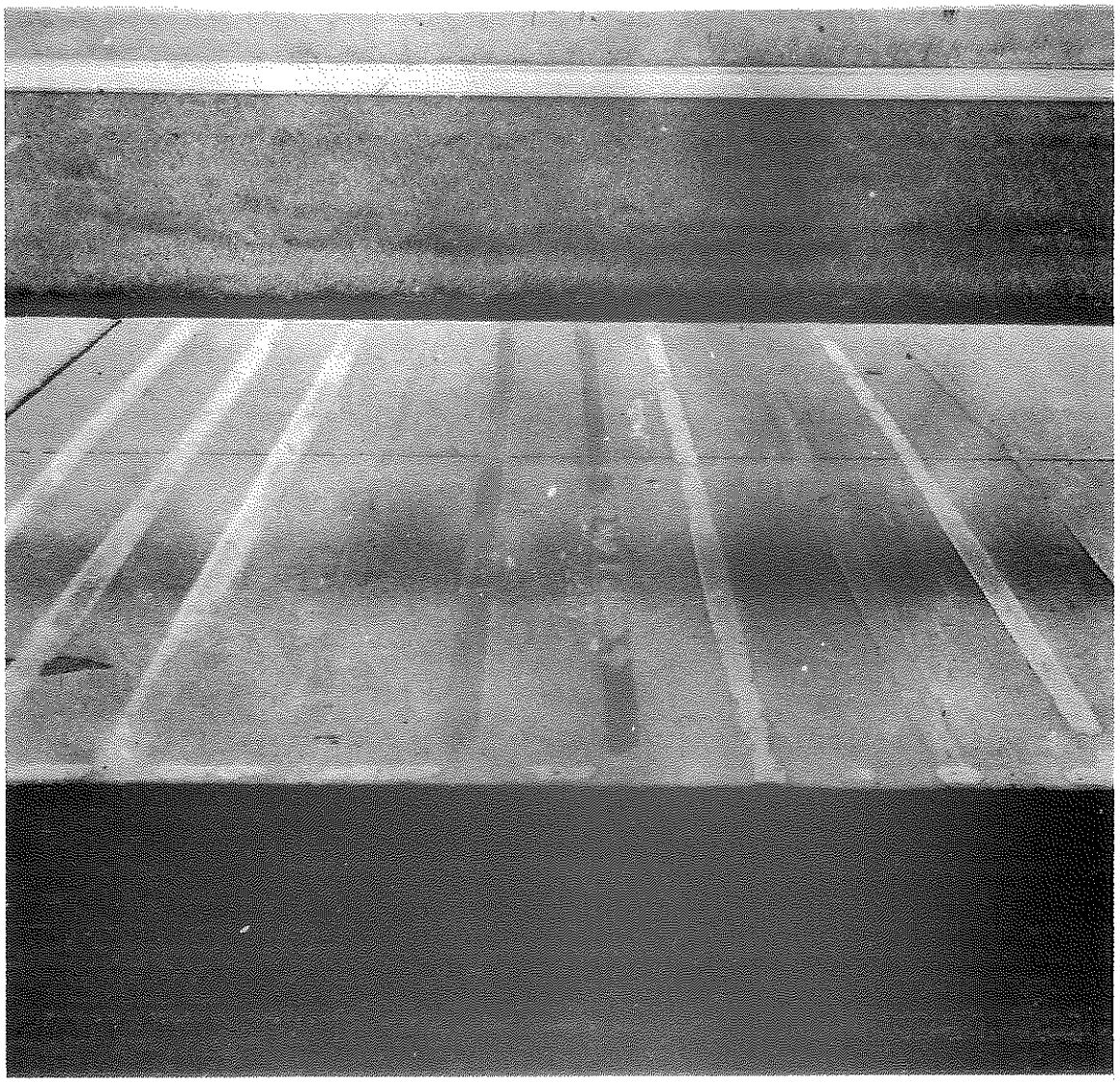


Figure 7: Transverse Lines on Portland Cement Concrete Pavement in Test Site 3, I 64, Shelby County. Lines were placed in October, 1962, Kentucky paint lines were repainted in the springs of 1963 and 1964, and photograph was taken during April, 1965. First 6 lines are Kentucky white and yellow paint--1, 2, and 3 applications, respectively; lines 7 and 8 are Perma-Lines; and lines 9 and 10 are Catatherm. Note spalling of all thermoplastic lines and flaking of Kentucky paint lines which received multiple applications.

ATTACHMENT 14

Figure 8: View of East-bound Lane of Test Site 3, I 64, Shelby County, showing a Portion of Subsection 1, Perma-Line. Photograph was taken during April, 1965 and shows spalling of the edge-line receiving drainage.

ATTACHMENT 15

Figure 9. Photograph Showing Poor Bond of Thermoplastics in Test Site 3, I 64, Shelby County. In many areas, portions of line as long as 10 feet could easily be pulled up by hand.

ATTACHMENT 16

Figure 10. Spalled Thermoplastic on the Recently Paved Shoulders of Test Site 3. It is possible that this material could fuse to the asphalt and create a hazardous condition.

ATTACHMENT 17

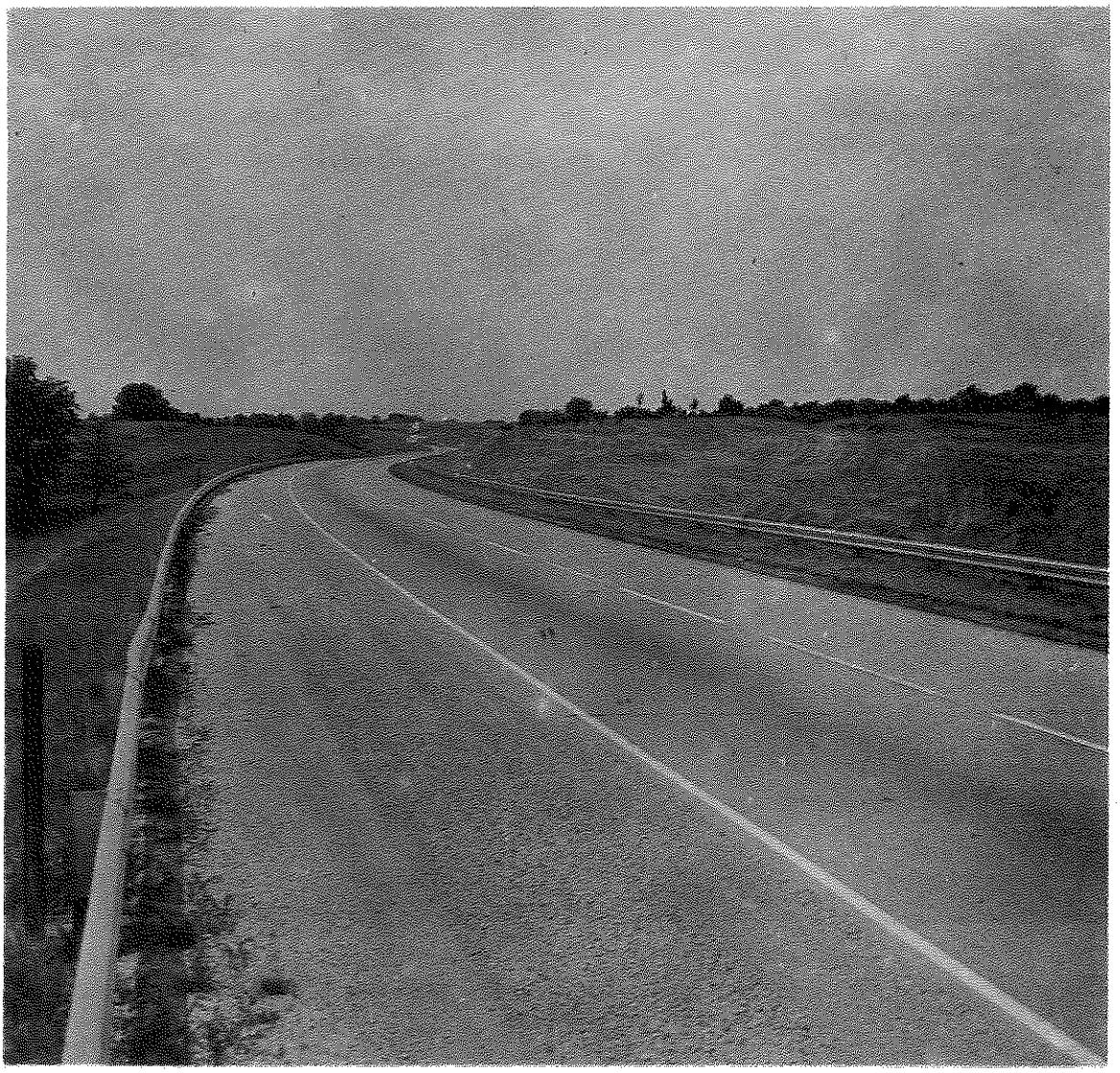


Figure 11. A Portion of the Kentucky Paint (Control) Section in Test Site 3, Eastbound Lanes I 64, Shelby County (Looking West). Since the original installation in 1962, the center-lines have been repainted three times and the edge-lines have not been repainted. Note contrasting quality of inside and outside edge-lines. Photograph was taken during April, 1965.

ATTACHMENT 18

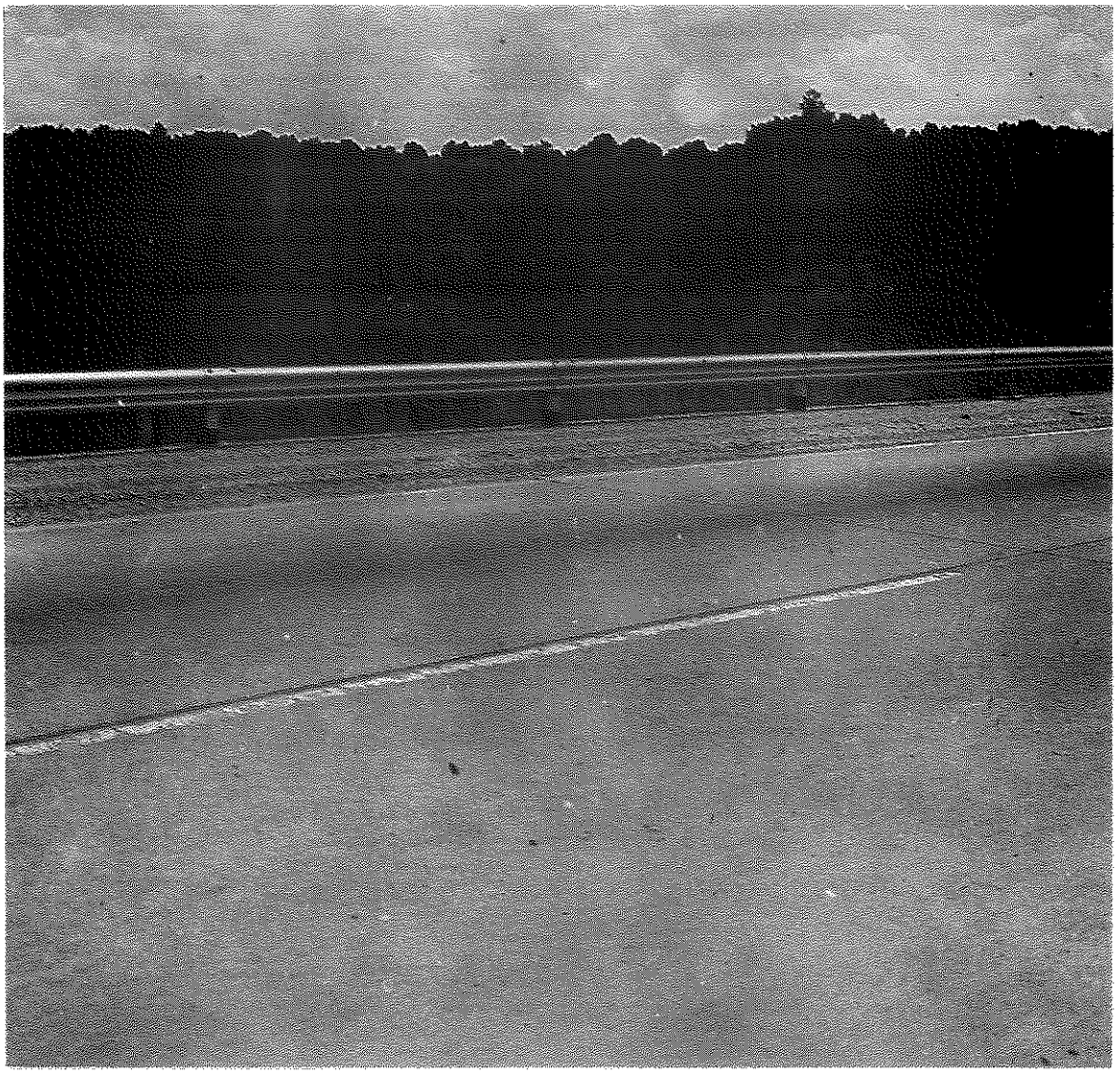


Figure 12. A Portion of the Catatherm Subsection, Test Site 3, I 64, Shelby County during April, 1965. Note extreme spalling of center-line and edge-line.

ATTACHMENT 19

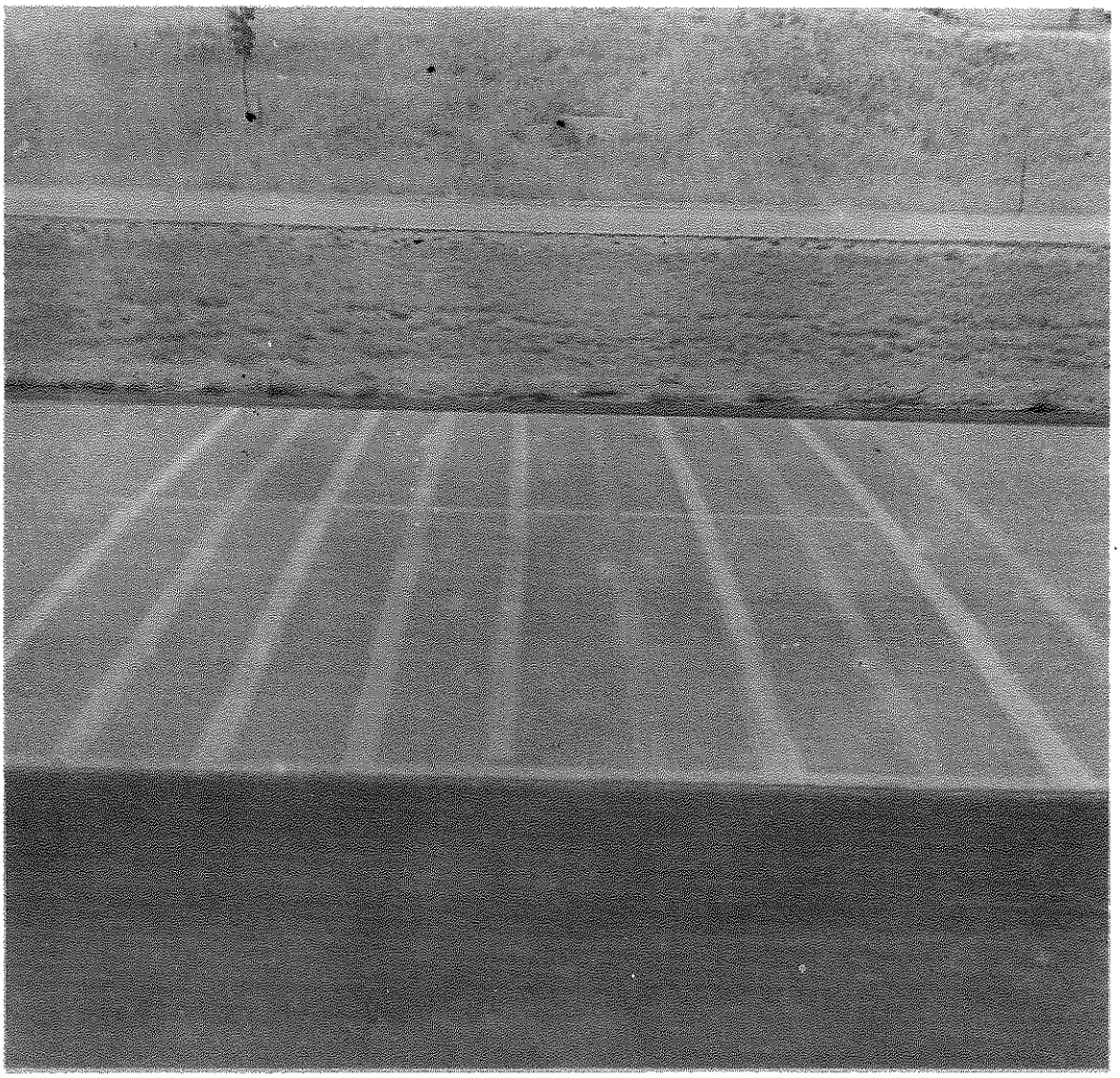


Figure 13. Transverse Lines on Bituminous Concrete Pavement in Test Site 4, I 64, Clark County. Lines were placed in November, 1962, and photograph was taken during April, 1966. Lines 1 and 2 are Catatherm, lines 3 and 4 are Perma-Line, and the succeeding pairs of lines are Kentucky paint--1, 2, and 3 applications, respectively. The Kentucky paint lines have not been repainted.

ATTACHMENT 20

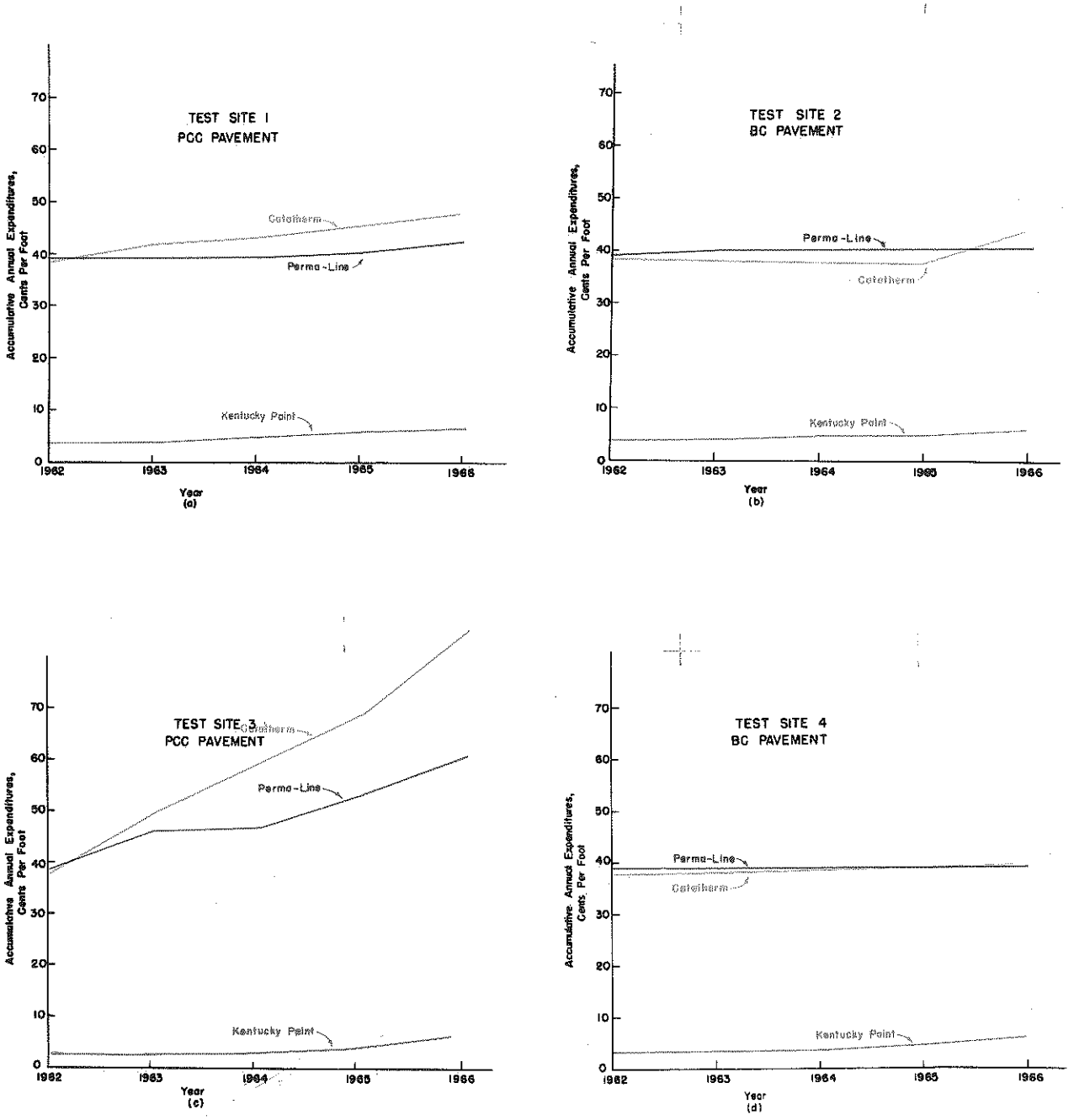


Figure 14. Comparison of Accumulative Annual Expenditures in Cents per Foot for the Edge- and Center-Lines of Catatherm, Perma-Line, and Kentucky Paint for Test Sites 1-4. Thermoplastic line which has been repaired or adjudged to be unsatisfactory but not covered by warranty has been assumed to have been replaced at a unit cost equal to original cost per foot.

ATTACHMENT 21

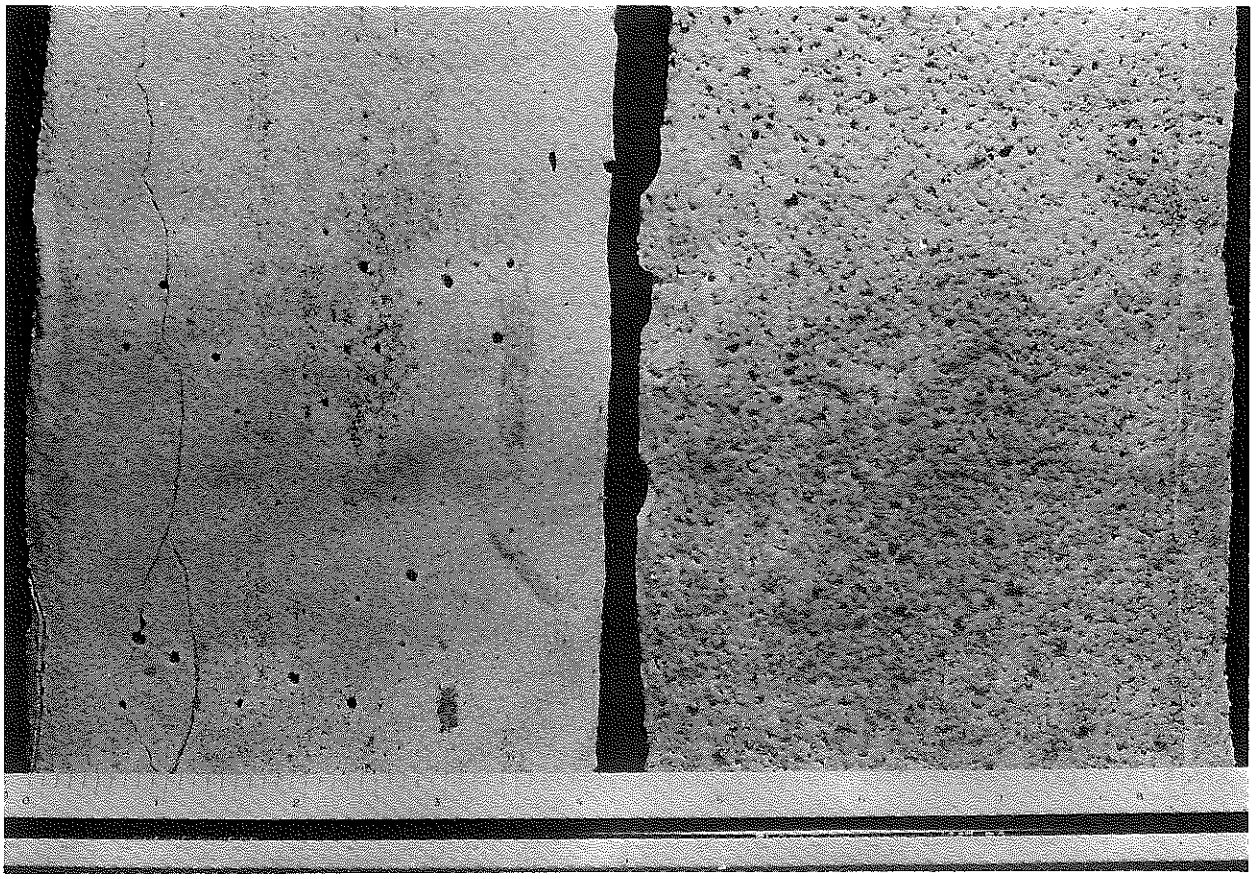


Figure 15. Photograph of a Portion of Spalled Line Showing Top and Bottom Surfaces. Note laitance on bottom surface.

ATTACHMENT 22

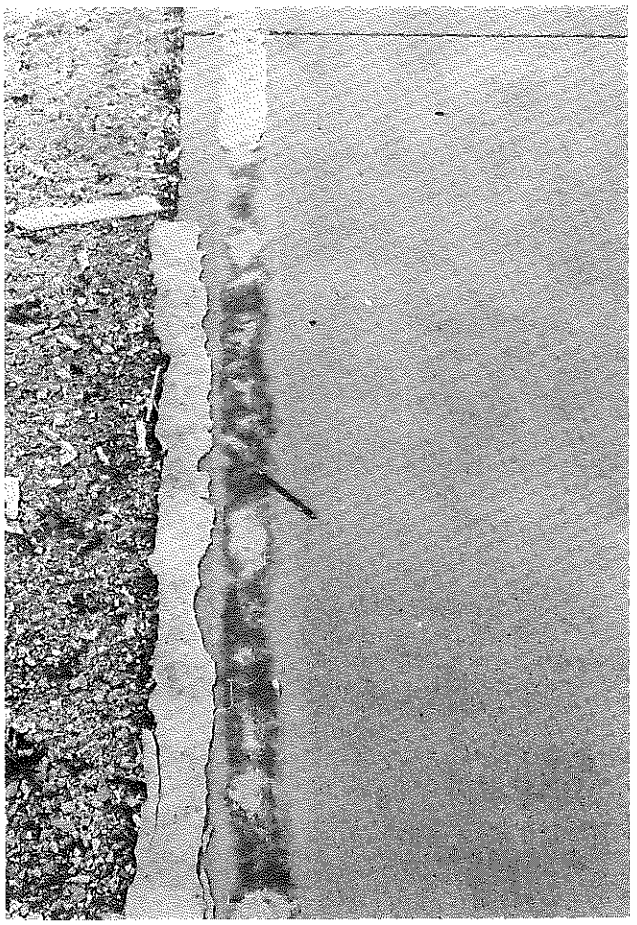


Figure 16.

Photograph Showing Retention of Water on the Underneath Side of a Thermoplastic Stripe.

Figure 17.

Thermoplastic Edge-Lines Impounding Water.