KTC-91-5

EVALUATION OF MODIFIED ASPHALT MIXTURES

by

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in cooperation with
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Commonwealth of Kentucky

and

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GOVERNOR

January 29, 1993

Mr. Paul E. Toussaint
Division Administrator
Federal Highway Administration
330 West Broadway
Frankfort, Kentucky 40601

Dear Mr. Toussaint:

SUBJECT: IMPLEMENTATION STATEMENT
Research Study, "Evaluation of Modified Asphalt Mixtures," (KYHPR-90-133)

The primary result from this research study is a methodology and a data base for selection of modified hot mix asphalt (HMA) systems in Kentucky. Six modified mixtures and a control mixture were evaluated in accordance with a statistically designed experiment. Laboratory studies indicate that some modified systems offer potential for reducing premature pavement distress. Field test sections have not been in service for sufficient time to provide full verification for laboratory results. However, preliminary results indicate that one of the polymer modified mixtures has potential for reducing rutting, while one of the fiber modified mixtures showed potential for reducing cracking. Long-term performance monitoring of the KY 80, Pulaski County project is recommended for the next three years; performance information from this project and others will be added to the modified asphalt data base. Upon conclusion of that long-term monitoring, decisions will be made regarding future uses of modified hot mix asphalt systems in Kentucky.

Sincerely,

J.M. Yowell, P.E.
State Highway Engineer

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16. Abstract

The primary objective of this study was to conduct a comparative analysis on various modified asphalt mixture systems in order to determine their suitability for conditions that are commonly encountered in Kentucky.

Several modified asphalt mixture systems were selected for laboratory and field testing (one-mile long field test section on KY 80, Pulaski County). These systems included the following asphalt mixtures: Control, Vestoplast, Polypropylene Fiber, Gilsonite, PMAC #1, Polyester Fiber, and PMAC #2. Laboratory testing included: Marshall stability and flow, mixture air voids and density, indirect tensile strength, moisture damage susceptibility, freeze-thaw damage susceptibility, resilient modulus, and repeated load permanent deformation. Statistically-based comparative analyses were conducted in order to determine any significant relative differences in the performance potential of different modified systems. All statistical analyses were conducted at 90% level of significance (i.e., alpha error rate = 10%).

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EXECUTIVE SUMMARY

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Several modified asphalt mixture systems were selected for laboratory and field testing through one-mile long field test sections on KY 80, Pulaski County. These systems included the following asphalt mixtures: Control, Vestoplast, Polypropylene Fiber, Gilsonite, PMAC #1, Polyester Fiber, PMAC #2. Laboratory testing included: Marshall stability and flow, mixture air voids and density, indirect tensile strength, moisture damage susceptibility, freeze-thaw damage susceptibility, resilient modulus, and repeated load permanent deformation. Statistically-based comparative analyses were conducted in order to determine any significant relative differences in the performance potential of different modified systems. All statistical analyses were conducted at 90% level of significance (i.e., alpha error rate = 10%).

Significant variations in the air voids and density of laboratory compacted specimens were observed which indicates that adjustments in future mix designs involving modified HMA may be necessary. No immediate recommendations as to the nature of these adjustments can be made at this time; however, a target air voids and density may be used to determine the compactive effort in the laboratory in a manner similar to the field compaction. Obviously, this is not for immediate implementation and should be viewed as a long-term consideration. At this time, the Division of Materials is quite satisfied with the Marshall method and does not deem the compaction modification as being necessary. For future projects, it is recommended that the mix design of modified mixtures be adjusted in order to obtain the desired properties.

Tensile strength data indicate that the Vestoplast, Polypropylene, and Gilsonite mixtures have less potential for cracking. Modified asphalt systems evaluated during this study did not offer any significant improvement in resistance to freeze-thaw damage as compared to the Control mixture. Potential for stripping was significantly lower in the Vestoplast, Gilsonite, and PMAC#1 mixtures. Thermal cracking is expected to be less of a problem in the Control and Polypropylene mixtures due to their compliance at low temperature. Fatigue cracking is expected to be less severe in the Polypropylene mixes due to lower resilient modulus at mid-range temperatures. At high temperature, all modified systems, except the PMAC#2, showed more potential for structural capacity signified by higher resilient moduli. The repeated load test results indicate that the Vestoplast and Polypropylene mixtures have the least potential for rutting, compared to other systems evaluated during this study. This has been partially verified by the field data; that is, preliminary field data indicate that the Vestoplast mixture has a better rutting resistance than other mixtures.

Long-term field performance data are needed for verification of the laboratory and field statistical inferences. It is recommended that this project be evaluated twice a year for the next three years.

INTRODUCTION

The hot mix asphalt (HMA) modifier market has grown significantly in the past few years. This trend has been accelerated primarily due to a wide range of performance deficiencies (rutting, thermal cracking, etc.) that have not been successfully addressed through mix design. Increasing highway traffic loads and tire pressures have placed an even greater performance demand on asphaltic pavements, particularly when they are constructed with inadequate or marginal HMA mixture designs.

The primary objective of this study was to conduct a comparative analysis on various modified asphalt mixture systems in order to determine their suitability for conditions that are commonly encountered in Kentucky.

SCOPE OF THE PROJECT

The initial scope of the project included laboratory and field evaluations of several new and existing projects in Kentucky. These projects were to include one or many of the following modifiers: fibers (polyester, and polypropylene), polymers, geogrid, and others. Considering the limited funds available for this study, this proved to be too ambitious of an undertaking. Hence, during the first year's review of the project the Study Advisory Committee recommended a priority-based listing of field projects. In order to complete the proposed work plan with the limited resources assigned to this research, the KY 80, Pulaski County project was assigned the highest priority.

The Kentucky 80 project consisted a 1-inch HMA overlay of an existing flexible pavement. The existing pavement surface was milled to approximately 1-inch depth prior to placement of the overlay. The HMA overlay construction included several modified asphalt systems and a control section, each one mile long: Control, Vestoplast, Polypropylene Fiber, Gilsonite, PMAC #1, Polyester Fiber, and PMAC #2. The 1-inch HMA overlay does not lend itself to structural analysis procedures such as Falling Weight Deflectometer (FWD) backcalculation. Neither does it allow for core specimen of sufficient thickness for mechanical mixture analysis tests. In view of these restrictive parameters, mixture analysis tests were limited to laboratory compacted specimens. Statistically-based comparative analyses were conducted in order to determine any significant relative differences in the potential performance of different modified systems. All statistical analyses were conducted at 90% level of significance (i.e. alpha error rate = 10%).

The statistical experiment for the laboratory and field research included only the driving lane; the passing lane was excluded from the experiment because of confounding effects due to differences in fine sand type and traffic.

LITERATURE REVIEW

This sections deals with the information cited in the literature on the performance of modified asphalt mixtures. This information has been synthesized in Tables G1 thorough G14, Appendix G. A summary listing of asphalt modifier systems based upon their chemical, physical, and functional classification is given in Tables G1 through G9, Appendix G; the information was obtained from the May 1989 and May 1991 issues of the Roads and Bridges magazine (1, and 2).

The lack of properly recorded historical field performance data with regard to asphalt modifier and/or reinforcer products in Kentucky is a problem. The solution to this problem, however, is a long-term one. For the purpose of this report, summary performance data from projects in Kentucky and elsewhere (3) are presented in a user-friendly, tabular format, Tables 10 through 14. A comprehensive list of references is provided in conjunction with these tables.

LABORATORY DATA

A statistically-based laboratory experiment was designed for the purpose of evaluating the materials' properties that directly or indirectly influence the field performance of HMA. Laboratory specimens were tested in triplicate, and statistical level of significance was set at 90% (i.e., alpha error rate = 10%). This allowed for determination of significant similarities and/or dissimilarities between different modified HMA systems. Particular attention was devoted to randomization of all laboratory and field procedures that could potentially introduce bias into the data. For a more complete description of statistical analysis, see Appendix A.

The following sections present results of the laboratory experiments. All laboratory data are based upon loose HMA samples collected in 5-gallon buckets at the construction site. The storage, handling, and re-heating conditions were the same for all mixtures, these procedures are reported in Appendix B. One can make the argument that re-heating may induce different levels of aging for different modified mixtures. However in the absence of any such data and/or standard aging procedures it is concluded that the procedures employed in this study produced valid qualitative comparisons. In fact, research studies (Reference 43) funded by the Strategic Highway Research Program (SHRP) indicate that some laboratory aging is necessary for valid simulation of long-term performance. Details of those laboratory aging procedures are still being finalized. The laboratory compactive effort was set at 75 blows with a standard Marshall hammer. The compaction procedures were consistent with the project mix design requirements (see Appendix B).

A mix design was prepared by the Division of Materials in accordance with the standard Marshall procedure (75 blows). This was done only for the control mixture which contained granite sand. Modified mixtures, however, had essentially the same mix design, except adjustments were made in the asphalt content in order to accommodate the addition of fibers or polymers. This approach, though expedient, lacks specific adjustments that may be needed for optimization of the mixture properties.

Marshall Stability and Flow

Marshall stability and flow are standard parameters for the evaluation of rutting resistance of asphalt mixtures. This methodology is being increasingly criticized within many circles, including the Asphalt Aggregate Mixture Analysis System (NCHRP-AAMAS 1990, Reference 44) and Strategic Highway Research Program (SHRP 1991, Reference 45) for its weak correlation to field performance. Table 1 presents the Division of Materials' Marshall data based upon specimens compacted at the hot mix laboratory.

Stability

The Control, PMAC #1, and Gilsonite mixtures form a group having no significant differences within, but are significantly different from all other mixtures.

The PMAC #2 mixture is significantly different from all other mixtures.

The Polypropylene mixture is significantly different from all other mixtures except the Polyester mixture.

The Vestoplast mixture is significantly different from all other mixtures except the Polyester mixture.

Flow

The Control and Vestoplast mixtures form a group having no significant differences within, but are significantly different from all other mixtures except the Gilsonite mixture.

The PMAC #2, Polyester, and Polypropylene mixtures form a group having no significant differences within, but are significantly different from all other mixtures except the PMAC #1 mixture.

The PMAC #1 and Gilsonite mixtures are not significantly different.

Mixture Air Voids and Density

Air voids and density of HMA are mainly controlled by the compactive effort and type of compaction. For the purpose of laboratory investigations during this study, it was decided to compact laboratory specimens in accordance with the same procedures that the Division of Materials employed for the KY 80 project mix design (i.e. 75 blows - standard Marshall).

A least significance statistical analysis procedure was conducted to determine whether the same compaction procedure will result in similar air voids and density among the one control and six modified mixtures. It was discovered that the air voids and density for different systems do vary and these variations can be significant (see Table 2, and Figure 1). The following is a summary of the statistical information presented in Table 2.

Mixture Air Voids

The Polypropylene and Gilsonite mixtures form a group having no significant differences within, but they are significantly different from all other mixtures.

The PMAC#1 and Polyester mixtures form another group having no significant differences within, but they are significantly different from others.

The remainder of the mixtures (Control, Vestoplast, and PMAC#2) proved to be significantly different from one another.

Mixture Density

The Polypropylene and Gilsonite mixtures form a group having no significant differences within, but they are significantly different from all other mixtures.

The PMAC#1 and Polyester mixtures form another group having no significant differences within, but they are significantly different from others.

The remainder of the mixtures (Control, Vestoplast, and PMAC#2) proved to be significantly different from one another.

The cited information suggests that in order to arrive at statistically similar air voids and densities for different modified mixtures the level of HMA compaction may need to be adjusted accordingly (NCHRP-AAMAS 1990, Reference 44). However, the nature of these adjustments is still the subject of research. For the purposes of this research, it was decided to adhere to current Kentucky DOH mix design standards (i.e. 75 blows Marshall hammer, Kentucky Method 64-411-91, etc.) simply because the field trial sections on the KY 80 project were constructed in accordance with current Kentucky mix design procedures. The rational for future modifications of existing methodology should focus on adjustments in the level of compactive effort in order to produce uniform air voids, density, and aggregate particle orientation.

Indirect Tensile Strength

Diametral indirect tensile strength (ASTM D4123) tests were conducted in order to determine the cracking susceptibility of different mixtures. These tests were conducted at room temperature (70°F) and loading rate of 2 inches per minute, Figure 2. The following is a summary of the statistical information presented in Table 3.

> Tensile strength characteristics of mixtures provided a clear delineation for two significantly different groups: the Vestoplast, Polypropylene, and Gilsonite mixtures exhibited significantly higher tensile strengths than all other mixtures included in this study.

Moisture Damage Susceptibility

Stripping is the cause of many premature failures in asphaltic pavements. An accelerated moisture damage test, commonly known as the Root-Tunnicliff Moisture Damage Susceptibility Test (Reference 46) was employed in this study in accordance with the procedures outlined in Ky Method 64-428-85. The test calls for measuring tensile strength before and after a moisture conditioning procedure which is patterned after the Lottman procedure (Reference 47). The tensile strength ratio, TSR (Reference 46), which is presented in Figure 3, represents a remaining strength factor. This ratio was determined by computing the ratio of each mixture's tensile strength after the moisture treatment to the tensile strength before the treatment.

The following is a summary of the statistical information presented in Table 4.

> Moisture damage susceptibility of the Vestoplast, Gilsonite, and PMAC#1 was significantly lower than the Control mixture.
>
> All other modified mixtures were not significantly different from the Control mixture.

Freeze-Thaw Damage Susceptibility

Long-term durability of the modified asphalt systems was characterized using the freeze-thaw test. In lieu of a standard procedure for this test, a procedure similar to what is commonly used for portland cement concrete was employed: 3-hours freeze cycle at 0°F, followed by 3-hours thaw cycle at 40°F. The indirect tensile strength was used as an index parameter to establish the freeze-thaw durability of various modified asphalt mixes. Results of this experiment are presented in Figure 4 and Table 5. The following statistical inferences are made based upon the data summarized in Table 5.

Individual mixtures that showed significant differences in their tensile strength prior to freeze-thaw maintained the same differences after the freeze-thaw. That is, the Vestoplast, Polypropylene, and Gilsonite, started with higher tensile strengths and maintained that superiority over other mixtures after 100 cycles of freeze-thaw. This could be due to the following:

None of the seven mixtures in this study showed any significant change in their tensile strength as a result of the 100 cycles of freeze-thaw.

These statistical inferences indicate that more cycles of freeze-thaw may be necessary for clearer differentiation between durability characteristics of these mixtures.

Resilient Modulus

In pavement technology, the resilient modulus has long been used in lieu of the modulus of elasticity (Reference 48). Generally, higher moduli indicate greater structural capacity. A high modulus asphaltic layer adds to the structural capacity of the pavement by protecting the base, subbase, and subgrade layers from being overstressed, and therefore it will reduce the probability of premature structural failure. However, a high modulus also coincides with higher brittleness, and such material will crack prematurely, both in fatigue and/or low temperature cracking modes of distress (Reference 49). The relationship between higher cracking life (both low temperature cracking and fatigue cracking) and lower modulus is reported by several researchers (References 50 and 51). Therefore, in addition to serving as a characterization tool for structural capacity of pavement, the resilient modulus offers insight into cracking performance potential of asphalt mixtures.

Figure 5 depicts the summary of resilient modulus test results. Resilient modulus tests were conducted at three temperatures: 32°F, 77°F, and 104°F. The tests were conducted in the compression mode on Marshall specimens. The loading was applied at their top and bottom 4-inch diameter faces at a frequency of one Hertz. The magnitude of load was maintained below 20% of the compressive strength of the mixture. Individual test data are presented in Appendix C. The following conclusions are based upon the relationships between resilient modulus and different performance characteristics as previously described. Statistical information presented in Table 6 may be summarized as follows.

At low temperature (32°F), the Control and Polypropylene mixtures had significantly lower resilient moduli than the PMAC #2 and Polyester mixtures. The other mixtures (PMAC #1, Gilsonite, and Vestoplast) were not significantly different from any of the mixtures. The group formed by the Control and Polypropylene mixtures is expected to be more compliant and therefore more resistant to fatigue cracking due to their lower resilient moduli.

At mid-range temperature (77°F), the Polypropylene mixture showed a significantly lower resilient modulus compared to the Control mix. This would qualify the Polypropylene for higher fatigue resistance. All other modified systems proved to be not significantly different from the Control mix at mid-range temperature with respect to their resilient modulus.

At high temperature (104°F), all modified systems, except PMAC#2, showed resilient moduli significantly higher than the Control mix. Hence, these mixtures are expected to offer a level structural capacity for the pavement which is significantly higher than the Control mix during hot seasons.

All mixtures demonstrated a significant temperature susceptibility marked by a statistically significant drop in their resilient moduli from 77°F to 104°F. This is contrary to asphalt modifier manufacturers' claims that their products maintain flexibility at low temperatures at no cost to the higher temperature stiffness.

Repeated Load Permanent Deformation

A simple repeated load test at high temperature (104°F) was conducted in the same manner that the resilient modulus test was performed. That is, one Hertz loading frequency, under 20% of the compressive strength, and Marshall specimens. The cumulative permanent strain was recorded up to 10,000 cycles (2.8 hours). The results are plotted on Figure 6, individual test data are presented in Appendix D. Statistical analyses are presented in Table 7. The following statistical inferences are presented based upon the data in Table 7.

Rutting is the accumulation of permanent strain. To characterize the rutting behavior of mixtures in the laboratory, it is common to measure the accumulated permanent strain after some number of loading cycles. A log-log plot of strain versus the number of cycles gives a straight line. A steep slope indicates a material that accumulates a large amount of permanent strain after only a few load cycles. A relatively flat line indicates a material that can take a large number of load cycles before it exhibits any significant accumulation of permanent strain. The slope of the line can be used as a parameter to characterize the rutting potential of different mixtures. A similar approach has been reported by FHWA (Reference 52).

The slope of the accumulated permanent strain versus number of cycles (b-parameter, Table 7 and Figure 6) may be treated as a measure of susceptibility to long-term rutting. The Vestoplast and Polypropylene had significantly lesser slopes as compared to the other mixtures. This clearly indicated that these mixtures are less susceptible to rutting. All other mixtures showed no significant differences.

The a-parameter in the permanent deformation model, the "intercept" (Table 7 and Figure 8), may be viewed as a measure of susceptibility to early or premature rutting. Once the two mixtures having significantly different slopes (Vestoplast and Polypropylene) were separated from others in the analysis, all other mixtures showed the same level of susceptibility to premature rutting, i.e. similar a-parameters.

FIELD PERFORMANCE DATA

Field trial sections were constructed during late August 1990. A 1-inch surface layer was studied. The primary purpose of a surface course is to protect the structural layers from environmental effects. A 1-inch surface layer was neither intended nor does provide any structural support. This field project, however, was selected for evaluation of modifiers in surface rehabilitation. The construction consisted of a series of control and modified asphalt sections as depicted in Figure 7. The statistical experiment for the field performance research included only the driving lane; the passing lane was excluded from the experiment because of confounding effects due to differences in fine sand type and traffic. The performance of the passing lane, however, will be monitored as with the rest of the project, but no statistical inferences will be made. In selection of the project location, care was taken to reduce the influences of intersection, driveway, and median opening turning movements to a negligible level.

All mix design information that was provided to KTC investigators by the Division of Materials' personnel are included in Appendix B.

The trial sections have been in service for less than a year. A comprehensive pavement performance analysis would require a long-term performance record. It is therefore recommended that monitoring of these experimental sections be continued for at least three additional years. At this time, visual observations indicate that the experimental pavement sections have not yet demonstrated any high severity modes of pavement distress.

A field survey of rutting was conducted for each of the seven sections. Two different procedures were employed to select the rut-depth measurement locations. First, after eight months of traffic, three mile-posts locations were selected at random within each section for rut measurements. These measurements were then averaged and plotted for each section, Figures 8 through 14. Individual rutting data points for each section and wheel path are summarized in Appendix E. A statistical analysis of the rutting data is presented in Table 8. The following is a summary of the information presented in Table 8. It is important to remember that these data are based upon a service time of eight months and hence the conclusions may be premature.

The Vestoplast section had no measurable rut depth, both on left and right wheel paths. However, this may have been due to uneven field loading conditions, which were suspected for this particular section.

Differences in the right versus left wheel paths were only statistically significant for the Control mix.

Second, after ten months of traffic, a <u>subjective and non-random</u> set of rut-depth measurement locations was selected to represent the project topography. However, it should be stated that the entire project did not include any severe profile grades. Table 9 presents a statistical analysis of rutting data collected after ten months of service. No significant differences were noted among the mixture types; however, any conclusions made at this time may be incomplete due to the subjectiveness (bias) of selection of the location of rut-depth measurement spots.

CONCLUSIONS AND RECOMMENDATIONS

Based upon information presented in this report, the following conclusions are made. These conclusions are based upon statistical analysis of laboratory and field data. However, conclusions based upon the field data may have been premature due to the short service time, less than a year, of the KY 80, Pulaski County project.

1. Significant variations in the air voids and density of laboratory compacted specimens were observed which indicates that adjustments in future mix designs involving modified HMA may be necessary. No immediate recommendations as to the nature of these adjustments may be made at this time; however, a target air voids and density may be used to determine the compactive effort in the laboratory in a manner similar to the field compaction.

2. Tensile strength data indicate that the Vestoplast, polypropylene, and Gilsonite mixtures have a lesser potential for cracking.

3. Modified asphalt systems evaluated during this study did not offer any significant improvement in resistance to freeze-thaw damage as compared to the Control mixture.

4. Potential for stripping was significantly lower in the Vestoplast, Gilsonite, and PMAC#1.

5. Thermal cracking is expected to be a less of a problem in the Control and Polypropylene mixtures due to their compliance at low temperature.

6. Fatigue cracking is expected to be less severe in the Polypropylene mixes due to lower resilient modulus at mid-range temperatures.

7. At high temperature, all modified systems, except the PMAC#2, showed more potential for structural capacity signified by higher resilient modulus.

8. The repeated load test results indicate that the Vestoplast and Polypropylene mixtures have the least potential for rutting compared to other systems evaluated in this study. This has been partially verified by the field data; that is, preliminary field data indicate that the Vestoplast mixture has a better rutting resistance than other mixtures.

9. Long-term field performance data are needed for verification of the conclusions. It is recommended that this project be evaluated twice a year for the next three years.

Table 1. Stability and Flow Data

Modifier	Stability (lbs.)	Flow (in.)
Control	2599 2535 2956	0.115 0.11 0.135 0.12
	Mean: 2697^{a}	Mean: 0.12^{e}
PMAC #2	2427 2403 2377	0.145 0.17 0.16
	Mean: 2402^{b}	Mean: 0.158^{f}
Polyester	1834 1946 1974	0.16 0.16 0.145
	Mean: 1918^{cd}	Mean: 0.155^{f}
PMAC #1	2708 2716 2730	0.135 0.15 0.15
	Mean: 2718^{a}	Mean: 0.145^{fg}
Gilsonite	2978 2634 2440	0.12 0.14 0.135
	Mean: 2684^{a}	Mean: 0.132^{eg}
Polypropylene	1844 1595 1663	0.16 0.155 0.135
	Mean: 1701^{c}	Mean: 0.15^{f}
Vestoplast	2215 1865 2146	0.115 0.12 0.13
	Mean: 2075^{d}	Mean: 0.122^{e}

Legend for row comparisons within each column (a,b,c,d,e,f,g)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

Specimen data provided by the Kentucky Transportation Cabinet, Division of Materials.

Table 2. Air Voids and Density Data

Modifier	Air Voids (%)	Density (pcf)	Air Voids* (%)	Density* (pcf)
Control	8.3^{a}	143.9^{f}	6.6^{k}	145.3^{q}
PMAC #2	8.7^{e}	139.5^{g}	5.7^{l}	147.1^{r}
Polyester	6.7^{d}	142.9^{h}	2.1^{m}	150.5^{s}
PMAC #1	6.5^{d}	142.3^{h}	3.2^{n}	149.9^{t}
Gilsonite	4.7^{c}	145.9^{i}	4.6^{o}	147.7^{r}
Polypropylene	4.8^{c}	144.9^{i}	4.8^{o}	146.3^{u}
Vestoplast	3.0^{b}	147.5^{j}	3.8^{p}	149.2^{v}

*- Plant-mix field compacted Marshall specimen data provided by Kentucky Transportation Cabinet.

Legend for row comparisons within each column (a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

(Actual data points provided in Appendix F.)

Table 3. Diametral Indirect Tensile Strength (ASTM D 4123)

Modifier	Indirect Tensile Strength (psi)
Control	236.0 220.1 186.9 235.4 257.3
	Mean: 227.1^{a}
PMAC #2	196.1 231.0 235.9 159.8 199.1
	Mean: 204.4^{a}
Polyester	211.7 213.0 181.1 209.4 229.2
	Mean: 208.9^{a}
PMAC #1	231.2 217.8 195.6 173.0 181.1
	Mean: 199.7^{a}
Gilsonite	287.0 263.0 260.0 258.5 266.9
	Mean: 267.1^{b}
Polypropylene	298.5 281.2 281.2 260.1 250.3
	Mean: 274.3^{b}
Vestoplast	292.2 258.1 253.9 263.1
	Mean: 266.8^{b}

Legend for row comparisons within each column (a,b)	
Significantly Different at 90%	Superscripts are different
Not Significantly at 90%	Superscripts are the same

Table 4. Tensile Strength Ratio, Moisture Damage Susceptibility

Modifier	Indirect Tensile Strength Ratio (%)
Control	61.4 71.0 85.7 84.8 80.6
	Mean: 76.7^{a}
PMAC #2	113.8 94.5 92.4 70.7
	Mean: 85.1^{ab}
Polyester	99.5 80.1 82.3 77.2 83.7
	Mean: 86.6^{ab}
PMAC #1	89.3 92.0 106.3 89.6
	Mean: 89.9^{b}
Gilsonite	90.1 98.3 79.9 92.2 89.1
	Mean: 94.3^{b}
Polypropylene	89.7 93.1 88.9 90.5 70.7
	Mean: 84.6^{ab}
Vestoplast	88.9 80.9 89.7 79.2 86.9
	Mean: 92.8^{b}

Legend for row comparisons within each column (a,b)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

Table 5. Freeze Thaw Damage Susceptibility Data

Modifier	Indirect Tensile Strength	Indirect Tensile Strength
Control	236.0 220.1 186.9 235.4 257.3	201.4 168.0 250.5 235.0 205.4 201.1
	Mean: $227.1^{a\alpha}$	Mean: $210.4^{c\alpha}$
PMAC #2	196.1 231.0 235.9 159.8 199.1	210.2 224.8 234.2 240.8 230.4
	Mean: $204.4^{a\beta}$	Mean: $228.2^{c\beta}$
Polyester	211.7 213.0 181.1 209.4 229.2	229.2 221.4 233.3 175.9 204.3 201.4
	Mean: $208.9^{a\gamma}$	Mean: $210.9^{c\gamma}$
PMAC #1	231.2 217.8 195.6 173.0 181.1	240.6 201.2 229.3 222.1 229.8 229.6
	Mean: $199.7^{a\eta}$	Mean: $225.4^{c\eta}$
Gilsonite	287.0 263.0 260.0 258.5 266.9	240.2 297.1 262.5 297.9 295.8 285.2
	Mean: $267.1^{b\delta}$	Mean: $279.8^{d\delta}$
Polypropylene	298.5 281.2 281.2 260.1 250.3	288.3 275.6 296.9 278.0 279.6 275.6
	Mean: $274.3^{b\lambda}$	Mean: $282.3^{d\lambda}$
Vestoplast	292.2 258.1 253.9 263.1	299.8 284.4 244.0 323.7 286.3 267.8
	Mean: $266.8^{b\phi}$	Mean: $284.3^{d\phi}$

Legend for row comparisons within each column (a,b,c,d,e)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90 %	Superscripts are the same

Legend for column comparisons within each row ($\alpha,\beta,\gamma,\delta,\eta,\lambda,\phi$)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90 %	Superscripts are the same

Table 6. Resilient Modulus Data, Compressive Mode

Modifier	Resilient Modulus @ 32°F (psi)	Resilient Modulus @ 70°F (psi)	Resilient Modulus @ 104°F (psi)
Control	80927.37 77975.44 85789.81	90889.19 85290.07 95895.11	42703.34 45118.29 54229.63
	Mean: $81564.21^{a\alpha}$	Mean: $90691.45^{c\alpha}$	Mean: $47350.42^{e\beta}$
PMAC #2	91171.40 91788.73 95876.37	90659.89 86622.73 86622.73	36581.44 54304.59 40187.51
	Mean: $92945.50^{b\gamma}$	Mean: $87968.45^{cd\gamma}$	Mean: $43691.18^{e\delta}$
Polyester	91224.31 99605.72 86406.17	86122.98 75304.66 86706.02	59323.75 64692.18 69932.71
	Mean: $92412.07^{b\zeta}$	Mean: $82711.22^{cd\zeta}$	Mean: $64649.55^{f\eta}$
PMAC #1	86572.75 92264.96 78305.28	82758.02 86822.62 79279.78	62387.71 63234.05 64979.54
	Mean: $85714.33^{ab\theta}$	Mean: $82953.48^{cd\theta}$	Mean: $63533.76^{f\lambda}$
Gilsonite	85623.23 85140.14 81169.35	85029.09 80127.77 80396.06	65195.38 64030.02 55157.73
	Mean: $83977.58^{ab\xi}$	Mean: $81850.97^{cd\xi}$	Mean: $61461.04^{f\pi}$
Polypropylene	84840.30 72563.19 73105.77	88525.68 74467.22 75711.59	66509.36 63780.14 62755.66
	Mean: $76836.42^{a\rho}$	Mean: $79568.17^{d\rho}$	Mean: $64348.39^{f\sigma}$
Vestoplast	80485.49 85106.83 87089.16	90829.22 76581.15 80169.86	62343.37 63502.79 63967.55
	Mean: $84227.16^{ab\phi}$	Mean: $82526.74^{cd\phi}$	Mean: $63271.24^{f\psi}$

Legend for row comparisons within each column (a,b,c,d,e,f)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

Legend for column comparisons within each row (α,β,γ,δ,ζ,η,θ,λ,ξ,π,ρ,σ,φ,ψ)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

Table 7. Repeated Load Creep Data (104°F)

Modifier	Slope (b)	"Intercept" (a)
Control	0.129[a]	0.0062[c]
PMAC #2	0.102[a]	0.0066[c]
Polyester	0.067[a]	0.0095[c]
PMAC #1	0.066[a]	0.0095[c]
Gilsonite	0.098[a]	0.0046[c]
Polypropylene	0.044[b]	0.0076
Vestoplast	0.011[b]	0.0698

Permanent Strain = $a(\text{Cycle Number})^b$

Legend for row comparisons within each column (a,b,c)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

(Data are based upon the average of three 75 blow - Marshall specimens.)

Table 8. Rut Depth Data

Modifier	Rut Depth (in.)	
	Left Wheel	Right Wheel
Control	0.156 0.188 0.094	0 0 0.031
	Mean: $0.146^{a\alpha}$	Mean: $0.010^{cd\beta}$
PMAC #2	0.062 0.125 0.125	0.062 0.031 0.031
	Mean: $0.104^{a\gamma}$	Mean: $0.042^{cd\gamma}$
Polyester	0.062 0.188 0.156	0.062 0 0.031
	Mean: $0.135^{a\delta}$	Mean: $0.031^{cd\delta}$
PMAC #1	0.094 0.125 0.125	0.062 0.125 0
	Mean: $0.115^{a\eta}$	Mean: $0.062^{c\eta}$
Gilsonite	0.094 0.062 0.062	0.031 0.062 0.031
	Mean: $0.073^{ab\lambda}$	Mean: $0.042^{cd\lambda}$
Polypropylene	0.094 0.125 0	0.094 0 0
	Mean: $0.073^{ab\phi}$	Mean: $0.031^{cd\phi}$
Vestoplast	0 0 0	0 0 0
	Mean: $0^{b\psi}$	Mean: $0^{d\psi}$

Legend for row comparisons within each column (a,b,c,d)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

Legend for column comparisons within each row ($\alpha,\beta,\gamma,\delta,\eta,\lambda,\phi,\psi$)	
Significantly Different at 90%	Superscripts are different
Not Significantly Different at 90%	Superscripts are the same

(Data are based upon measurements taken on KY 80 in Pulaski County, 5-14-91.)

Table 9. Rut Depth Data

Modifier	Rut Depth (in.)		Profile Grade
	Left Wheel	Right Wheel	Slope Up = + Slope Down = -
Control	0.125	0.047	Low
	0.125	0.062	+Medium
	0.148	0.047	+Steep
PMAC #2	0.078	0.062	Low
	0.125	0.062	-Medium
	0.078	0.031	-Steep
Polyester	0.078	0.062	Low
	0.078	0.016	+Medium
	0.062	0.078	+Steep
PMAC #1	0.094	0.062	Low
	0.062	0.047	-Medium
	0.094	0.031	+Steep
Gilsonite	0.062	0.062	Low
	0.078	0.062	+Medium
	0.062	0.062	+Steep
Polypropylene	0.094	0.078	Low
	0.125	0.094	+Medium
	0.062	0.094	-Steep
Vestoplast	0.062	0.031	Low
	0.062	0.094	-Medium
	0.094	0.062	-Steep
Control with Natural Sand	0.062	0.031	-Low
	0.062	0.062	+Low
	0.031	0.047	-Medium
	0.031	0.031	+Medium
	0.094	0.062	-Steep
	0.062	0.109	+Steep

1- No significant differences were found upon analysis of the data.
2- Low, medium, steep are subjective designations to roadway profile grade, July 16, 1991

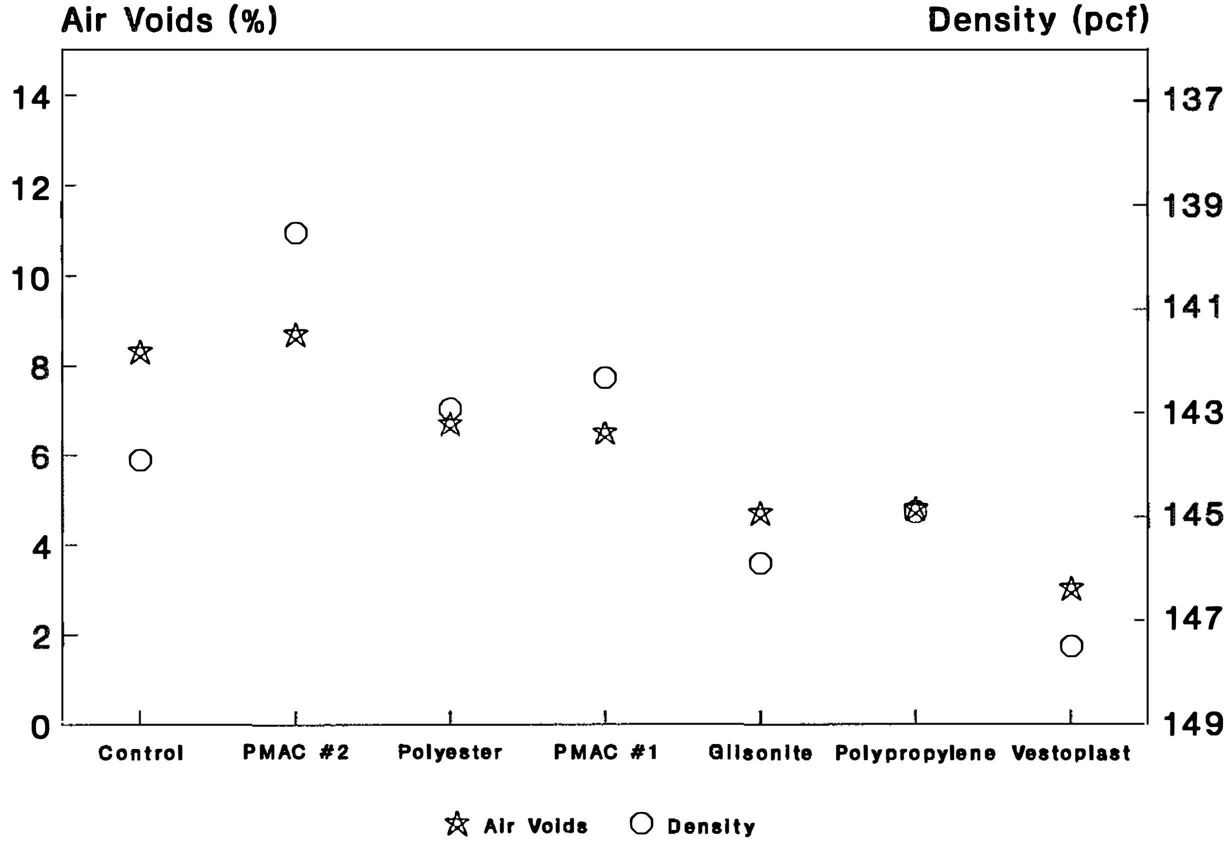


Figure 1. Air Voids and Density Data

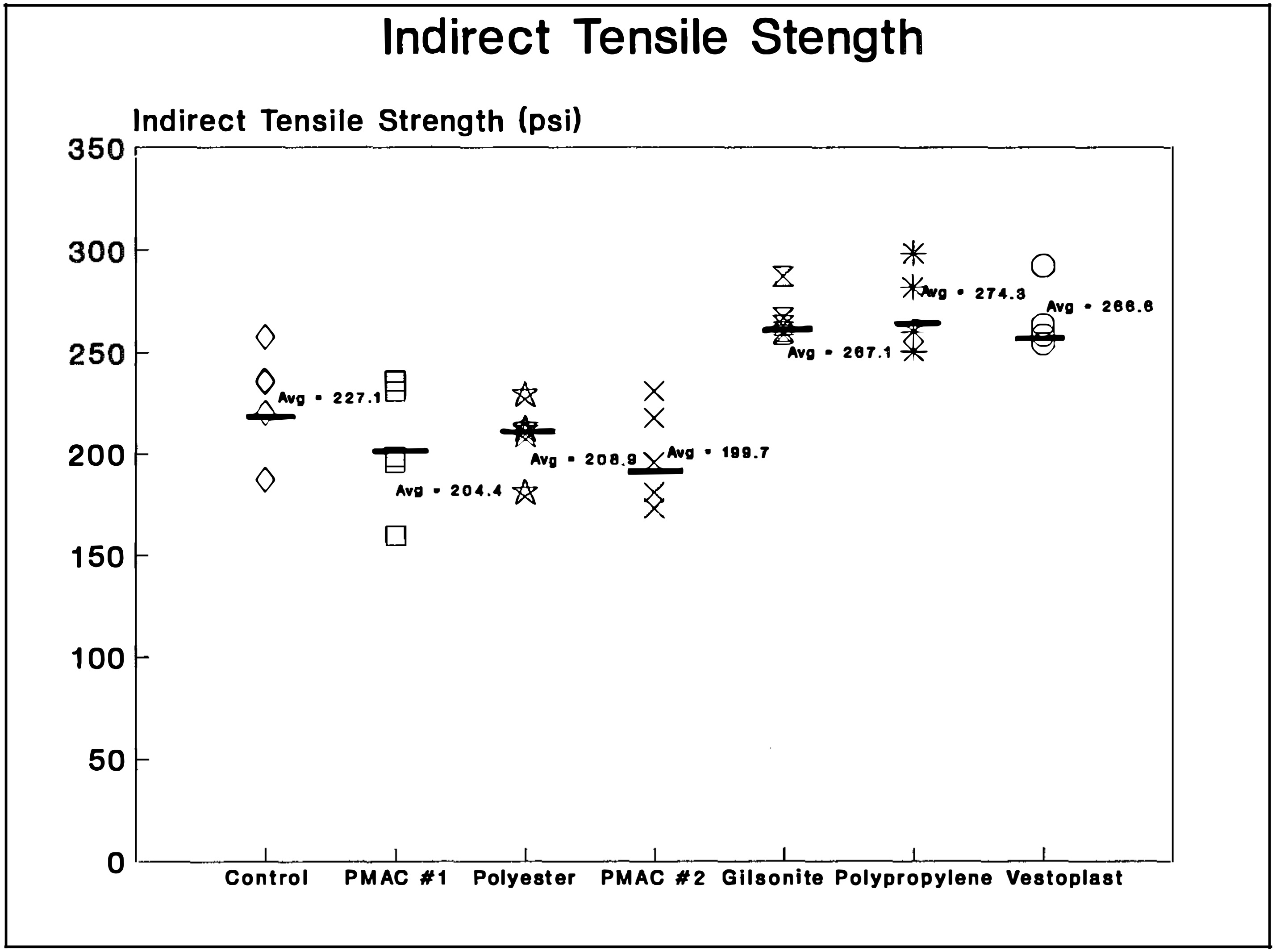


Figure 2. Indirect Tensile Strength Data

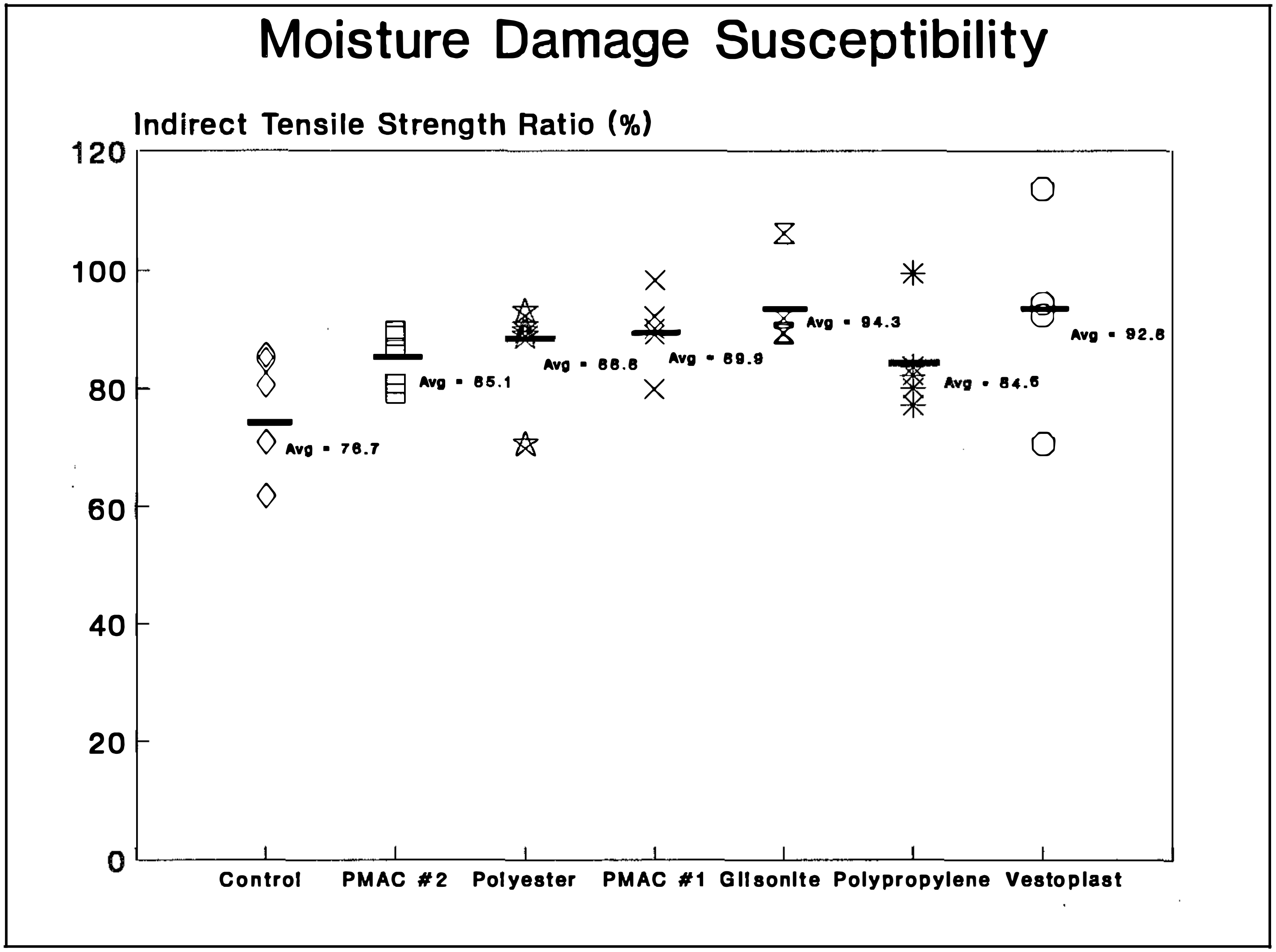


Figure 3. Moisture Damage Susceptibility Data

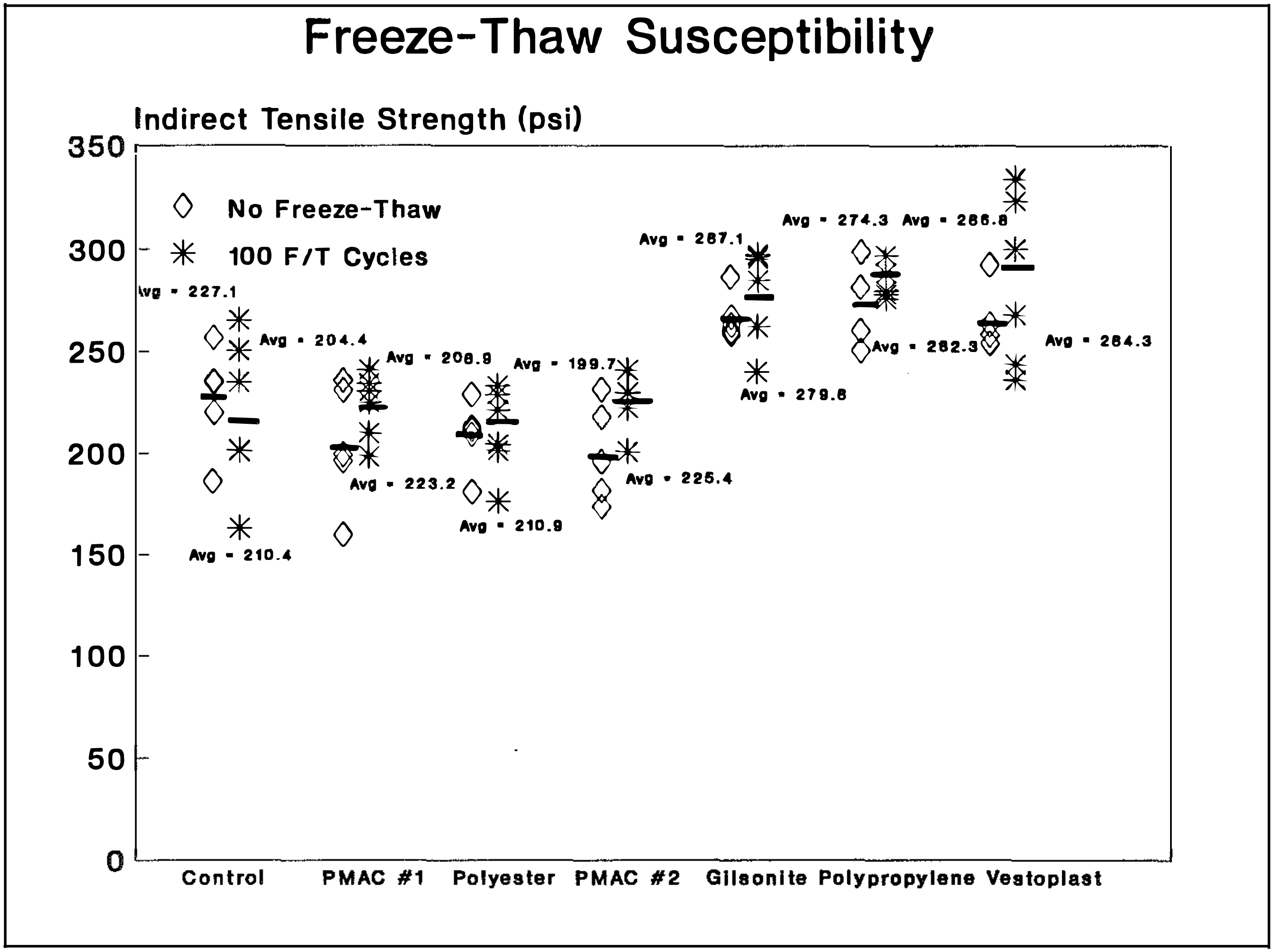


Figure 4. Freeze-Thaw Damage Susceptibility Data

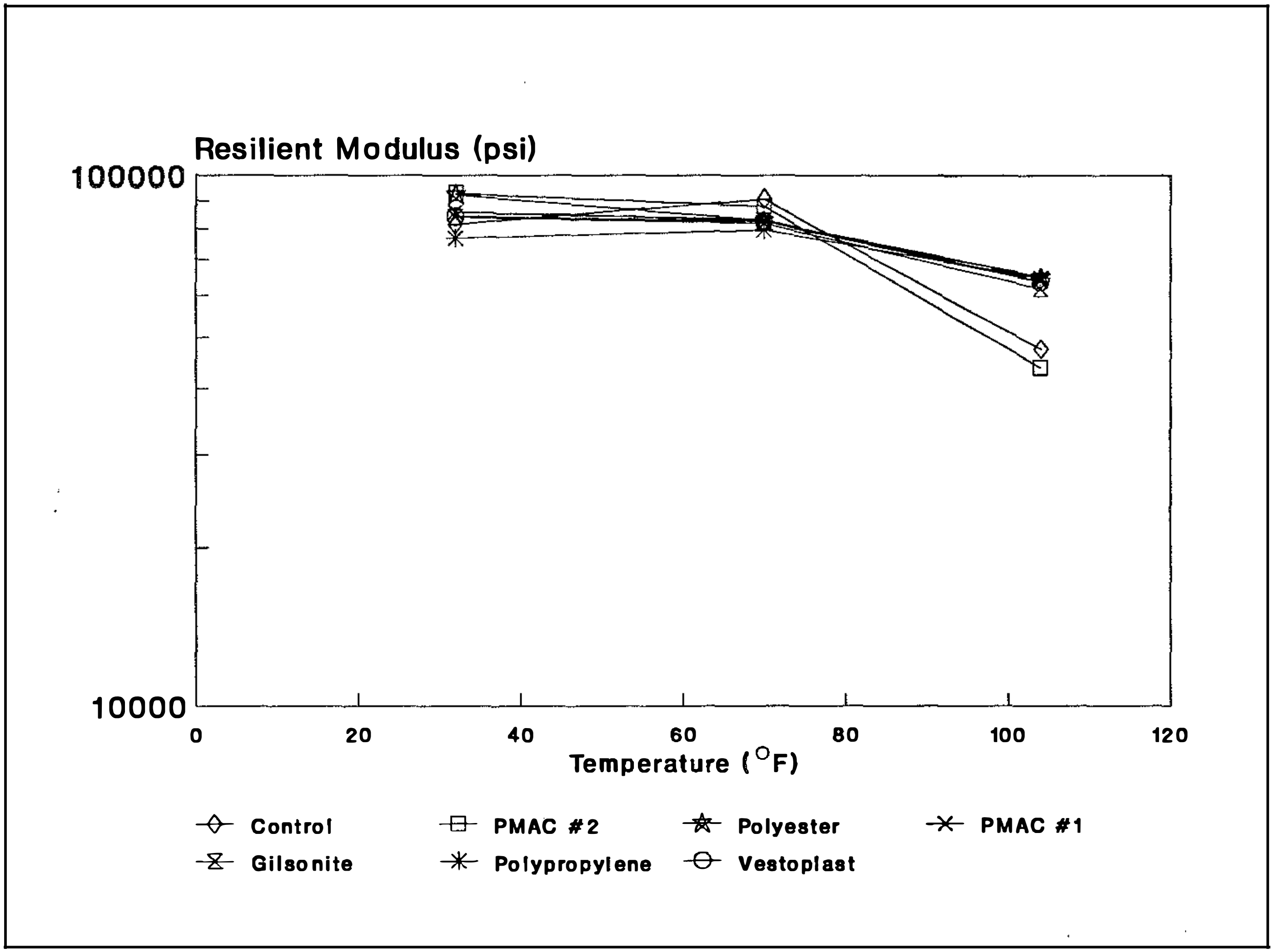


Figure 5. Average Resilient Modulus Data

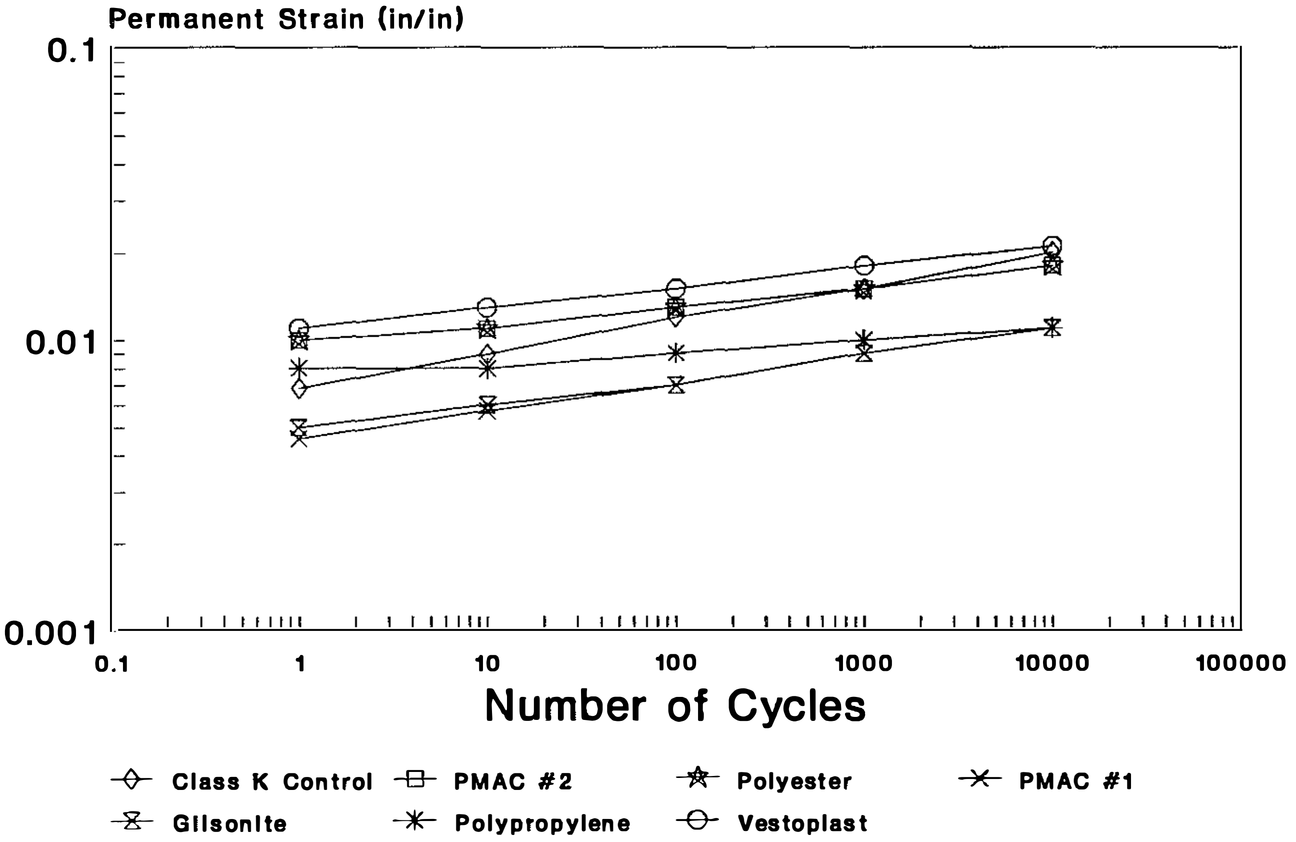


Figure 6 . Average Repeated Load Permanent Deformation Data

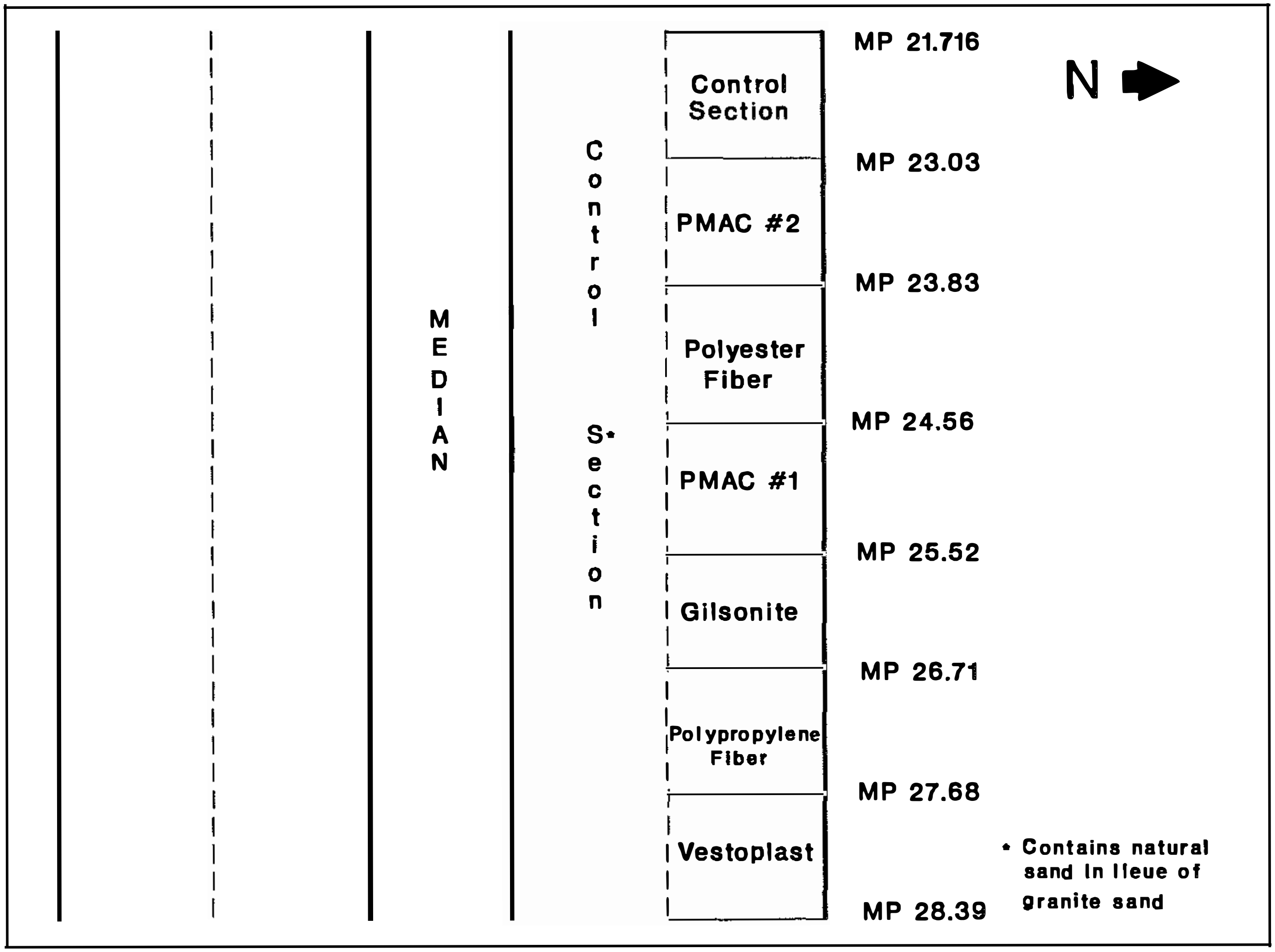


Figure 7. Schematic of the KY 80, Pulaski County Project

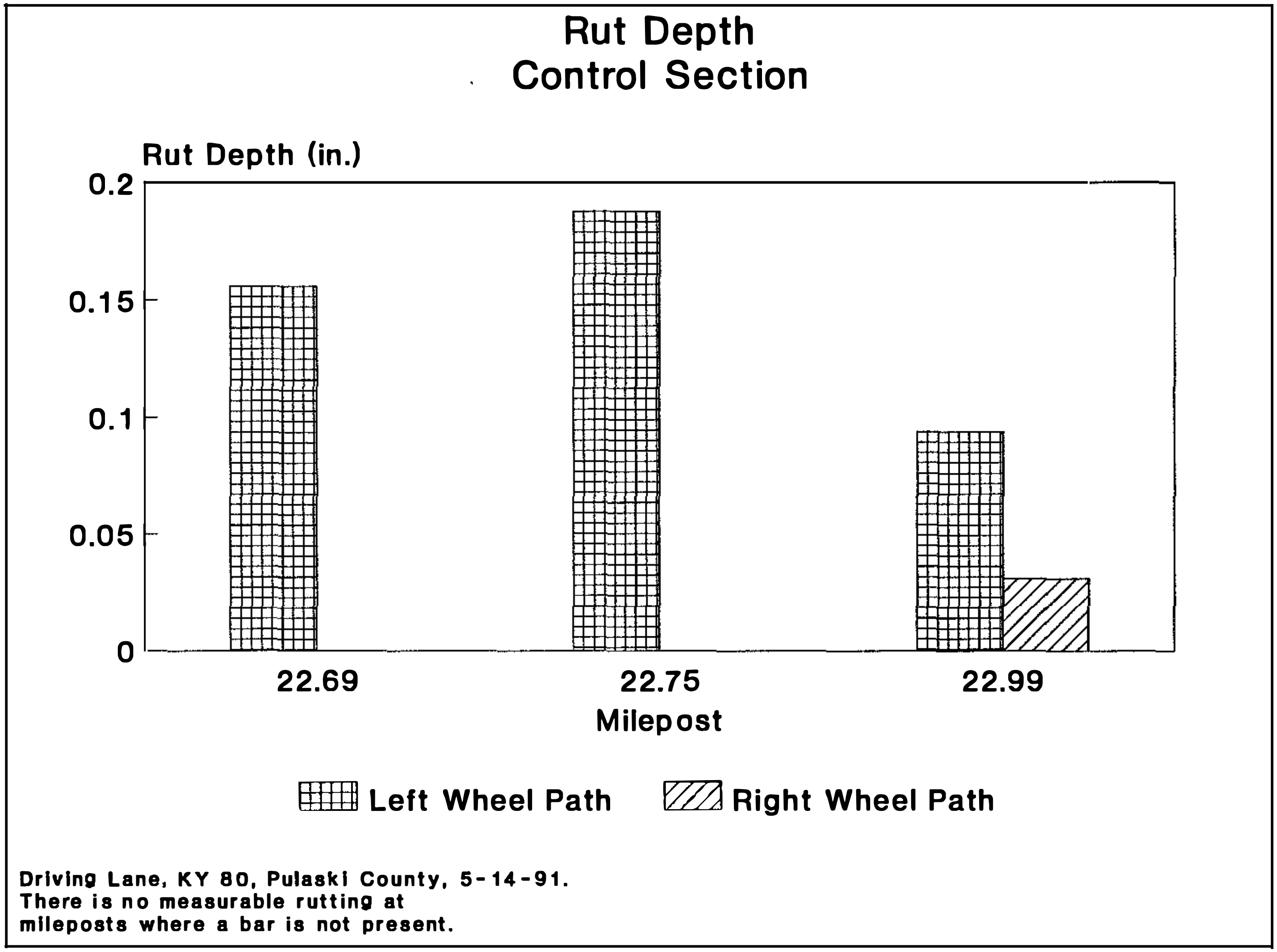
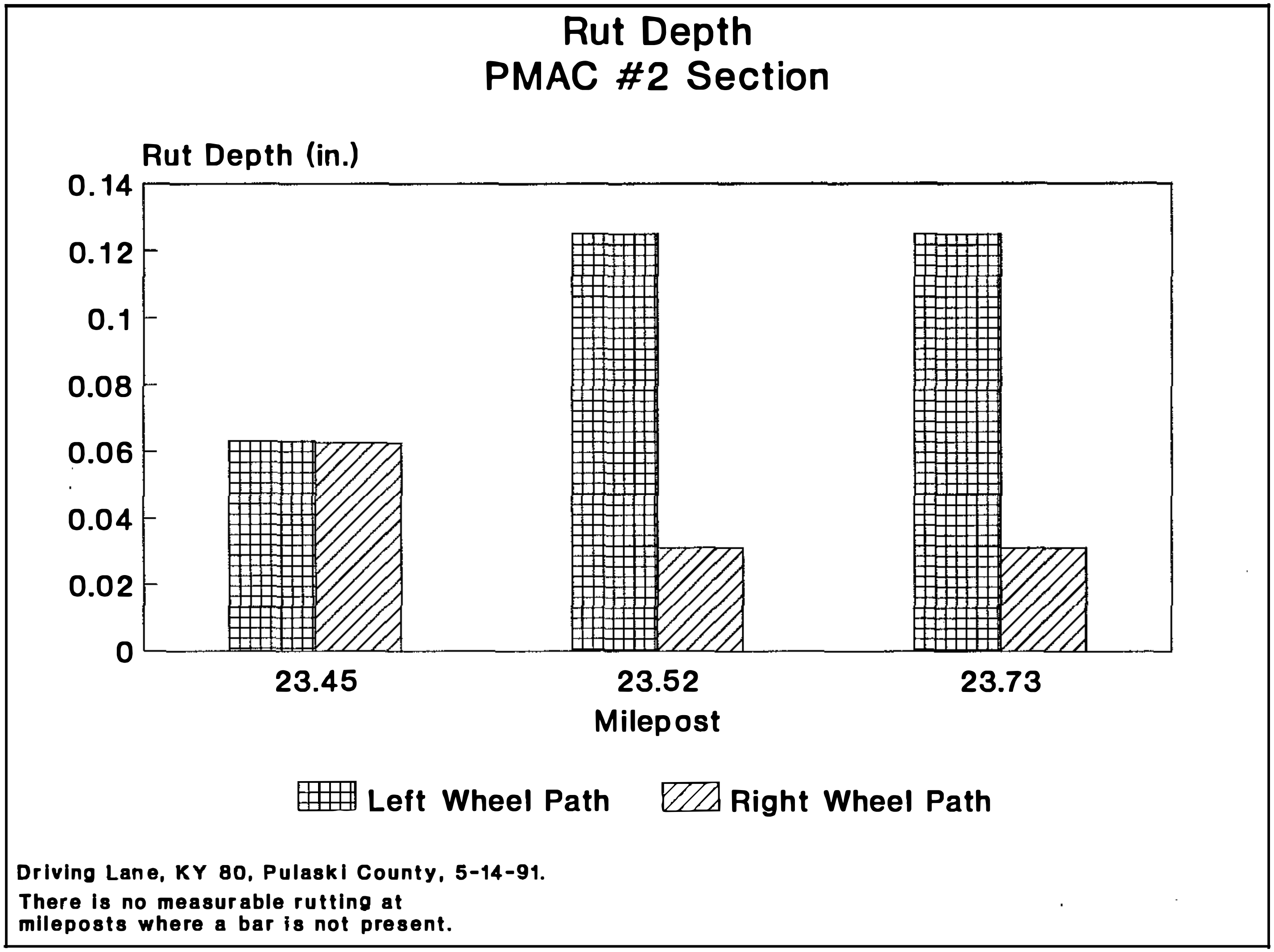


Figure 8. Average Rut Depth Data for the Control Section



Driving Lane, KY 80, Pulaski County, 5-14-91.
There is no measurable rutting at
mileposts where a bar is not present.

Figure 9. Average Rut Depth Data for the PMAC #2 Section

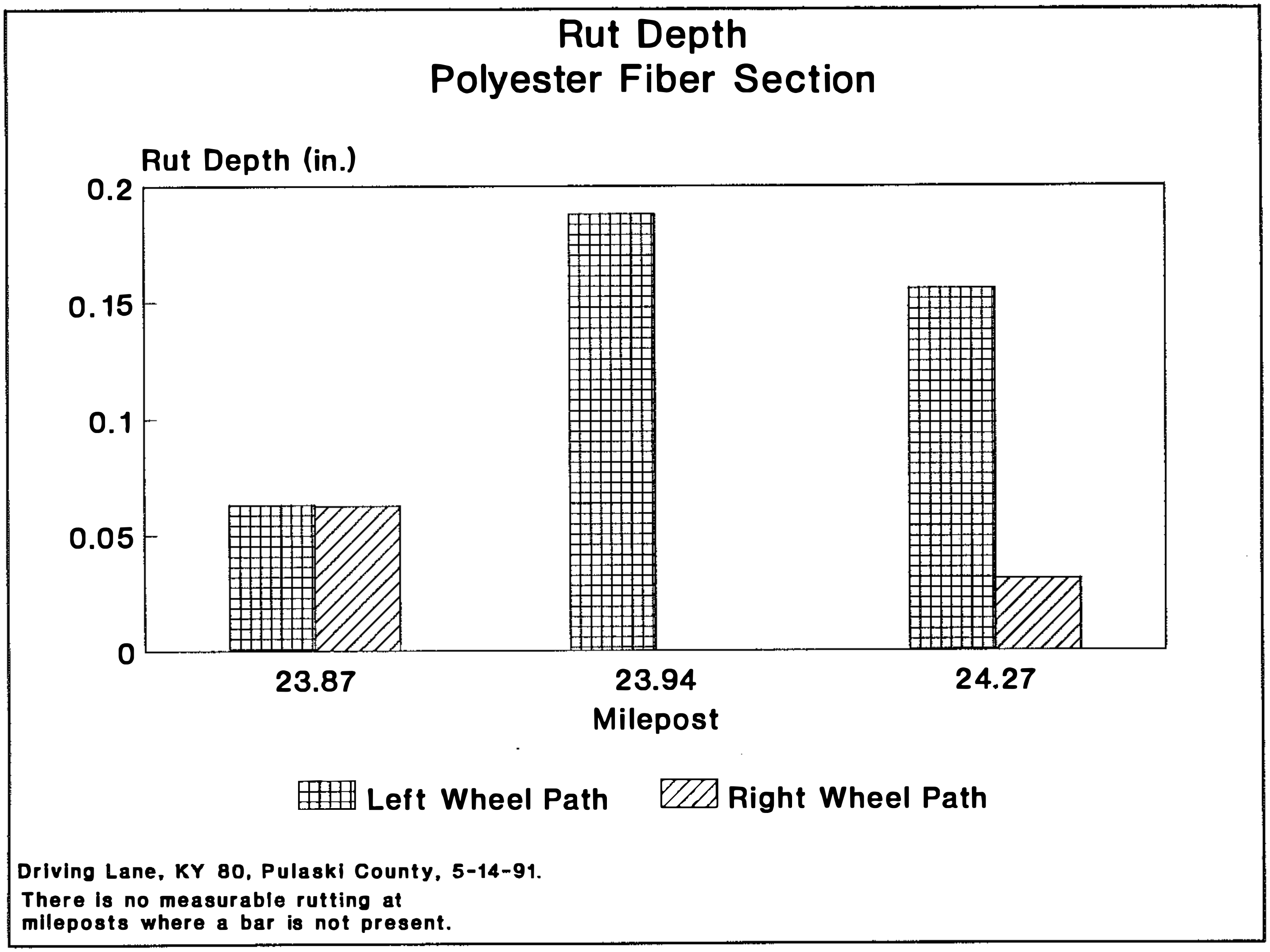


Figure 10. Average Rut Depth Data for the Polyester Fiber Section

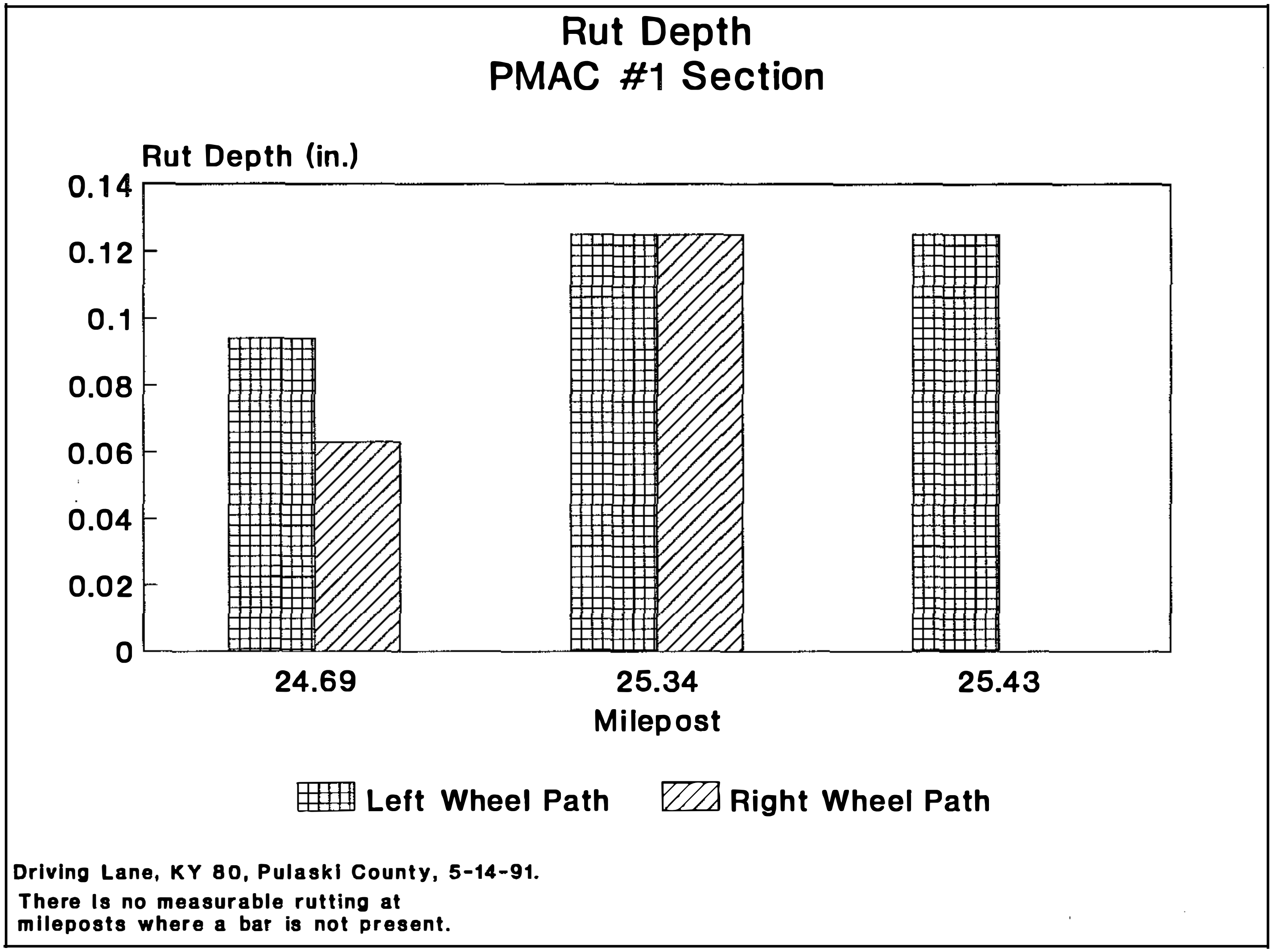
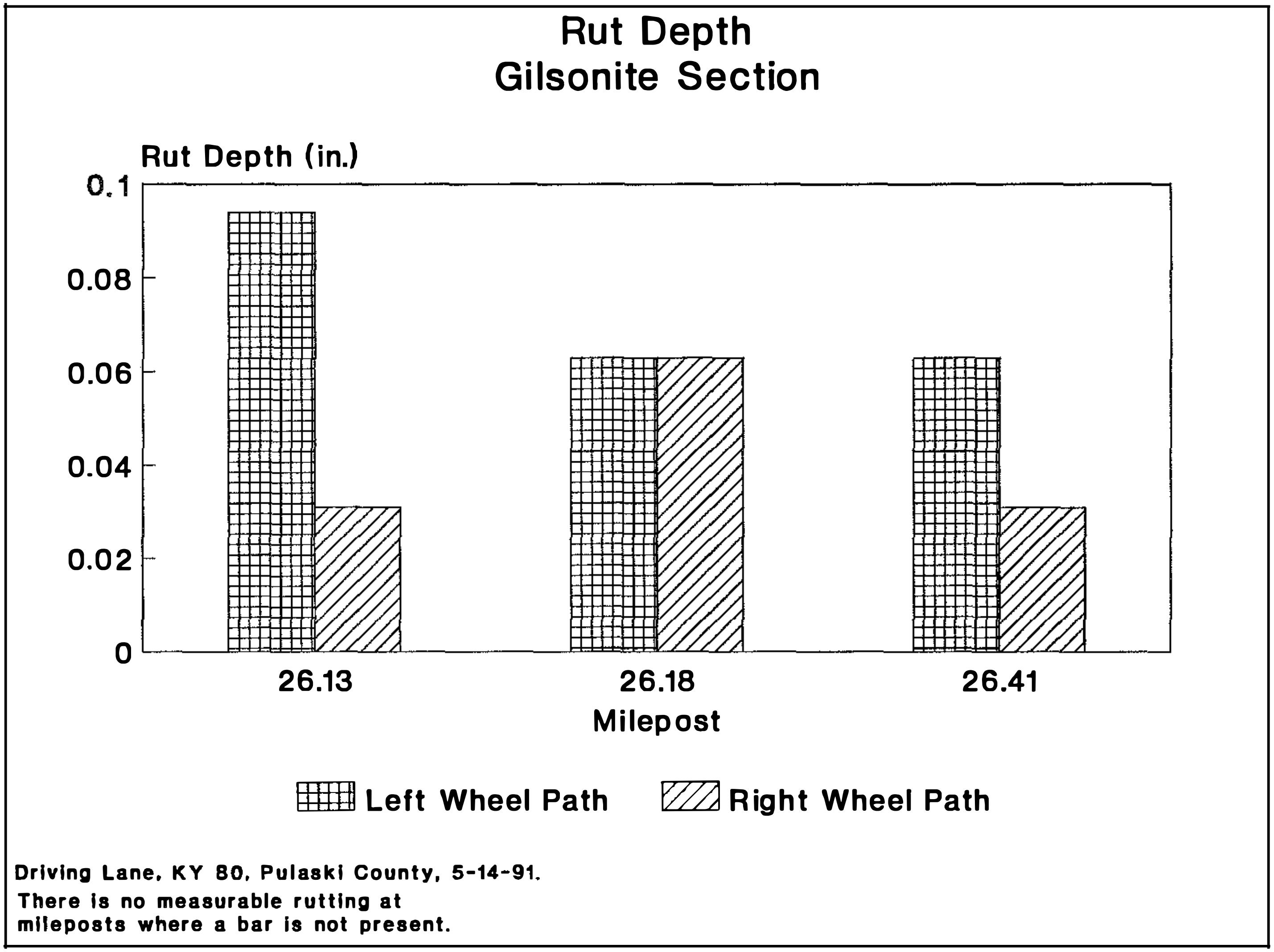


Figure 11. Average Rut Depth Data for the PMAC #1 Section



Driving Lane, KY 80, Pulaski County, 5-14-91.
There is no measurable rutting at
mileposts where a bar is not present.

Figure 12. Average Rut Depth Data for the Gilsonite Section

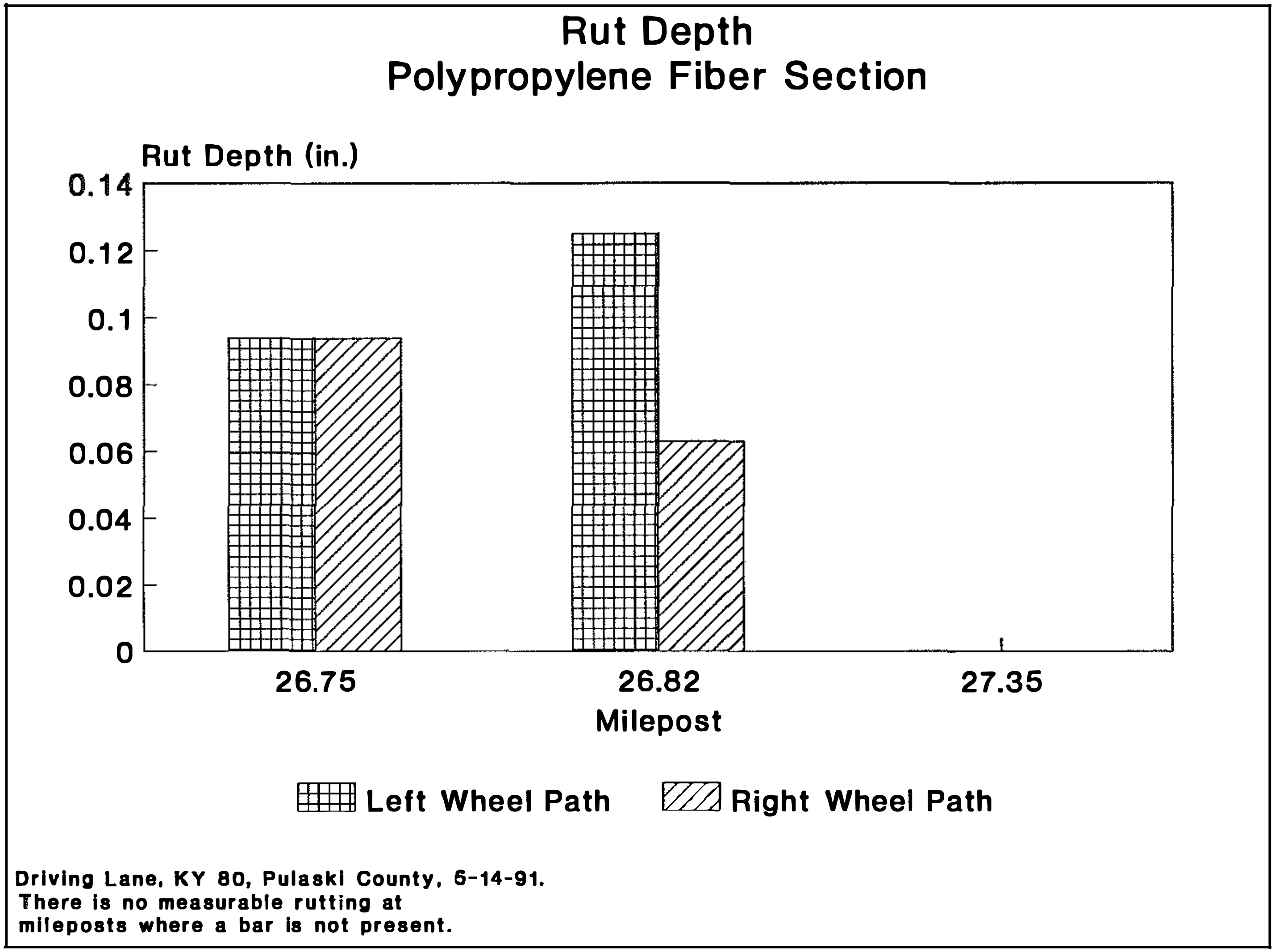
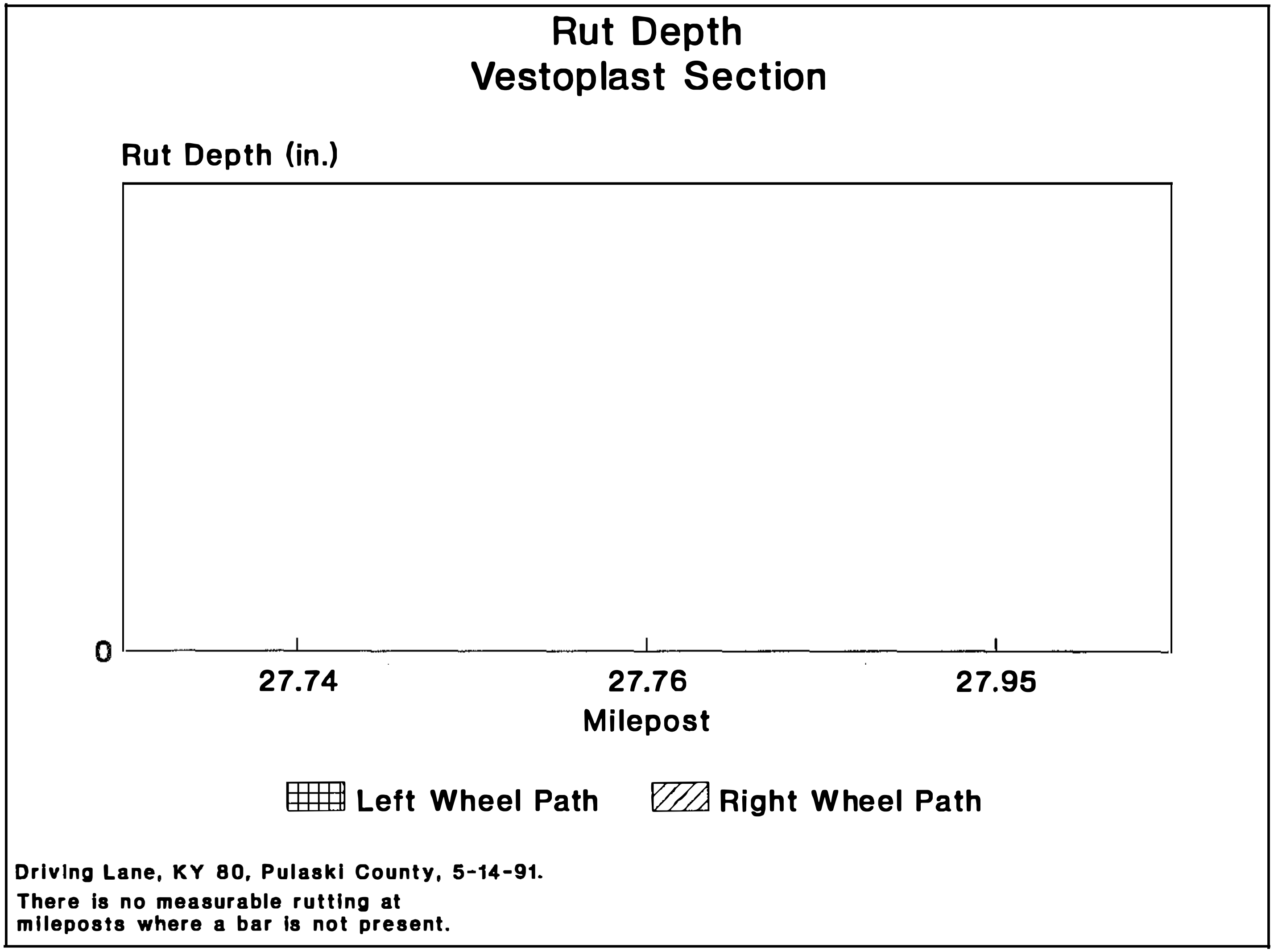


Figure 13. Average Rut Depth Data for the Polypropylene Fiber Section



Driving Lane, KY 80, Pulaski County, 5-14-91.
There is no measurable rutting at mileposts where a bar is not present.

Figure 14. Average Rut Depth Data for the Vestoplast Section

Appendix A - Statistical Analysis Procedure (Least Significant Difference Method)

The statistical analysis included two types of analyses. The first was the Least Significant Difference procedure. This procedure was used on all data except the repeated load data where a regression analysis procedure using the SAS computer program was utilized.

Analysis of Variance

An analysis of variance was performed on each data set.

Source	Degrees of Freedom	Sums of Squares	Mean Squares
Modifier	t-1	$\sum \frac{Y_{i.}}{r_i} - \frac{Y_{..}^2}{\sum r_i}$	SS/df
Residual	t(r-1)	$\sum Y_{ij}^2 - \sum \frac{Y_{i.}}{r_i}$	SS/df
Total	tr-1	$\sum Y_{ij}^2 - \frac{Y_{..}^2}{\sum r_i}$	

t = number of types of mixes
r = number of replications
i = 1,...,t
j = 1,...,r
SS = sums of squares
df = degrees of freedom
$Y_{..}$ = sum of all replicates for all mixes
$Y_{i.}$ = sum of all replicates within each mix
Y_{ij} = the individual observation for the jth replicate in the ith mix

Once the analysis of variance table has been completed, the Least Significance Difference can be completed.

a. Find the mean for each type of mix.

b. Rank the means from lowest to highest.

c. ~~Any two modifiers will be declared significantly different in their effects if the~~ two observed means differ (in absolute magnitude) by a value greater than or equal to the least significant difference.

$$LSD=t_{(\alpha,v)}\sqrt{\frac{MSE(r_i+r_j)}{r_i r_j}}$$

or

$$LSD=t_{(\alpha,v)}\sqrt{\frac{2MSE}{r}}$$

for equal replication

where $t_{(\alpha,v)}$ is the critical 2-sided (100α)% value of the Student's t distribution with v = degree of freedom associated with the residual mean square (MSE) obtained from the analysis of variance.

d. Systematically compare all pairs of observed means. If the absolute difference between two means is greater than or equal to the LSD, the corresponding treatments are declared significantly different in their effects.

Given equal replication, it is convenient to use the following procedure to systematically compare the treatment means:

1. Compute the difference between the largest and the smallest means. If this difference is greater than or equal to the LSD, declare the corresponding modifiers significantly different in their effects. Next, compute the difference between the second largest and smallest means and compare with the LSD. Continue to make comparisons with the smallest mean until either all differences involving the smallest mean are found to be significant or a difference involving the smallest mean is found to be smaller than the LSD. In the latter case, stop and make no further comparisons with the smallest mean.

2. Now make similar comparisons with the second smallest mean, etc. In practice, it may not be necessary to test all possible pairs.

Example: Tensile Strength Ratio Data

Raw Data

	Control	Vestoplast	Polpypropylene	Gilsonite
	61.4	113.8	99.5	89.3
	71.0	94.5	80.1	92.0
	85.7	92.4	82.3	106.3
	84.8	70.7	77.2	89.6
	80.6		83.7	
$Y_{i.}=$	383.5	=371.4	=422.8	=377.2

	PMAC #1	Polyester	PMAC #2
	90.1	89.7	88.9
	98.3	93.1	80.9
	79.9	88.9	89.7
	92.2	90.5	79.2
	89.1	70.7	86.9
$Y_{i.}=$	449.6	=432.9	=425.6

t = 7

r varies

rt = 33

$\Sigma Y_{i.}^2/r_i$ = 249,356.45

ΣY_{ij} = 251,809.78

$Y_{..}$ = 2,863.0 $Y_{..}^2/rt$ = 248,386.94

Source	Degrees of Freedom	Sums of Squares	Means Squares
Modifier	6	249,356.45 - 248,386.94 = 969.51	969.51/6 = 161.58
Residual	26	251,809.78 - 249,356.45 = 2,453.33	2,453.33/26 = 94.36
Total	32	251.809.78 - 248,386.94 = 3,422.84	

Least Significant Difference

---

a.

Mean	Modifier
76.7	Control
92.8	Vestoplast
84.6	Polypropylene
94.3	Gilsonite
89.9	PMAC #1
86.6	Polyester
85.1	PMAC #2

b.

Mean	Modifier
76.7	Control
84.6	Polypropylene
85.1	PMAC #2
86.6	Polyester
89.9	PMAC #1
92.8	Vestoplast
94.3	Gilsonite

c.

$t_{(\alpha,v)} = 1.706$

Assuming equal replication at 5 per modifier:

$$LSD = 1.706\sqrt{\frac{(2)(94.36)}{5}} = 10.48$$

d.

Control vs. Gilsonite

diff = 94.3 - 76.7 = 17.6

significantly different

Control vs. Vestoplast

diff = 92.8 - 76.7 = 16.1

significantly different

Control vs. PMAC #1

diff = 89.9 - 76.7 = 13.2

significantly different

Control vs. Polyester
    diff = 86.6 - 76.7 = 9.9
    not significantly different
Control is not significantly different from Polyester, PMAC #2 or Polypropylene.

Polypropylene vs. Gilsonite
    diff = 94.3 - 84.6 = 9.7
    not significantly different

The procedure is stopped here because any means falling between and including Polypropylene and Gilsonite are not significantly different from each other.

Conclusions

Control^{a} Polypropylene^{ab} PMAC #2^{ab} Polyester^{ab}

PMAC #1^{b} Vestoplast^{b} Gilsonite^{b}

Means with like superscripts are not significantly different as shown in Table 4.

Appendix B - Consolidated Mix Design Data

Mixture were obtained from the hopper of the paver and placed in 5-gallon buckets. Four buckets, which were filled to approximately 80 percent volume, were taken for each type of mix. The samples were then immediately transported to the laboratory. The buckets were closed and not disturbed until time for re-heating. Each bucket was re-heated to 280°F and standard Marshall samples were compacted at 75 blows. These samples were allowed to cure for 7 days before testing.

Table B1. Mixture Properties

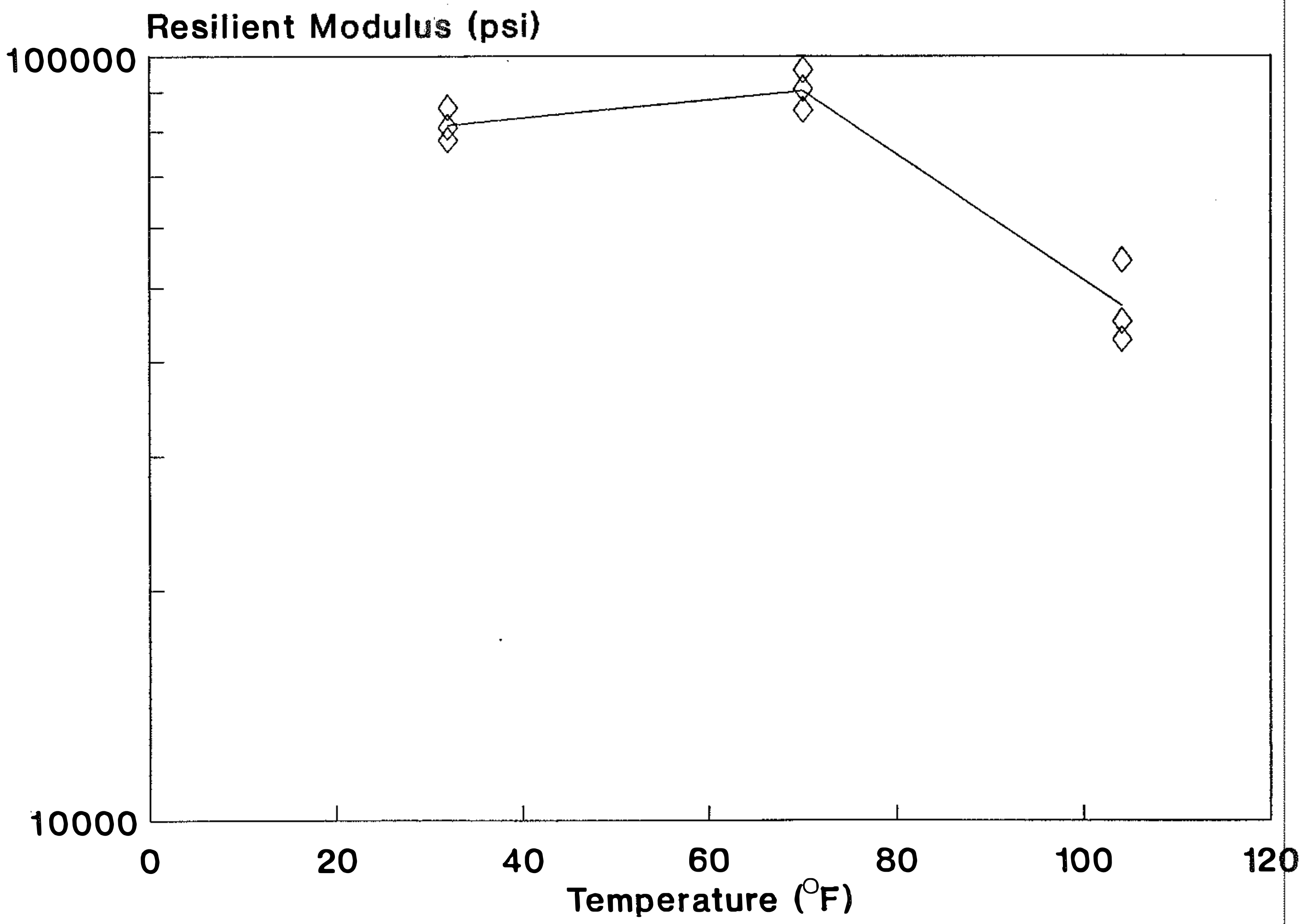
	Unit Weight (pcf)	% Air Voids	% VFA	Stability	MSG	% VMA	% Abs. Asphalt Content	Flow	% Eff. Asphalt Content
Control	147.3	5.2	67	2540	2.49	15.6		0.11	4.5
PMAC #2	147.1	5.7	64	2760	2.50	15.7	0.97	0.14	4.4
Polyester	150.5	2.1	86	2820	2.46	15.1	0.0	0.16	5.5
PMAC #1	149.9	3.2	77	3490	2.48	14.1	0.64	0.14	4.7
Gilsonite	147.7	4.6	70	3170	2.48	15.3	0.64	0.15	4.7
Polypropylene	146.3	4.8	70	2410	2.46	16.3	0.45	0.16	5.1
Vestoplast	149.2	3.8	74	2910	2.49	14.5	0.74	0.15	4.6
Control with Natural Sand	150.3	2.8	78	2820	2.48	12.9	1.01	0.13	4.3

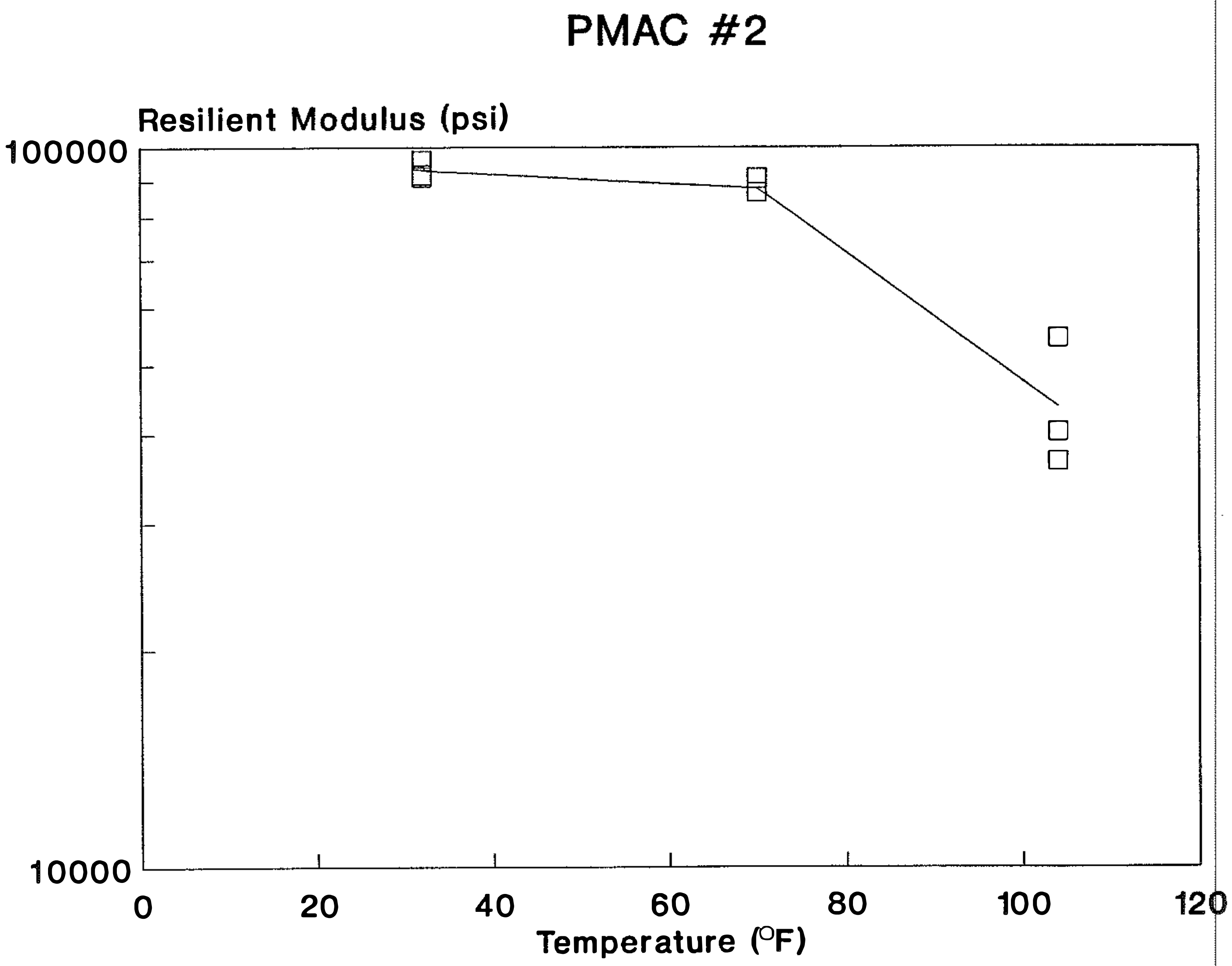
Table B2. Washed Gradation for Each Mixture Type

Sieve Size	Percent Passing							
	Control	PMAC #2	Polyester	PMAC #1	Gilsonite	Polypropylene	Vestoplast	Control with Natural Sand
0.5"	100	100	100	100	100	100	100	100
0.375"	92	92	92	92	92	92	92	92
#4	54	54	54	54	54	54	54	55
#8	38	38	38	38	38	38	38	40
#16	27	27	27	27	27	27	27	30
#30	19	19	19	19	19	19	19	21
#50	13	13	13	13	13	13	13	11
#200	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5

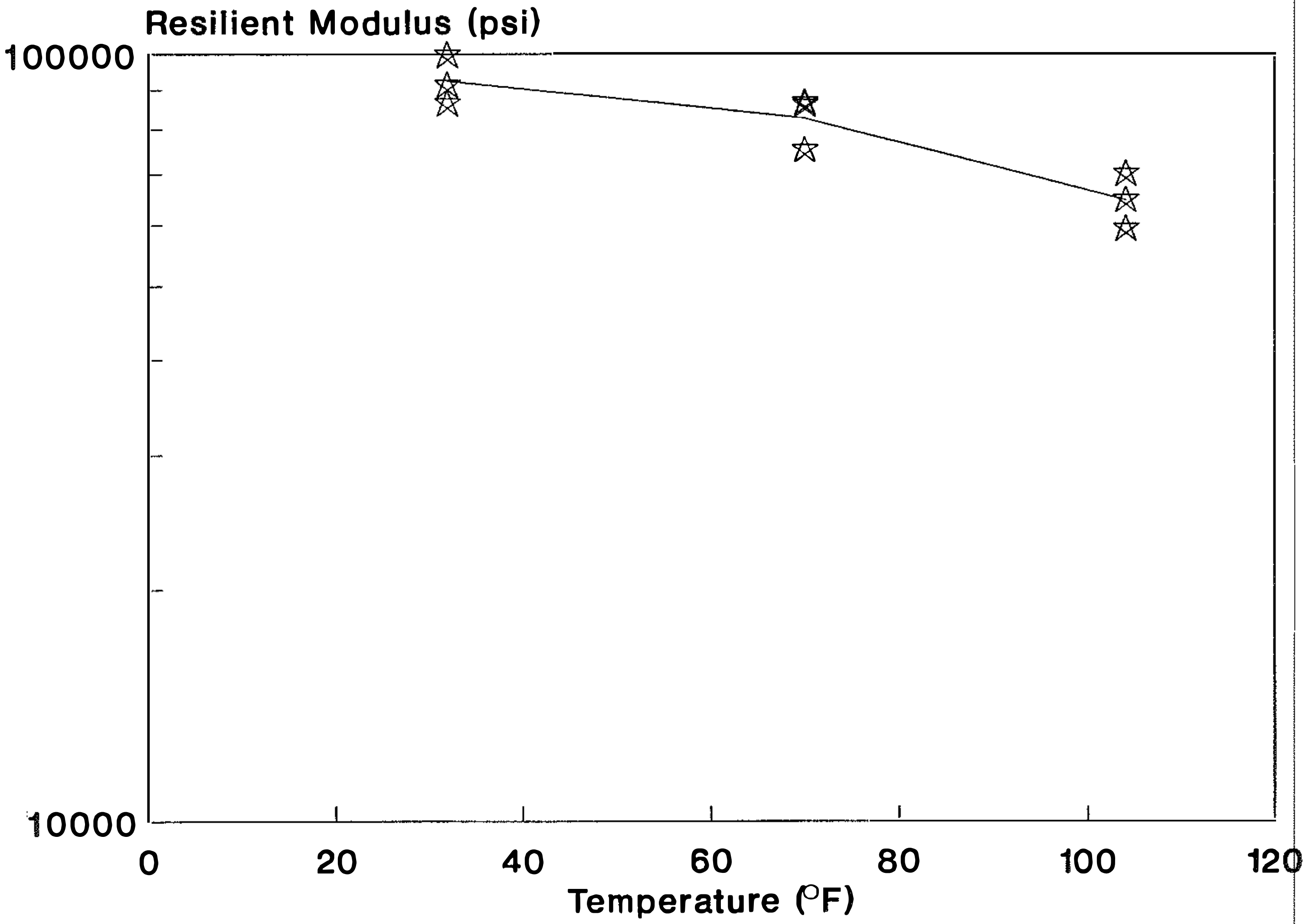
Appendix C - Resilient Modulus Data

Class K Control

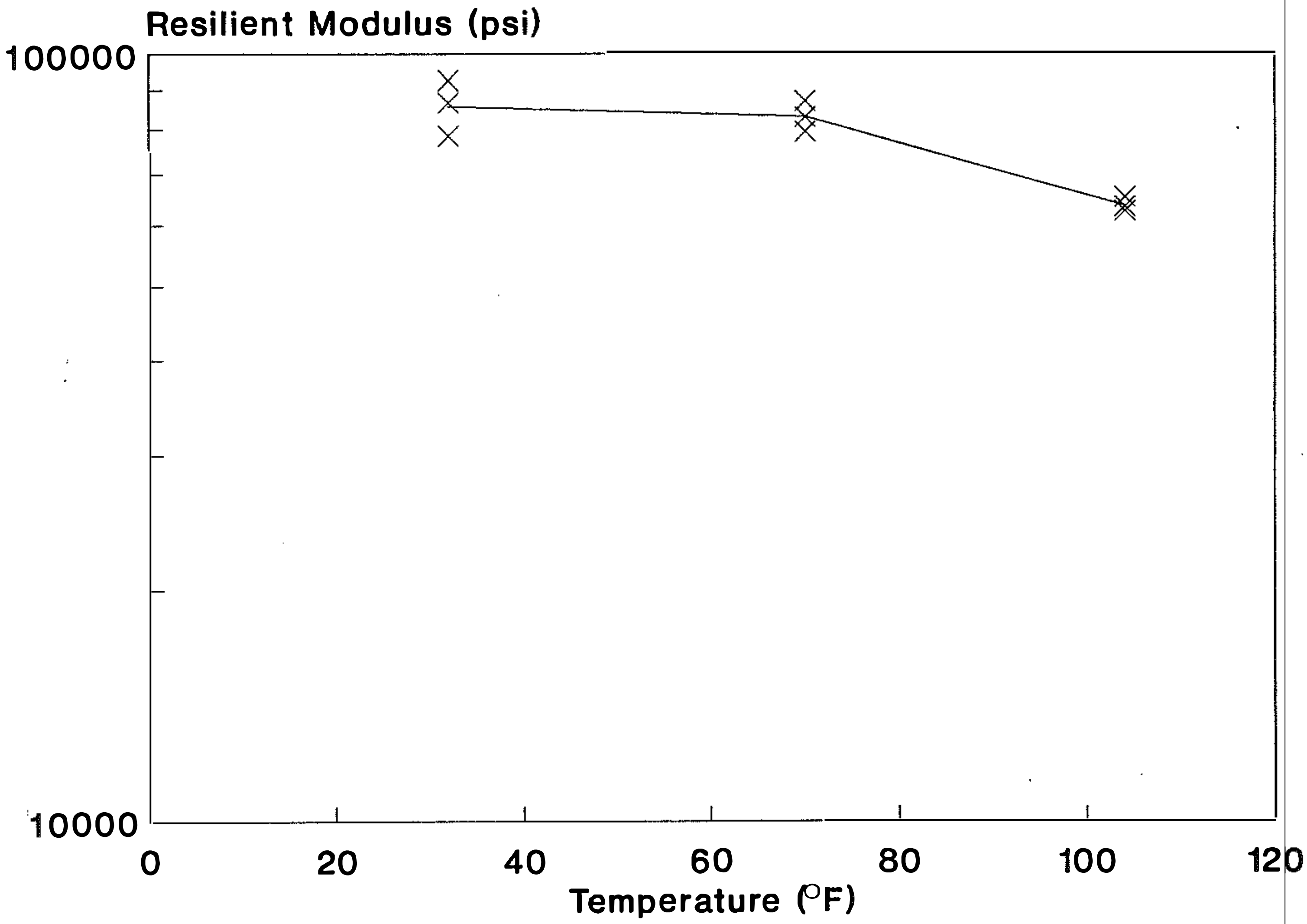



PMAC #2
Resilient Modulus (psi)
100000
10000
0
20
40
60
80
100
120
Temperature (°F)

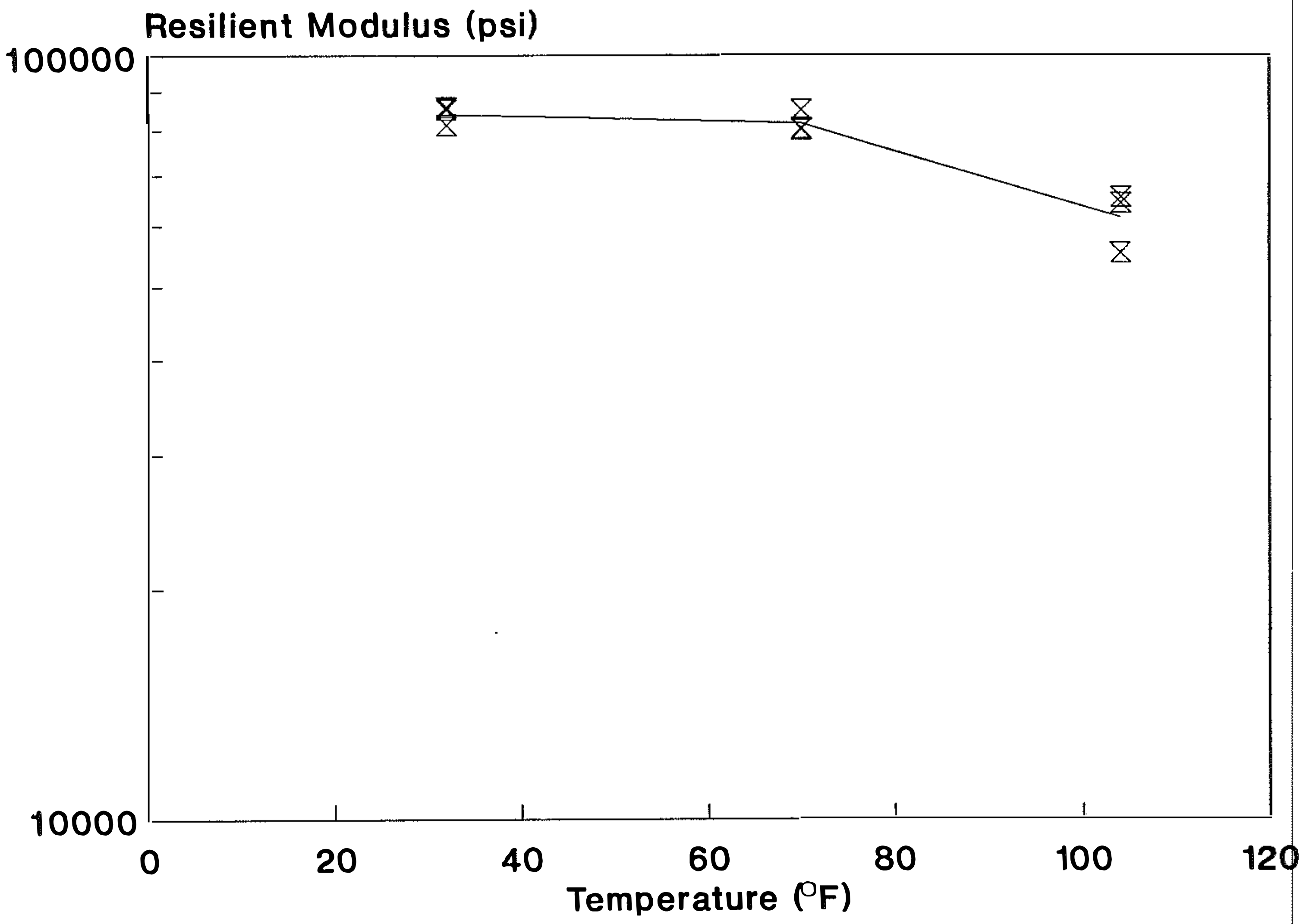
Polyester Fiber

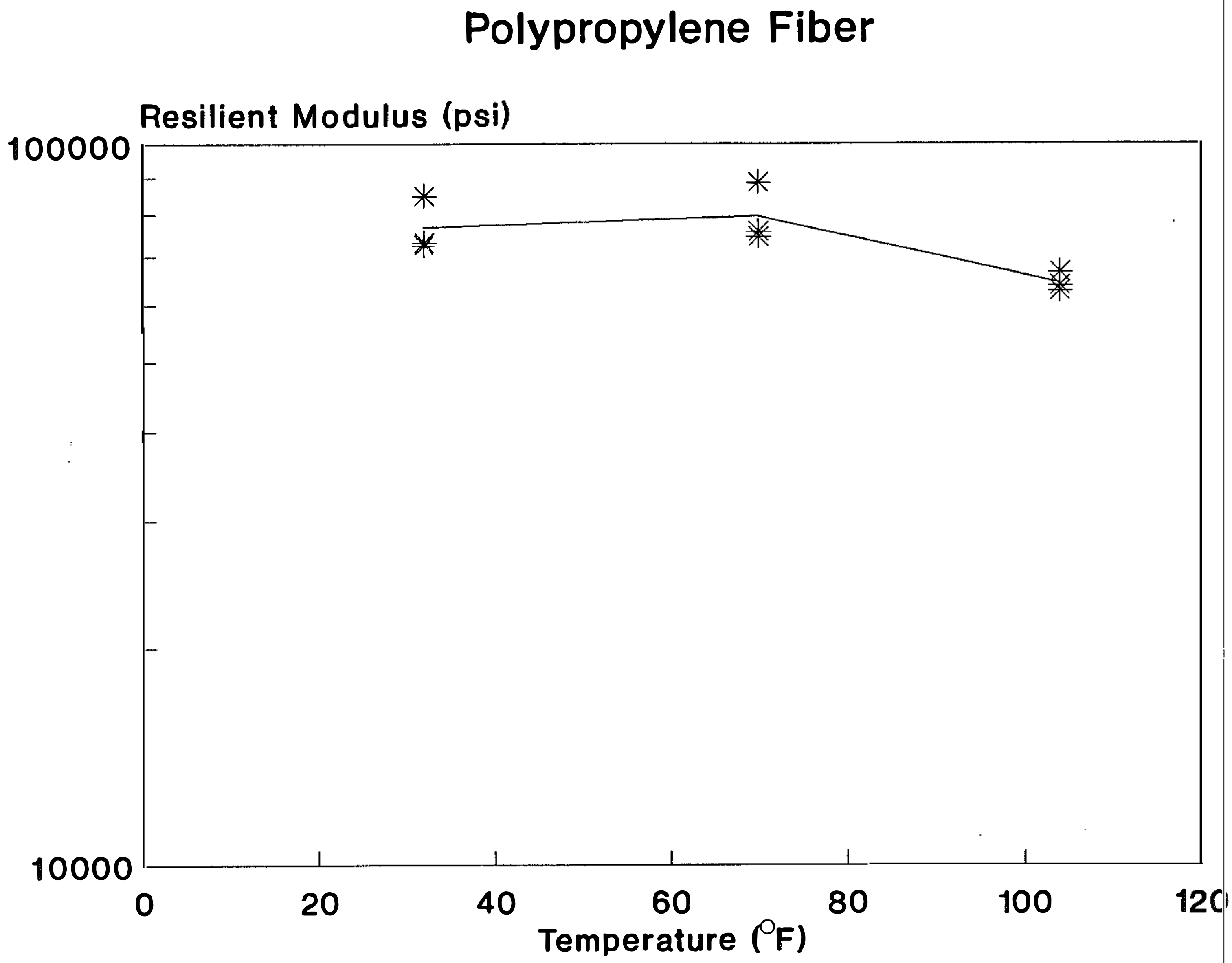


PMAC #1

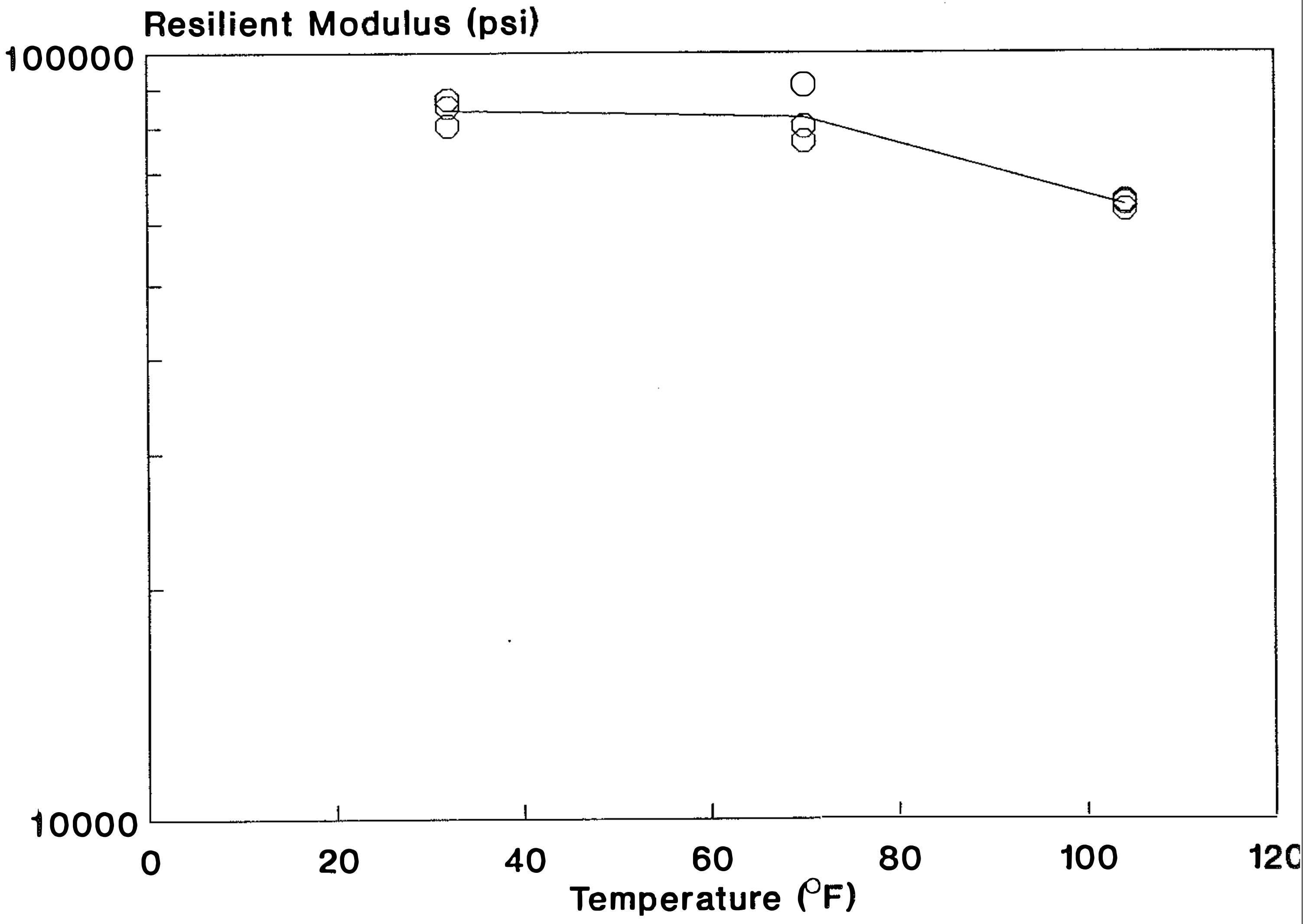

Resilient Modulus (psi)
100000
10000
0
20
40
60
80
100
120
Temperature (°F)

Gilsonite


Resilient Modulus (psi)
100000
10000
0
20
40
60
80
100
120
Temperature (°F)

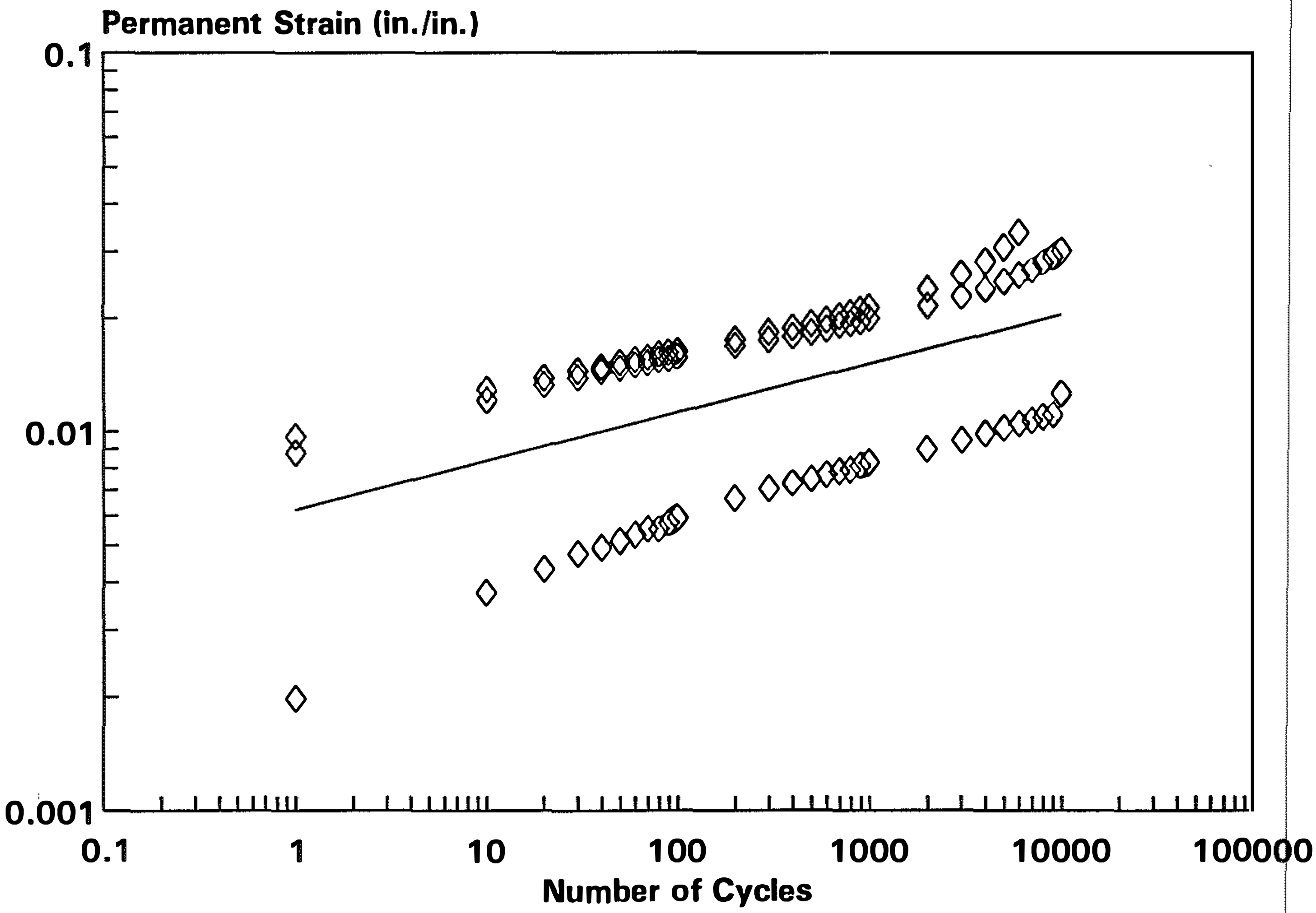

Polypropylene Fiber
Resilient Modulus (psi)
100000
10000
0
20
40
60
80
100
120
Temperature (°F)

Vestoplast

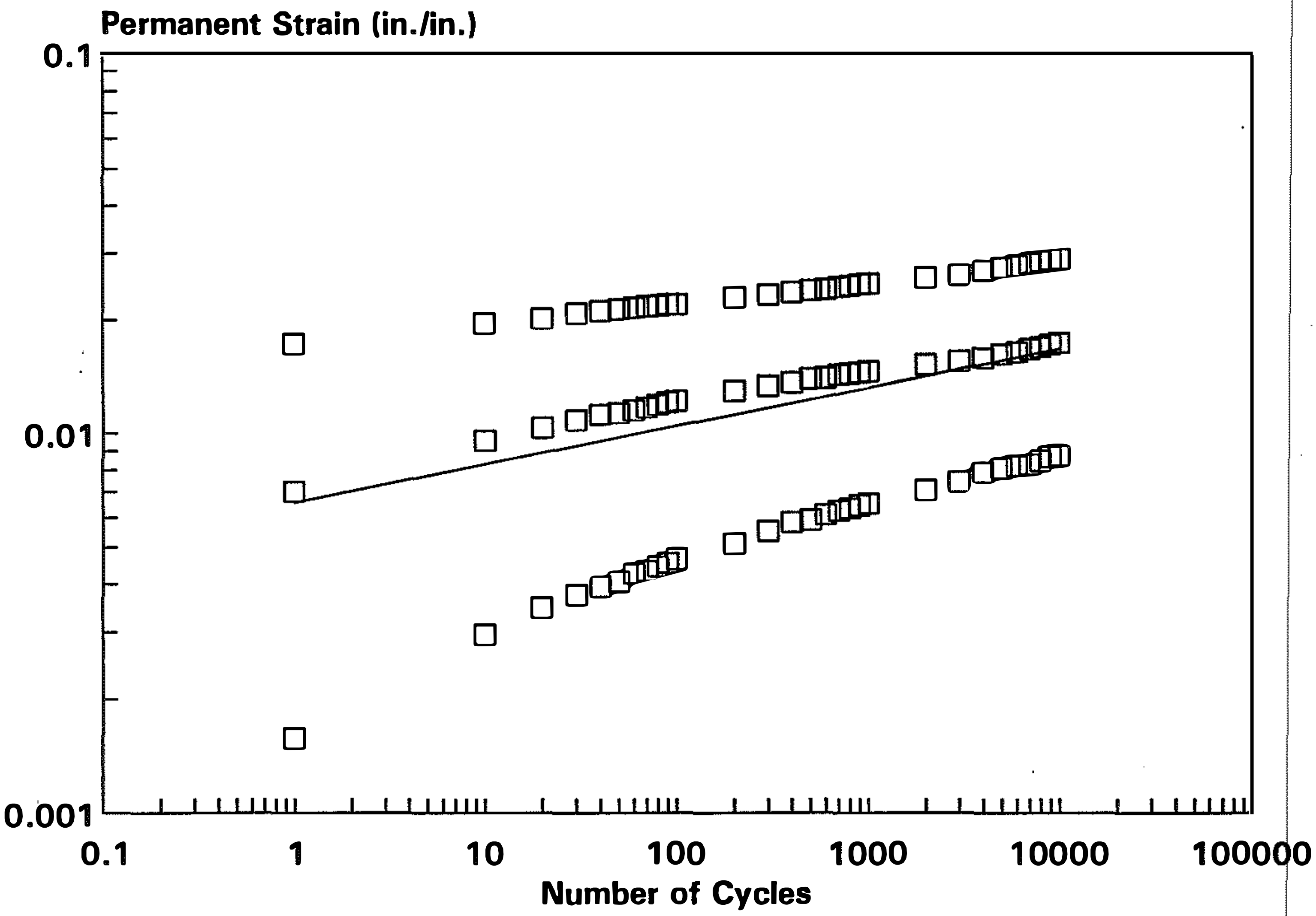

Resilient Modulus (psi)
100000
10000
0
20
40
60
80
100
120
Temperature (°F)

Appendix D - Repeated Load Permanent Deformation Data

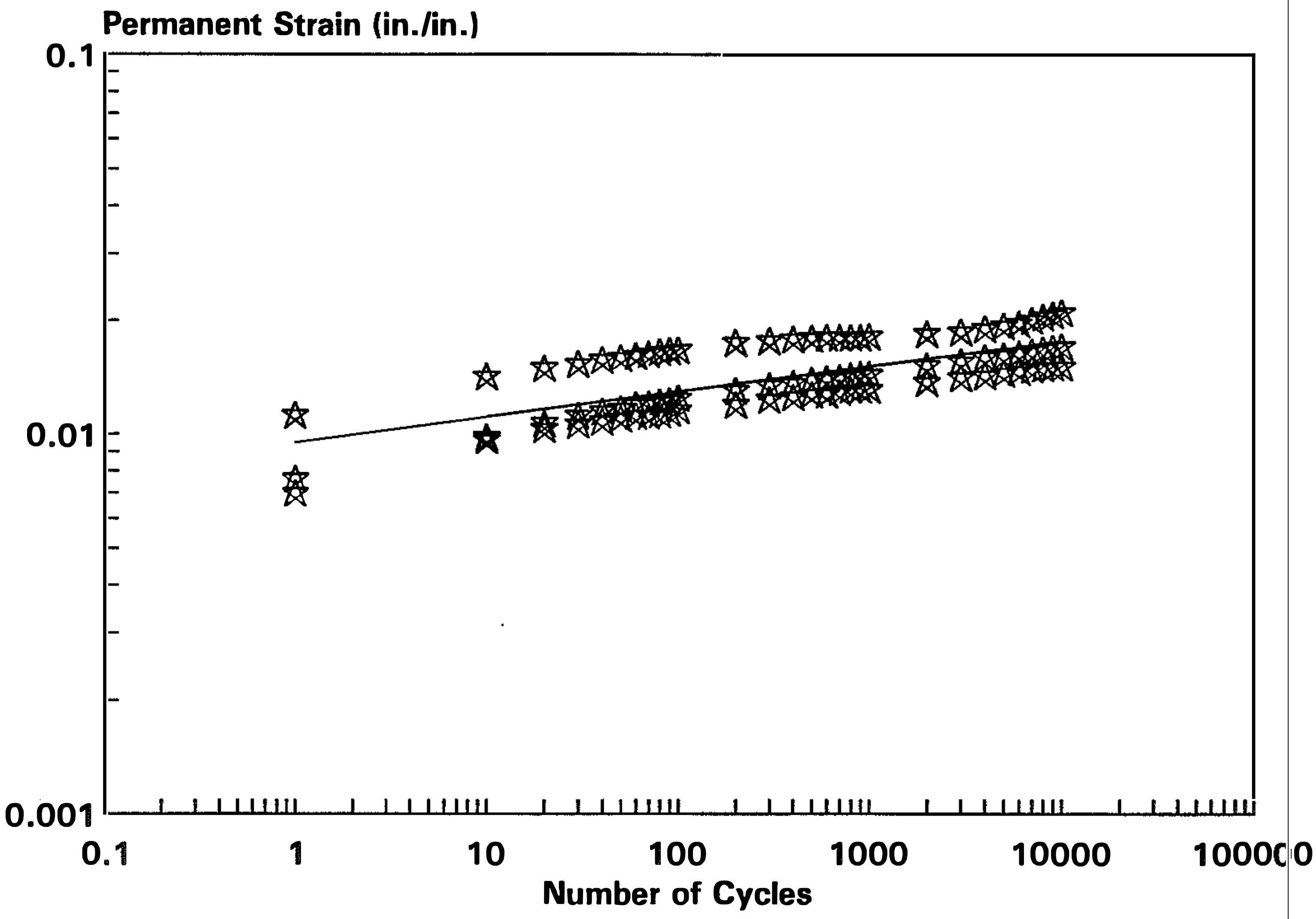
Class K Control

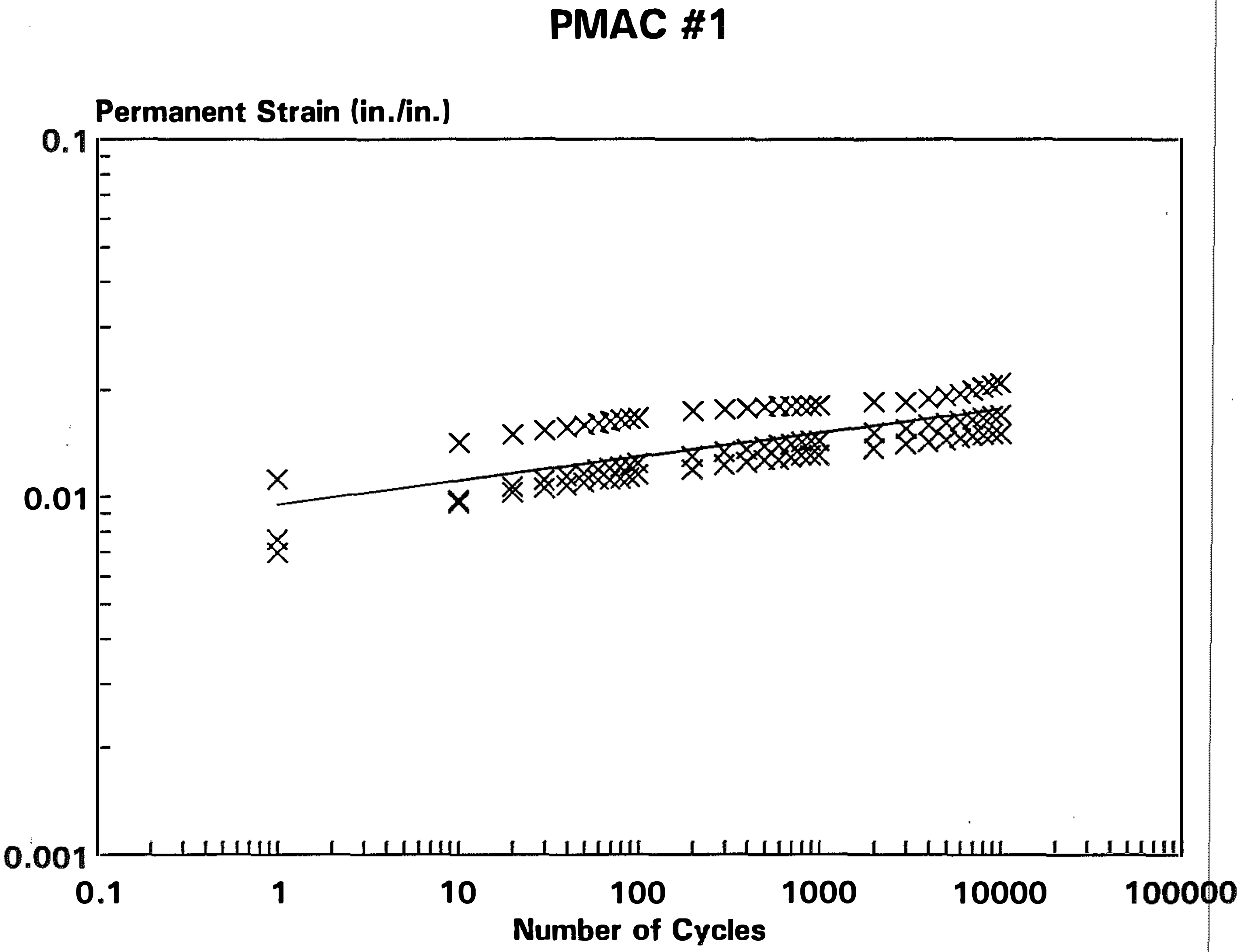


PMAC #2

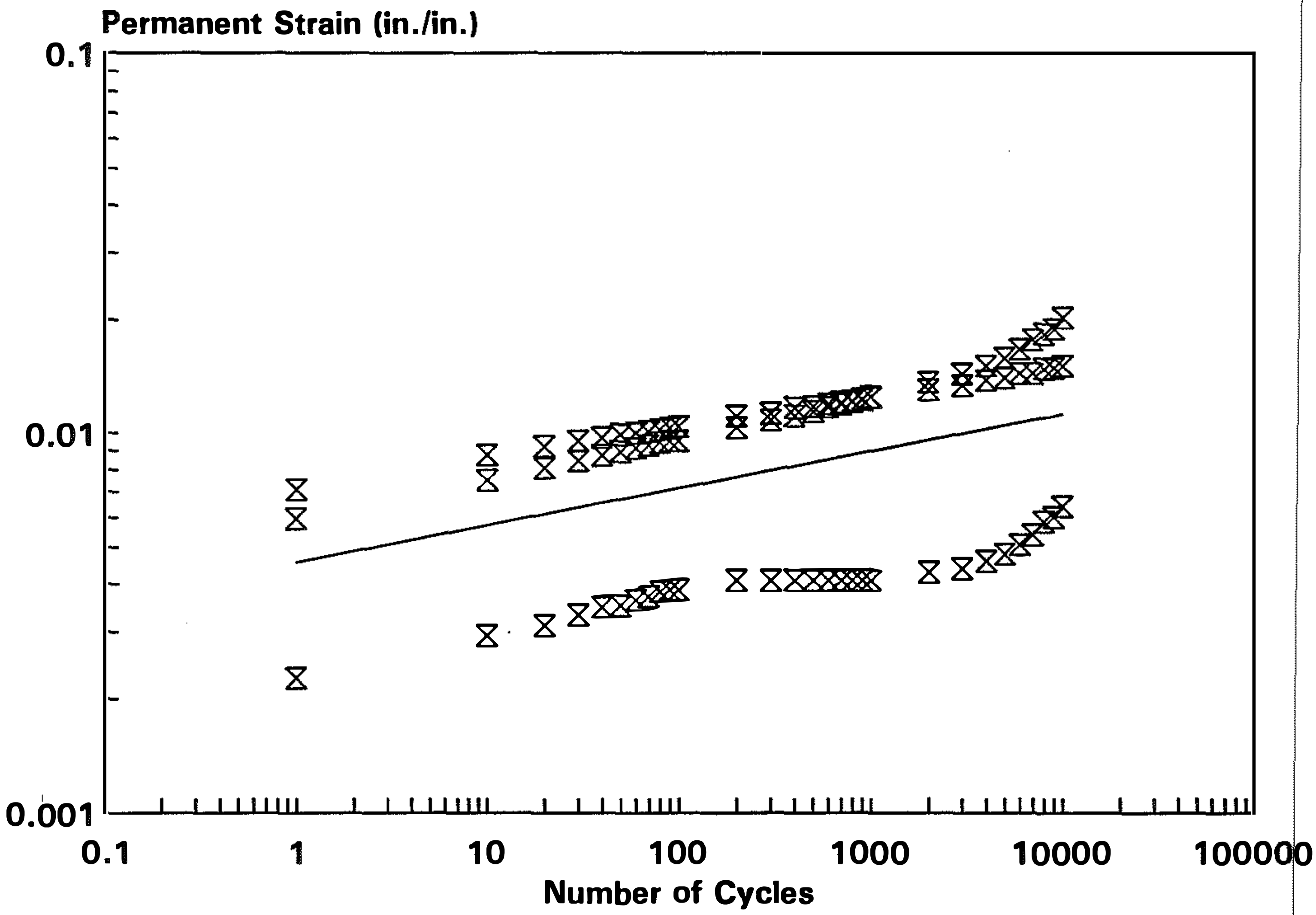

Permanent Strain (in./in.)
0.1
0.01
0.001
0.1
1
10
100
1000
10000
100000
Number of Cycles

Polyester Fiber

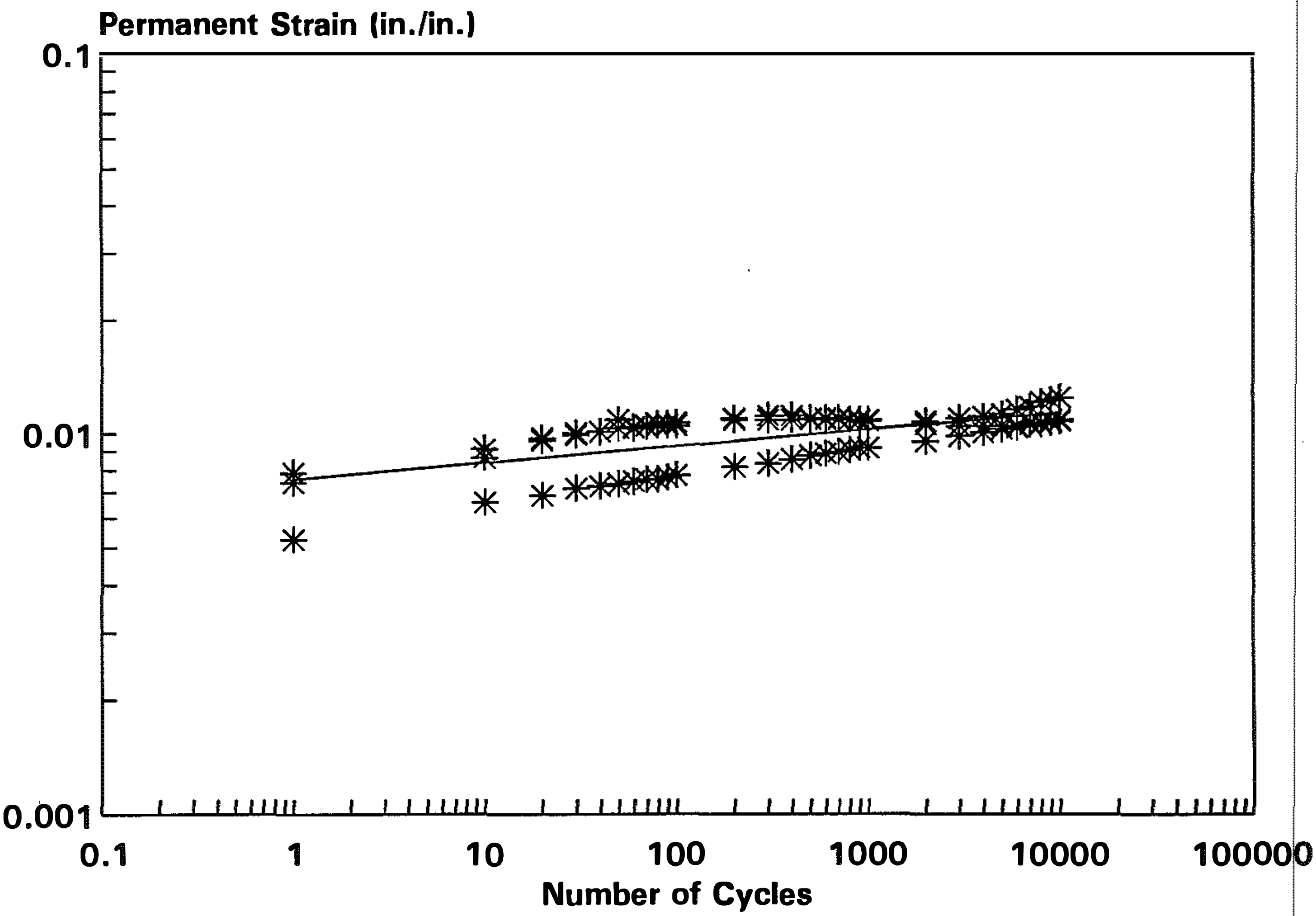



PMAC #1
Permanent Strain (in./in.)
0.1
0.01
0.001
0.1
1
10
100
1000
10000
100000
Number of Cycles

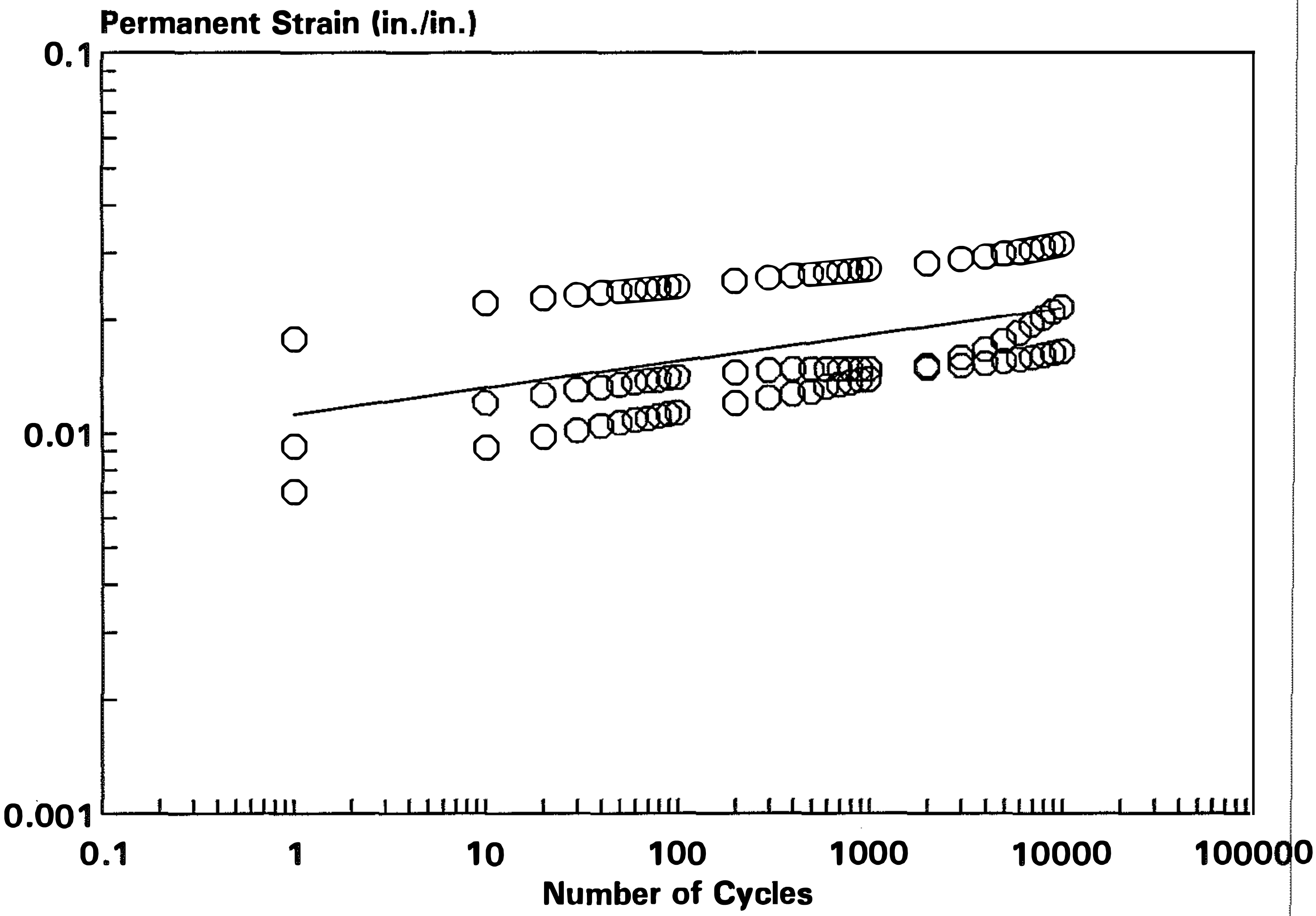
Gilsonite


Permanent Strain (in./in.)
0.1
0.01
0.001
0.1
1
10
100
1000
10000
100000
Number of Cycles

Polypropylene Fiber

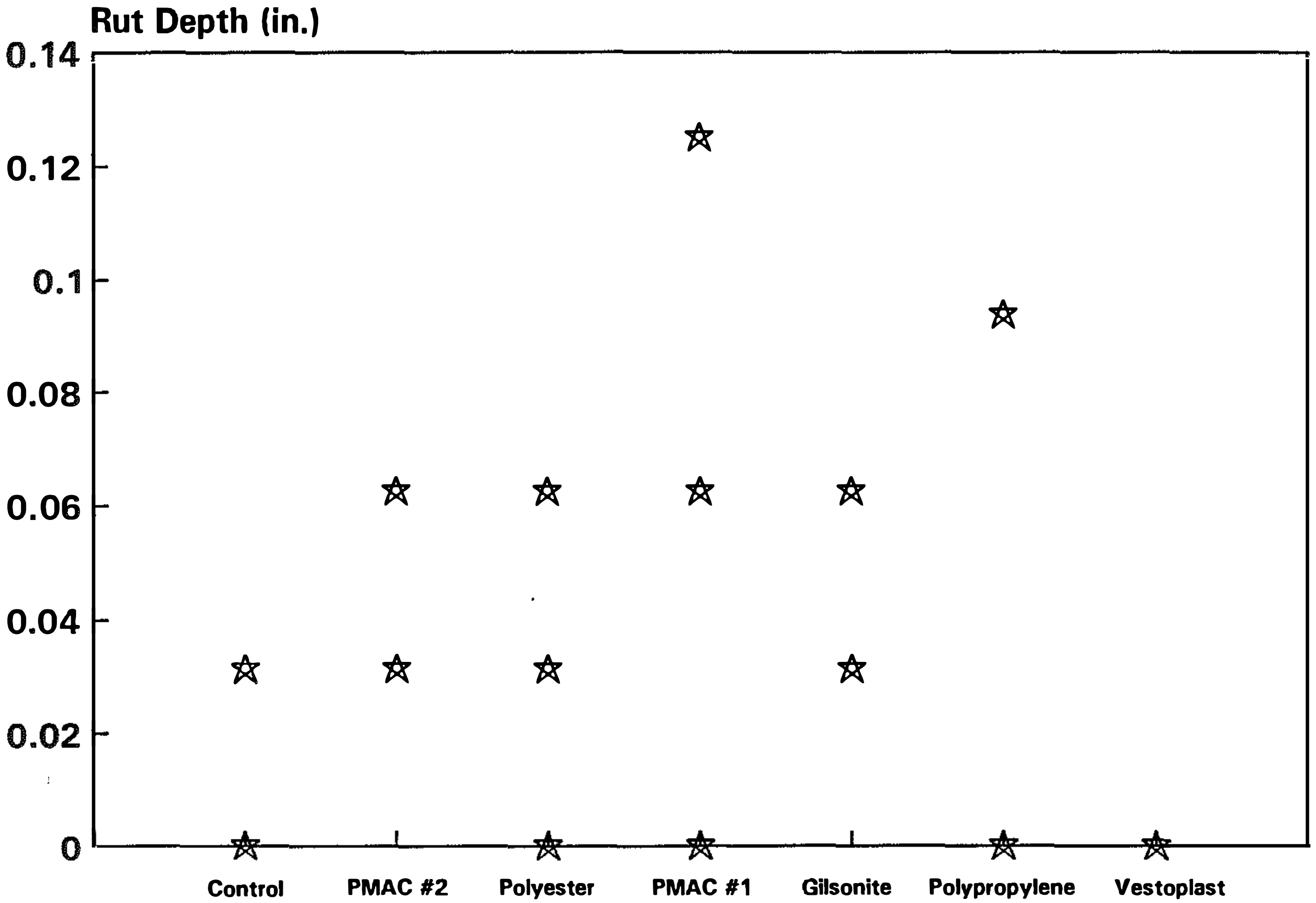


Vestoplast

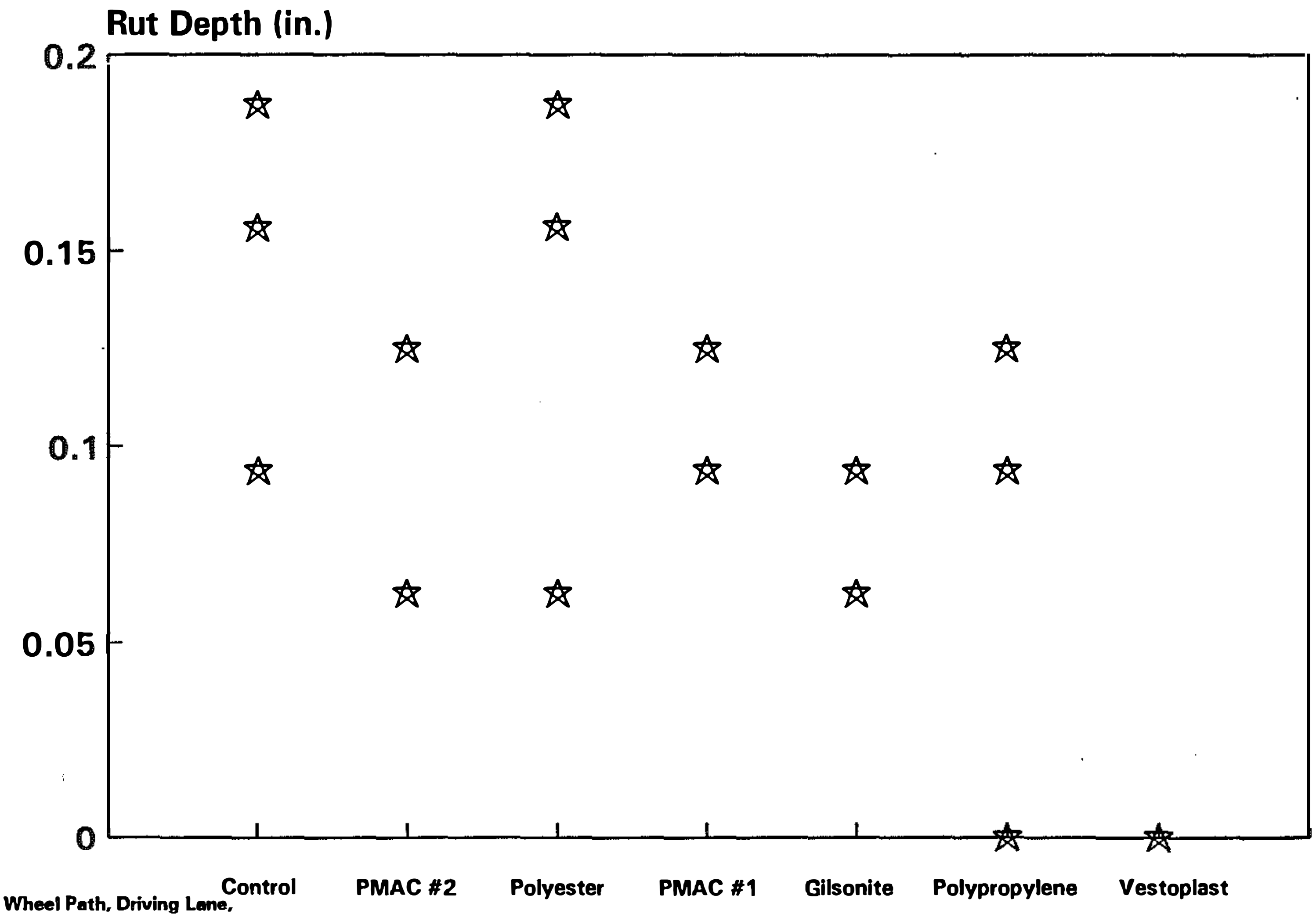


Permanent Strain (in./in.)
0.1
0.01
0.001
0.1
1
10
100
1000
10000
100000
Number of Cycles

Appendix E - Rut Depth Data



Right Wheel Path, Driving Lane,
KY 80, Pulaski County, 5-14-91.



Left Wheel Path, Driving Lane,
KY 80, Pulaski County, 5-14-91.

Appendix F - Air Voids and Density Data

	Air Voids (%)	Density (pcf)	Field Air Voids (%)	Field Density (pcf)
PMAC #2	7.6	141.3	5.7	147.0
	9.2	138.7	5.7	147.1
	9.4	138.6	6.0	146.5
	9.2	138.9	5.7	147.1
	9.1	139.0	5.5	147.3
	8.8	139.4	5.5	147.4
	9.2	138.8		
	9.9	137.8		
	10.5	136.9		
	10.3	137.2		
	8.9	139.3		
	9.7	138.1		
	10.0	137.5		
	10.6	136.7		
	10.7	136.4		
	10.8	136.3		
	9.0	139.1		
	9.2	138.8		
	9.3	138.7		
	8.7	139.6		
	9.7	138.0		
	9.5	138.3		
	9.0	139.0		
	9.7	138.1		
	8.6	139.7		
	9.0	139.1		
	8.5	139.8		
	7.7	141.2		
	8.2	140.3		
	8.3	140.2		
	5.1	145.1		
	5.4	144.6		
	5.4	144.6		
	6.0	143.8		
	6.0	143.6		
	Mean: 8.7	Mean: 139.5	Mean: 5.7	Mean: 147.1

	Air Voids (%)	Density (pcf)	Field Air Voids (%)	Field Density (pcf)
Polyester	5.4	144.9	2.1	150.5
	5.7	144.4	2.4	150.0
	6.1	143.9	2.8	149.5
	5.4	144.9	1.7	151.1
	5.8	144.3	1.8	150.9
	6.1	143.9	1.8	150.9
	5.7	144.5		
	6.5	143.3		
	5.9	144.1		
	6.5	143.2		
	6.7	142.9		
	6.5	143.1		
	6.2	143.6		
	6.1	143.8		
	6.1	143.7		
	7.3	142.0		
	7.6	151.5		
	8.3	140.5		
	5.8	144.2		
	6.2	143.7		
	6.7	142.9		
	6.8	142.7		
	7.5	141.7		
	7.4	141.8		
	7.9	141.1		
	7.4	141.8		
	7.2	142.2		
	7.5	141.7		
	7.1	142.2		
	7.9	141.0		
	7.1	142.3		
	6.7	142.9		
	7.0	142.4		
	7.1	142.3		
	Mean: 6.7	Mean: 142.9	Mean: 2.1	Mean: 150.5

	Air Voids (%)	Density (pcf)	Field Air Voids (%)	Field Density (pcf)
PMAC #1	4.6	145.2	3.3	149.6
	4.9	144.7	3.2	149.9
	4.6	145.2	3.4	149.5
	5.0	144.7	3.2	149.8
	4.8	144.8	3.1	150.0
	6.4	142.4	2.8	150.4
	5.8	143.3		
	5.5	143.8		
	5.7	143.5		
	6.1	142.9		
	6.1	142.9		
	6.8	141.8		
	6.6	142.2		
	6.1	143.0		
	6.3	142.6		
	7.2	141.2		
	8.0	140.1		
	6.9	141.7		
	6.3	142.6		
	7.4	141.0		
	7.4	140.9		
	6.4	142.4		
	6.5	142.3		
	6.1	142.9		
	7.0	141.6		
	6.5	142.3		
	7.0	141.5		
	7.1	141.4		
	7.1	141.4		
	6.9	141.7		
	7.3	141.1		
	7.8	140.3		
	7.6	140.7		
	7.7	140.5		
	8.6	139.1		
	Mean: 6.5	Mean: 142.3	Mean: 3.2	Mean: 149.9

	Air Voids (%)	Density (pcf)	Field Air Voids (%)	Field Density (pcf)
Gilsonite	4.9	145.6	4.6	147.6
	5.1	145.4	4.8	147.3
	5.2	145.2	5.1	146.8
	4.9	145.7	4.4	148.0
	5.9	144.1	3.8	148.9
	5.3	145.0	4.6	147.6
	4.1	146.8		
	4.8	145.7		
	5.2	145.1		
	4.7	146.0		
	5.3	145.0		
	5.1	145.3		
	4.9	145.6		
	4.5	146.3		
	4.8	145.7		
	4.3	146.6		
	4.2	146.7		
	4.6	146.1		
	4.3	146.6		
	5.5	144.7		
	4.5	146.2		
	4.8	145.8		
	4.9	145.6		
	4.8	145.8		
	3.8	147.3		
	4.2	146.7		
	3.8	147.4		
	5.1	145.4		
	4.5	146.3		
	4.6	146.2		
	4.8	145.8		
	4.5	146.2		
	4.4	146.5		
	4.6	146.1		
	4.3	146.5		
	4.7	145.9		
	4.2	146.7		
	5.2	145.2		
	4.5	146.2		
	4.9	145.6		
	Mean: 4.7	Mean: 145.9	Mean: 4.6	Mean: 147.7

	Air Voids (%)	Density (pcf)	Field Air Voids (%)	Field Density (pcf)
Polypropylene	3.3	147.2	4.6	146.5
	3.0	147.7	4.6	146.5
	3.5	146.8	5.1	145.8
	4.2	145.9	4.8	146.3
	3.9	146.2	4.7	146.5
	4.1	145.9	5.0	146.0
	4.1	146.0		
	3.9	146.3		
	3.3	147.2		
	3.7	146.5		
	3.2	147.4		
	3.6	146.7		
	4.2	145.8		
	5.0	144.6		
	5.0	144.6		
	5.1	144.4		
	5.1	144.4		
	6.0	143.0		
	5.3	144.1		
	6.3	142.5		
	6.0	143.0		
	6.0	143.1		
	5.6	143.7		
	6.5	142.3		
	5.0	144.6		
	5.7	143.5		
	6.9	141.7		
	6.3	142.7		
	6.1	142.9		
	6.4	142.4		
	7.4	140.9		
	3.0	147.7		
	2.8	148.0		
	3.8	146.4		
	Mean: 4.8	Mean: 144.9	Mean: 4.8	Mean: 146.3

	Air Voids (%)	Density (pcf)	Field Air Voids (%)	Field Density (pcf)
Vestoplast	3.2	147.3	3.8	149.2
	3.4	146.9	3.9	149.0
	2.8	147.9	4.1	148.8
	2.9	147.7	3.3	149.9
	2.3	148.7	3.5	149.8
	3.2	147.2	4.1	148.7
	2.6	148.1		
	2.8	147.8		
	4.3	145.6		
	3.7	146.4		
	2.8	147.9		
	3.2	147.3		
	3.5	146.7		
	1.9	149.2		
	2.7	148.0		
	2.7	147.9		
	3.3	147.0		
	3.8	146.3		
	3.4	147.0		
	3.6	146.6		
	4.7	145.0		
	3.7	146.4		
	3.4	146.8		
	3.7	146.5		
	3.5	146.8		
	3.8	146.4		
	4.0	146.0		
	4.2	145.7		
	3.9	146.1		
	3.9	146.1		
	6.8	141.8		
	5.3	144.0		
	4.1	145.9		
	Mean: 3.0	Mean: 147.5	Mean: 3.8	Mean: 149.2

Appendix G - Modified Asphalt Performance Data Base

TABLE G1. FILLERS/REINFORCING AGENTS/EXTENDERS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Reinforcing Agent	American Gilsonite	Gilsonite HMA Modifier	8-10 lb/ton of hot mix	Standard plus 15 sec	Meltable bags, 50 lb bags, bulk bags or bulk	Standard	Increases stability, reduces rutting and shoving. Improves asphalt/aggregate bond.
Carbon Black	Cabot Corp.	Microfil 8	10-15%, by weight of the asphalt binder	Normal	Polyethylene bags or pre-blended with asphalt for tank truck delivery	Normal	Improves durability, increases resistance to rutting and deformation, increases resistance to load associated or non-load associated cracking of asphalt mixes.
Natural Asphalt	Ziegler Chemical & Mineral	Gilsonite	10% substitution of asphalt cement	Standard for drum plant, add 10 sec for batch mixer	Polyethylene or paper bag, or flexible sack	325-375°	Reduces pavement instability due to asphalt plasticity at elevated temperatures. Stiffens the asphalt to reduce rutting, shoving, and pushing.
Reinforcement Fiber	Forta Corp.	Forta AR (ES-6)	1 lb/ton	Standard, add 10 sec dry mixing	2 lb/bag, 8 bags/box, 128 bags/pallet	Standard	Modifies cracking mechanism, increases fatigue strength.
	GFC Materials	Petroflex	3-6 lb/ton	10-15 sec dry mix; 30-45 sec wet mix	Polyethylene bags or bulk cartons	Standard	Provides mix reinforcement; fiber metering equipment available.
	Hercules	Fiber Pave	6 lb/ton	Standard	Custom bags	280-305°	Fibers are easily dispersed; retard cracking, rutting, shoving, and raveling.
	Kapejo	BoniFibers	2.5-7.5 lb/ton as a function of traffic density	60 sec total (30 sec dry, 30 sec wet)	5, 7.5, 10 and 15 lb bags; and custom bags	DOT requirements	Resists reflective and thermal cracking, rutting, shoving and pothole formation.
	Mitchell Fibercon	Fibercon	20 lb/ton	Standard	40 or 50 lb boxes	275-300°	Increases stability, elasticity and heat transfer. Reduces rutting and shoving.
	Phillips Fibers Corp.	Petrofiber	as specified 3-6 lb/ton typically	Standard	12, 18 and 24 lb bags	270-300°	Retards reflective and thermal cracking. Increases resistance to rutting, shoving, and fatigue life.
Cellulose Fiber	J. Reitenmaier & Son (Germany) Agent ScanRoad Inc.	ARBOCEL VIATOP	0.3-0.6% by wt. total mix	Normally increases mix times 6-10 sec	1 kg. meltable poly bags for batch plant's or pelletized for drum mix plants	Dependent on mix type and AC grade	Used thruout Europe in special HMA applications i.e.: Stone Mastic Asphalt and open graded friction courses.
Sulfur (sulphur)	The Sulphur Institute/ Various Producers	Sulfur	1-3%	Standard	50 lb bags 3000 lb bags; bulk containers	265-300°	Reduces asphalt content; increases stability; reduces cracking and rutting; improves durability.

TABLE G2. ORGANIC SURFACE-ACTIVE COMPOUNDS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Organic Polyamine	Morton International	Pave Bond	0.25-1.0%	Premix in AC	Drum, bulk	NA	Increases durability of the pavement.
Polyamine Mixture	ScanRoad, Inc.	Kling-Beta LV (HM)	0.25-1.0% in AC	Premix in AC	Drum or bulk	Standard	Improves durability, reduces moisture for difficult aggregates.
	ScanRoad, Inc.	Perma-Tac	0.5-1.0% in AC	Premix in AC	Drum or bulk	Standard	Three products for various asphalt-aggregate combinations. Improves Lottman values.
	ScanRoad, Inc.	Kling-Beta-KY Kling-Beta-XX	0.25-1.0% in AC	Premix in AC	Drum or bulk	Standard	Designed for limestone and gravel mixes. Reduces moisture damage and susceptibility.

TABLE G3. THERMOPLASTIC POLYMERS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Ethylene Vinyl Acetate (EVA)	DuPont	Elvax	2-4%	Varies	Free-flowing pellets; 50 lb bags or unit loads	275-300°	Increases durability, toughness, tenacity, resistance to cracking.
Styrene-Butadiene (Vulcanized) Binder	Elf Asphalt	Styrelf	Replaces asphalt	NA	Truck transport	NA	Arrives at jobsite ready to use; needs no incorporation equipment.
Ethylene Vinyl Acetate (EVA)	Exxon Chemicals	Polybilt	2-5%	Varies	50 lb bags, 1000 lb boxes and bulk	275-325°	Improves workability, temperature susceptibility and resistance to permanent deformation.
Polyethylene modified asphalt cement	Novophalt America, Inc.	NOVOPHALT	Depending upon application, 4.5-6% of asphalt cement; approx. 0.23% to 0.3% of total hot mix	Standard	Preblended and ready to use. Either blended on site by supplier or delivered in tanker trucks.	300-325°	Improves pavement strength, durability, resistance to moisture damage. Reduces deformation and other forms of pavement distress. No changes required in production, laydown or compaction of hot mix.
Thermoplastic Polymers	Royston Laboratories	Rosphalt 50	45 lb/ton	60-90 sec	22.5 lb bags	425°	Densifies mix for waterproofing layer; extends high and low temperature ranges; adds skid resistance.
Styrenic Block Co-polymer	Shell Chemical	Kraton D, Kraton G	6-9%	15 min or longer, depending on polymer grade and form.	Pellets or powder; in bags or bulk boxes	Kraton D, 320-380°; Kraton G, 320-495°	Reduces permanent deformation and thermal and fatigue cracking. No changes required in mix design, placement, or compaction.

TABLE G4. THERMOSET POLYMERS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Styrene Butadiene Latex	BASF Corp.	Butanol NS 175 Butanol NS 198 Butanol NS 120 Butanol NS 117 Butanol NS 134	1.5-3%	5-10 sec	Drums or bulk	325°	Improves resistance to rutting and cracking.
Polychloroprene	DuPont	Neoprene	1.5-3%	Standard	55 gal drums or bulk	200-300°	Increases elasticity, toughness, tenacity.
Styrene Butadiene Rubber Latex	Goodyear, Textile Rubber & Chemical	Ultrapave 70 Ultrapave 65 Ultrapave 65 K-VC	2-5%	35-50 sec	50 gal drums and bulk tanks	Varies	Makes asphalt less susceptible to temperature changes; reduces rutting and shoving; prevents cracking; improves aging.
	Rub-R-Road	R-504 R-550	3-5%	10-15 sec	Drums, tanks	Above 295°	Adds resistance to rutting.

TABLE G5. THERMOTROPIC POLYMERS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Petroleum-based polymer	LBD Asphalt Products	Ductilad D1004	3%	Standard	Liquid, bulk, or 55 gal drums	Standard	Improves ductility before and after aging. Improves low temperature flexibility.

TABLE G6. AGING INHIBITORS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Asphaltine Peptization Modifier	Akzo Chemicals, Inc.	Redicote AP	0.2-1.0% BWA	NA	Bulk/drum	250°-350°F	Enhances asphaltine peptization; improves asphalt and emulsion performance factors; asphalt compatabilizer reduces air hardening and oxidation.
Anti-oxidant	Lubrizol	Ductilad D1000	0.3-4%	Pre-mix in AC	Liquid, bulk, or 55 gal drums	Standard	Reduces oxidative aging of AC. Reduces age hardening of polymer modified AC.
Lime	National Lime Association/ Various Producers	Lime	1-1.5%	Varies	Bulk	Varies	Reduces age hardening.

TABLE G7. ADHESION PROMOTERS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Metallo-amine Complex	Morton Thiokol Inc., Ventron Div.	CarStab BA-2000	0.5%	Premix in AC	Drum or bulk	NA	Improves adhesion and cohesion of aggregate/asphalt.
Amine Compound	LBD Asphalt Products	Aqua-Shield AS4115	0.25-0.5%	Standard	Bulk, 55 gal drum	Standard	Improves adhesion and cohesion of aggregate/asphalt; works in cutbacks.
	LBD Asphalt Products	Aqua-Shield II	0.25-0.5%	Standard	Bulk, 55 gal drum	Standard	Improves adhesion and cohesion of aggregate/asphalt.
	LBD Asphalt Products	Aqua-Shield III	0.5%	Standard	Bulk, 55 gal drum	Standard	Improves adhesion and cohesion of aggregate/asphalt.
	ScanRoad, Inc.	Kling-Beta 2550 (HM)	0.25-0.5% in AC	Premix in AC	Drum or bulk	Standard	Improves asphalt-aggregate bond. Reduces water damage to pavement.
	ScanRoad, Inc.	Kling-Beta-LV	0.25-1.0% in AC	Premix in AC	Drum or bulk	Standard	Designed for cutback applications. Improve aggregate coating.
	ScanRoad, Inc.	Catimuls 101-AP	0.25-0.5% in AC	Premix in AC	Drum or bulk	Standard	Designed for emulsion applications. Improves coating of anionic emulsions for cold-mix and chip sealing.
	Akzo Chemicals, Inc.	Redicote 82-S Redicote 90-S Redicote 91-S Redicote 95-s	0.5-1.0% BWA	NA	Drum of bulk	NA	Promotes adhesion and resistance to water (antistripping).
Lime	National Lime Association/ Various Producers	Lime	1-1.5%	Varies	Bulk	Varies	Promotes and improves adhesion of asphalt to aggregate.

TABLE G8. LIQUID POLYMERS
(After Reference 1 and 2)

Modifier Type	Producer	Trade Name	Dosage Total Mix	Mix Time	Packaging	Mix Temperature	Attributes
Styrene based Co-polymer	Lubrizol	Ductilad D1002	3%	Standard	Liquid, bulk, or 55 gal drums	Standard or slightly lower	Improves ductility before and after aging. Improves low temperature flexibility.

TABLE G9. SPECIFIER'S GUIDE TO PAVING FABRICS
(After Reference 1 and 2)

Manufacturer	Trade Name	Grab Strength (lbs, ASTM D4362)	Grab Elongation (%, ASTM D4362)	Asphalt Retention (gal/sq yd)	Melting Point (F, ASTM D276)
American Engineering Fabrics, Inc.	AEF 480	90	100	0.20	550°
	AEF 480HS	120	75	0.20	350°
Exxon Chemical Co.	125EX	90	45	0.20	325°
	130EX	100	50	0.20	325°
	150EX	150	50	0.25	325°
Hoechst Celanese Corp.	Trevira 1112	80	50	0.40	485°
	Trevira 1114	100	50	0.40	485°
Phillips Fibers Corporation	Petromat PM-4	105	60	0.20	325°
	Petromat PM-5	130	60	0.25	325°
	Petromat PM-6	155	60	0.30	325°
Polyfelt, Inc.	Polyfelt PGM 13	90	50	0.20	330°
	Polyfelt PGM 15	110	50	0.25	330°
	Polyfelt PGM 20	145	50	0.25	330°
Reemay, Inc.	Reepav	65	>50	Saturated >0.10	>350°
Webtec, Inc.	TerraTex OL-H	90	60	0.20	325°
	TerraTex OL	90	60	0.20	325°
	TerraTex H06	120	60	-	325°
	TerraTex H08	160	60	0.64	325°
Wellman Quline	Hatelit Pavement Reinforcing Grid	400	14	NA	493°

compiled by Sandra Patyk

TABLE G10. ASPHALT ADDITIVES TO CONTROL RUTTING AND/OR CRACKING IN PAVEMENTS
(After Reference 3)

Category	Generic Name	Trade Name or Manufacturer	How Added	Sugg. Conc. (in asphalt)	Approx. Cost Increase per Ton HMAC	References
Synthetic Rubber Type Copolymers	SBR (Styrene-Butadiene-Rubber)	Dow Chemical Goodyear Polysar Ultrapave Finaprene	Added in a mix plant as a separate stream after addition of asphalt cement	3-5%	----	4,5,8,9,10
	SBS (Styrene-Butadiene-Styrene)	Shell Kraton D	Preblended with asphalt cement using high shear	3-5%	$6-10	4,5,11,12
	SBS (Vulcanized)	Styrelf	Preblended with asphalt using high shear	3-5%	$6-10	----
	Neoprene Latex	DuPont	-----	---	----	4
	SEBS (Styrene-Ethylene-Butylene Styrene)	Shell Kraton G	Preblended with asphalt using high shear	3-5%	$10-15	4,5,11
	SEPS (Styrene-Ethylene-Propylene Styrene)	None	-----	---	----	11

Table G10. (continued)
(After Reference 3)

Category	Generic Name	Trade Name or Manufacturer	How Added	Sugg. Conc. (in asphalt)	Approx. Cost per Ton HMAC	References
Polymers	Polyolefins a. Polyethylene	Novophalt 3M-Asphadur	Preblended with asphalt cement using high shear	5%	$5	4,5,13,14,15,17, 18,19
	b. Polypropylene	None		----	----	4,5
	Polysulfides Polyisoprenes Polybutenes Polybutylene	None	------	----	----	4,5
	Nylon and polyner resin byproducts	Solar Laglugel	------	----	----	20,21
Copolymers	EVA (Ethylene-Vinyl Acetate)	Exxon-EX 042 DuPont-Elvax	Preblended with asphalt cement using high shear	3-5%	$3-5	6,22
	Unknown	Accorex	Preblended with asphalt shear using high shear	1% by wt. of mix	$20	23
	Polyisobutylene & Polyvinyl acetate EDPM (Ethylene-Propylene-Diene-Monomer)	None	------	----	----	----

Table G10. (continued)
(After Reference 3)

Category	Generic Name	Trade Name or Manufacturer	How Added	Sugg. Conc. (in asphalt)	Approx. Cost per Ton HMAC	References
Dry Powder	Carbon Black	Cabot-Microfil-8	Batch Plant-Preweighed poly-ethylene bags Drum Plant-High shear blended in asphalt cement with dispersing agent	10-15%	$8-10	24,26
	Hydrated Lime	Several	Slurry on aggregate	1% by wt. of mix	$2	----
Organic Metallic Complex	Manganese (exact formulation propietary)	Chemkrete-Lubrisol	Preblended with asphalt cement using low shear	2-4%	$2-5	26,27
Acrylics	------	Rhom & Haas	Note: Not presently marketed as an asphalt additive but may be soon	---	----	----
Anti-Oxidants	Lead and Zinc diethyldithio-carbonate Lead diamyldithocarbonate Lead and Zinc-dialkyl-dithiocarbonate	------	Preblended with asphalt using low shear	1-2%	$2-3	28,29,30,31,32

TABLE G11. SUMMARY OF EFFECTS OF ADDITIVES ON ASPHALT CEMENT
(After Reference 3)

Trade Name	Laboratory Data						
Latex (SBR) (Ref. 5)	Base Bitumen	Percent Latex by wt. Asphalt	Penetration @ 77°F	$T_{R\&B}$, °F	Fraax Bk. Pt., °F	Plasiticity Range,°F	Penetration Index
	60/70 Bitumen	0%	64	129	3	126	+0.42
		5%	53	145	5	1405	+1.76
		10%	42	156	7	159	+2.30

Trade Name	Base Bitumen	Percent Latex by Wt. Asphalt	Penetration		$T_{R\&B}$, °F	Ductility (39.2°F)
			39.2°F	77°F		
Latex "Dow Downright" (SBR) (Ref. 7)	AC-10	0	23	65	115	2
		3	24	61	129	11
		5	27	56	137	150
	AC-20	0	15	42	118	1
		3	16	37	129	8
		5	18	36	131	14

Trade Name	Base Bitumen	Percent Latex by Wt. Asphalt	Penetration		Viscosity		Ductility (39.2°F)	Sp. Gr. (77°F)	Flash C.O.C.	Brittleness
			32°F	77°F	140°F	275°F				
Latex Goodyear & Polysar (SBR) (Ref. 8)	AC-5	0	4	145	473	1.8	14	1.018	600	56
		2% of pliopave	4	133	776	4.6	141	1.014	600	45
		2% of polysar	12	131	769	4.0	110	1.014	600	39
	AC-10	0	2	95	899	2.5	6	1.023	600	55
		2% of pliopave	3	83	1709	5.3	46	1.019	600	50
		2% of polysar	3	85	1388	4.8	33	1.017	600	50

Table G11. (continued)
(After Reference 3)

Trade Name	Laboratory Data						
	Base	Condition	Penetration		$T_{R\&B}$ (°F)	Ductility (39.2°F)	Toughness
			32°F	77°F			
Latex Goodyear Ultrapave (SBR) (Ref. 9)	85-100 pen	Untreated	25	97	117	10	15
		Treated	27	80	128	+150	90
	100-120 pen	Untreated	26	106	112	-	-
		Treated	32	90	125	-	-
	120-15- pen	Untreated	38	127	110	-	-
		Treated	35	109	123	-	-

Trade Name	Base Asphalt	% of Additive by weight	$T_{R\&B}$ (°F)	T_{FRAASS} (°F)	Plasticity Range	Penetration Index
SBS Rubber (Ref. 5)	40/50 Asphalt	0	129	9	120	-0.5
		5%	165	-13	178	+3.5

Trade Name	Base Asphalt	% of Add. by wt.	Penetration (°F)	$T_{R\&B}$ (°F)	Ductility (39.2°F)	Toughness	Tenacity	Viscosity				P.I.	Pen-vis No.
								176°F	212°F	248°F	275°F		
Shell KRATON D (SBS) (Ref. 11,12)	AC-5 (Shell Wood River)	0	164	106	10	26	6	6800	1400	480	-	-	-
		3	84-124	120-161	20-53	53-153	26-117	16800-112500	3300-5250	1000-1300	-	-	-
	AC-5 (Exxon)	0	128	112	31	17	10	78	-	-	250	-0.9	-0.9
		3	100	121	98	85	67	560	-	-	570	0.5	0.2
		6	78	193	91	171	141	-	-	-	1675	6.8	1.0

Table G11. (continued)
(After Reference 3)

Trade Name	Laboratory Data									
Shell KRATON G (SEBS) (Ref. 11)	Base Asphalt	% of Add. by weight	Penetration (77°F)	$T_{R\&B}$ (°F)	Ductility (39.2°F)	Toughness	Tenacity	Viscosity		
								175°F	212°F	248°F
	ac-5 (Shell Wood River)	0	164	106	10	26	6	6800	1400	480
		3	83-177	126-151	12-21	55-92	16-74	18500-22000	3900-4400	1200-1400
Shell KRATON D (SIS) (Ref. 11)	Base Asphalt	% of Add. by weight	Penetration (77°F)	$T_{R\&B}$ (°F)	Ductility (39.2°F)	Toughness	Tenacity	Viscosity		
								176°F	212°F	248°F
	AC-5 (Shell Wood River)	0	164	106	10	26	6	6800	1400	480
			97-106	122-135	12-45	62-127	30-96	12600-37000	2700-4100	800-1000
Novophalt (polyethylene) (Ref. 14)	Base Asphalt	% of Add. by weight	Penetration	Viscosity				Ductility (39.2°F)	Solubility in Trichloroethylene	Flashpoint °F
				39.2°F	77°F	140°F	275°F			
	Unknown	0	83	1434	1420	1362	354	4.7	99.92	615
		Unknown	68	1850	2190	3752	957	3.25	95.72	620
3M Asphadur (polyethylene) (Ref. 15)	Base Asphalt	% of Add. by weight of Asp.		Penetration (77°F)		Ductility (77°F)	$T_{R\&B}$ (°F)		Viscosity (140°F)	
	120/150 Pen.	0		68		150+	120		1192	
		6		59		125	123		1998	

Table G11. (continued)
(After Reference 3)

Trade Name	Laboratory Data						
	Binder	Pen 77°F	R & B °F	Temperature °C		After RFTOT	
				For Viscosity of 2 Poise	For Viscosity of 50 Poise	Pen 77°F	R & B °F
EVA (Athylene Vinyl Acetate) (Ref. 4)	Conventional Bitumen (A)	56	126	174	112	37	142
	(94%A + 6% 300pen) + 5% EVA	42	154	184	115	33	165
	(78%A + 22% 300pen) + 5% EVA	51	145	178	109	38	158
	A+ 2% EVA	52	140	181	117	32	154
	A + 3.5% EVA	41	147	186	116	29	160
	A + 5% EVA	35	158	195	120	26	172

Trade Name	Type	Pen 77°F	R & B °F	Viscosity @ 113°F (poise)
EVA (Athylene Vinyl Acetate) (Ref. 4)	Bitumen	48	131	9.0 x 10^4
	Bitumen + 5% EVA	52	147	3.5 x 10^5

Table G11. (continued)
(After Reference 3)

Trade Name	Laboratory Data	
	% Carbon Black Filler	**Degree of Erosion After 300 Hrs. of UV and Water Spray**
Carbon Black (Ref. 24)	0	Complete erosion in three areas, metal substrate exposed
	2	Complete erosion in only one area
	15	No exposed metal substrate, same alligator cracks

Temperature °F	Viscosity, poises						
	100% 300-400 pen Asphalt	300-400 pen + 21.2 pha' Microfil 25	300-400 pen + 21.2 pha Microfil 8	100% 150-200 pen Asphalt	150-200 pen + 21.2 pha Microfil 25	100% 85-100 pen Asphalt	85-100 pen + 21.2 pha Microfil 8
140	2.4×10^2	5.0×10^2	3.0×10^3	6.0×10^2	1.0×10^3	1.3×10^3	1.9×10^3
77	8.6×10^4	2.8×10^5	1.6×10^6	3.4×10^5	9.4×10^5	1.8×10^6	5.2×10^6
39.2	2.0×10^7	1.9×10^7	5.5×10^7	6.7×10^7	6.0×10^7	-	-

Asphalt Grades and Blends with Carbon Black Filler	Viscosity at 140°F (poise)	Pen. at 39.2°F 200 g., 60 sec.	Pen. at 77°F 100 g., 5 sec.
300 - 400 pen	240	71	277
21.2 pha Microfil 8	6060	52	163
21.2 pha Microfil 25	500	89	257
150 pen	600	40	148
21.2 pha Microfil 25	1020	49	144
85-100 pen	1340	25	67
21.2 pha Microfil 25	1930	32	72

TABLE G11. (continued)
(After Reference 3)

Trade Name	Laboratory Data							
	Asphalt Grade	% Mn	Pen. 100g 5 sec 0.1 mm				Viscosity	
			50°F		77°F		140°F (poises)	140°F poises x 10^3
			Unaged	Aged	Unaged	Aged	Unaged	Aged in Extended RTFOT
Chemkrete (Ref. 26)	AC-2.5	0.00	27	8	200	19	318	207
		0.08	54	8	>330	19	178	250
		0.125	76	8	>330	20	130	199
		0.20	138	7	>330	17	78	1,550
	AC-5	0.00	19	7	128	15	545	-
		0.08	36	6	252	16	303	-
		0.125	51	7	>330	16	225	-
		0.20	95	6	>330	17	120	-
	AC-20	0.00	11	5	50	12	2090	126
		0.08	19	5	98	13	932	404
		0.125	23	5	135	13	575	228
		0.20	44	5	243	13	305	894

TABLE G11. (continued)
(After Reference 3)

Trade Name	Laboratory Data										
Chemkrete (Ref. 26) (Ref. 27)	Grade	Arizona		California		Georgia		Illinois		Virginia	
		Control	Chemkrete	Control	Chemkrete	Control	Chemkrete	Control	Chemkrete	Control	Chemkrete
		AR8000	AR4000	AR8000	AR4000	AC20	AC20	AC20	AC20	AC20	AC20
	Curing	Roadway 1 month	Roadway 1 month	Unknown	Unknown	None	None	None	None	28 days @ 140°F	28 days @ 140°F
	Pen. 77°F 100g 5 sec.	17.5	7.8	16	8	90	138	69	103	43	18
	Viscosity 140°F poises	19,975	300,000+	19,594	104,284	1955	1031	1820	995	5092	108,638
	Viscosity 275°F CS	796	2,823	696	1290	399	295	345	344		
	Ductility 77°F CM	100+	1.1	100+	0					105+	6

Trade Name		Viscosity		Penetration 77°F 100 g. 5 sec.	
Solar Laglugel (Nylon and Synthetic Resins) (Ref. 20)		AC20	Treated	AC 20	Treated
	@ 140°F poises	1970	2075	63	60
	@ 275°F CS	310	328		

TABLE G12. SUMMARY OF EFFECTS OF ADDITIVES ON ASPHALT PAVING MIXTURES
(After Reference 3)

<table>
<tr><th>Trade Name</th><th colspan="8">Laboratory Data</th></tr>
<tr><td rowspan="2">Styrelf
(SBS-Vulcanized)
(Ref. 10)</td><td>Marshall Stability</td><td>Flow</td><td colspan="2">Hveem Stability</td><td colspan="2">Compressive Strength (Dry)</td><td colspan="2">Compressive Strength (Wet)</td></tr>
<tr><td>20% inc.</td><td>0-7% inc.</td><td colspan="2">0-2% inc.</td><td colspan="2">40% inc.</td><td colspan="2">50-70% inc.</td></tr>
<tr><td rowspan="2">Novophalt
(Polyethylene)
(Refs. 13,14, 16,17)</td><td>Marshall Stability</td><td>Flow</td><td>Fatigue Life</td><td>Complex Modulus</td><td>Wheel Tracking Rate</td><td>Indirect Tensile Strength</td><td>Creep</td><td>Permanent Deformation, cm.</td></tr>
<tr><td>20-70% inc.</td><td>20% inc.</td><td>3.2 times inc.</td><td>1-3 times inc.</td><td>50 pen: >2
Novophalt: <0.5</td><td>1.5-2 times</td><td>Significant dec.</td><td>4.35-0.33(40°C)
1.28-0.05(20°C</td></tr>
<tr><td rowspan="2">3M Asphadur
(Polyethylene)
(Ref. 15,18, 19)</td><td colspan="2">Marshall Stability</td><td colspan="2">Flow</td><td colspan="2">Indirect Tension Strength @ 140°F</td><td colspan="2">Cold Water Abrasion Test (9)</td></tr>
<tr><td colspan="2">7-60% inc.</td><td colspan="2">12-23% dec.</td><td colspan="2">10-70% inc.</td><td colspan="2">30% reduction with 4% of ASPHADUR</td></tr>
</table>

TABLE G12. (continued)
(After Reference 3)

Trade Name	Laboratory Data			
Accorex (Ref. 33)			AC with Accorex	AC Standard
	Hveem Stab.		27	28
	Resilient Modulus psi x 10^3	104°F	100	40
		77°F	750	540
		33°F	2050	2130
	Indirect Tension @ 77°F Ult. Stress, psi		190	150
DuPont Elvax (EVA) (Ref. 22)		Unmodified	95% AC 20 5% Elvax 360	97% AC 20 3% Elvax 360
	Initial Marshall Stabs. lbs.	1155	1175	1007
	After 16 Day Immersion at 140°F Stabs. lbs.	751	1114	980
	% of Initial Stab. after 16 Day Immersion	65.0	98.4	97.3
	% of AC Control Sample After 16 Days	100	148	131

TABLE G12. (continued)
(After Reference 3)

Trade Name	Laboratory Data				
Carbon Black (Ref. 25)		15 parts/100 asphalt Microfil 8	AR 1000	AR 2000	AR 4000
	Compressive Strengths	Dry % of Control	115	98	149
		After Immersion % of Control	173	181	152
		After Immersion % of Dry	61	51	70
Solar Laglugel (Nylon & Synthetic Resins) (Ref. 21)			Control	Treated	
	Marshall Stabs. lbs.		1310	1370	
	Tensile Strength, % Retained After Moisture Treatment		45	65	
	Stripping Resistance % Asphalt Retained 24 hrs. at 60°C		26	47	

TABLE G12. (continued)
(After Reference 3)

Trade Name	Laboratory Data								
Chemkrete (Ref. 26)	Location	Arizona		Colorado		Oklahoma		Wyoming	
	Sample Condition	Control	Chemkrete	Control	Chemkrete	Control	Chemkrete	Control	Chemkrete
	Asphalt Grade	AR 4000	AR 4000	AC-10	AC-10	85-100	85-100	AC-10	AC-10
	Specimen Curing Methods	28 days	28 days	?	?	Road Cores 8 months	Road Cores 8 months	28 days at 140°F	28 days at 140°F
	Marshall:								
	Stab. lbs.	3380	7485	--	--	1709	453	2627	4185
	Flow 0.01"	15	17	--	--	12	13	10	13
	Hveem:								
	Stability	49	61	29	37	48	54	--	--
	Cohesion	373	892	284	310	312	437	--	--
	Unconfined Comp.								
	Str. Dry psi	686	1308	451	598	--	--	396	820
	Wet psi	453	626	281	478	--	--	257	668

TABLE G13. DESCRIPTION OF SELECTED FIELD TESTS ON ASPHALT ADDITIVES (After Reference 3)

Location	Additives Tested	Pavement Section	Summary of Tests and Results
New Jersey Rt 41 & Rt 154	Chemkrete Latex-Dow Solar Laglugel 3M Additive 5990 (polyolefin) Plus Ride (tire rubber) Control Section	$1^{1}/_{2}$" top course $1^{1}/_{2}$" binder course 6" stabilized base	Placed in August 1984. New construction. Sections are 1740′ lf x 36′ wide. After one year in service, all sections are performing well. A few cracks have appeared in the section containing 3M additive which produced relatively stiff lab mixtures. Although rideability is good on all sections, Plus Ride exhibits the worst rideability. Rutting ($^{1}/_{16}$-$^{1}/_{8}$") was noted only in the Plus Ride secion. Approximately 600 tons of each mix was produced using batch plant. Chemkrete (3.3%) was preblended with AC-10. Laglugel (1.3%) was preblended with AC-20. 3M additive and Plus Ride in preweighed plastic bags were added in pug mill following AC-20 at a rate of 8.3 and 60 lb. per ton of mix, respectively. Latex (3%) was metered into pug mill following AC-20. Mixing temperature for 3M, Plus Ride and latex were increased to about 350°F, and were compacted immediately behind paver. Mix production and paving operations went well for all mixtures.
California IH80 near Monte Vista	Shell Kraton D (SBS) Microfil 8 (carbon black) Latex Ramflex (devulcanized tire rubber) Bonifibers (polyester) Hercules fibers (polyethylene)	3" HMAC Fabric 9" PC Concrete 4" Cement Trt. Base	Overlay installed in June 1985 in a mountainous region. Long haul from plant to construction site required production of extra hot mixtures (320-330°F). SBS plus asphalt at high temperatures for a long period apparently resulted in reduced viscosity of binder and tender mixture during construction. Also polypropylene fibers melted. After 3 months in service pavements are performing well. Carbon black section is exhibiting slight flushing; however, it may be about 0.4% more than the design binder content. Test sections = 2000′ in one 12′ lane. Used batch plant. Estimated traffic @ 70,000 -- 18 kip EAL.
Bowie, Texas US 287	Chemkrete Control Section	2" HMAC A-R Sealcoat $1^{1}/_{2}$" HMAC Sealcoat 11" Flexbase	Overlay placed in July 1985, 1.86 mi., 1-lane. No construction or early performance problems. Drum mix plant temperatures ranged from 255 to 200°F. Chemkrete was added to AC-5 in a tank truck with low shear blending. No difference in performance to date.
LaGrange, Texas SH71	Chemkrete Control Section	$1^{1}/_{4}$" RMAC $1^{1}/_{2}$" HMAC Flexbase	Overlay placed in May 1984, 2-mile, 1-lane. Some rain occurred during construction. Asphalt content was too high (5.8% instead of 5.3%) in portions of the test section. Chemkrete was metered in-line into AC-10 prior to entering drum mix plant. Plant temperature about 300°F. Twenty-five percent exhibited excessive rutting and shoving by the middle of the second summer in service. Reconstruction is scheduled for the fall of 1985.
College Station, Texas FM 2818	Shell Kraton G (SEBS) Control Section	$1^{1}/_{2}$" HMAC 2 Sealcoats 6" Flexbase 8" pit-run gravel 6" lime-stab. subgrade	Overlay placed in Spring 1985. Kraton G was preblended with 120-150 pen asphalt at 3% prior to shipping to plant site. One transport of modified asphalt was utilized. No construction or early performance problems. Modified mix was noticeably stiffer than control mix and did not lay as smoothly; however, no difference after 3 months.

TABLE G13. (continued)
(After Reference 3)

Location	Additives Tested	Pavement Section	Summary of Tests and Results
A421 South of Marston Moretain, United Kingdom	Novophalt (Ref. 34)	Sealcoat	In August 1984, tests were performed on a trial section to assess the performance of the product with regard to rideability, rutting and surface texture after two years of heavy trafficking. The rolling straight eadge results satisfied the specifications, and the rideability is good. The surface texture measurements show that there has been little loss of surface texture. The rut depth measurements show no rutting to have taken place in the wheel tracks. The bitumen used was 50 pen grade, straight run containing 4% Novophalt. The handling properties of the material appeared similar to those of "normal" asphalt. The chippings appeared well gripped by the binder. Difficulties were experienced in carrying out tests on binder and also in carrying out analyses when the polyolefins floated in the methylene chloride solution. Mixture was stable at a storage temperature of 320°F. The wheel tracking results indicate that the material is not damaged excessively under heavy traffic. March 1982.
Prater Flyover (section 1220 of the A20 Motorway), Austria	Novophalt (Ref. 34)	Wearing Course	Placed September 1977 with 8% polyethylene. Visual inspections were performed on July and September 1979. 2400 ft long and 90 ft wide. Heavy, high speed traffic. The occasional roughness of the surface is probably due to segregation during the laying process. Adhesion of the chippings to the mortar is excellent. The few cracks that occurred are largely due to the type of the bridge construction. The depth of ruts were only about one third of the rut depth of the next section. The skid resistance measurements did not indicate any significant difference. The increased viscosity of the modified binder would permit an increase of the binder content by 0.5% in absolute terms as compared to conventional asphaltic concrete without any unacceptable deformations. The Marshall values for Novophalt do not differ from the usual values, but the bearing values are approx. 40% higher than the next section. Flow values are accordingly lower and rigidity is twice as high. Because of the high viscosity of the binder, the laying temperature hould be 36°F above the usual value. The test results obtained with recovered bitumen explain the high deformation resistance under the influence of heat as well as the diminished susceptibility to cracking. Tensile splitting tests show a substantial improvement of cohesion at higher temperatures. The resistance to dynamic deformation of the Novophalt surfacing is about three times as high as that of conventional asphalts.

TABLE G13. (continued)
(After Reference 3)

Location	Additives Tested	Pavement Section	Summary of Tests and Results
Crowthorne, Berkshire	EVA (Ref. 5)	2" HMAC	140 tons of asphalt modified with 5% EVA and 50 tons of a conventional 50 pen bitumen were miced and placed. Precoated chippings (20 mm) were applied to all teh asphalts to provide surface texture. The control asphalt was mixed at 355°F and compacted to a thickness of 2". Seventy tons of the EVA modified 70 pen bitumen was mixed at a temperature of 355°F but attempts to roll this asphalt at 320°F failed. Additional loads of the modified asphalt were allowed to cool to between 195°F and 210°F before rolling, and at these temperature the asphalt exhibited good handling characteristics. The remainder of the asphalt containing EVA was mixed at 320°F and compacted at temperatures between 160°F and 210°F. Only when the temperature fell below about 175°F was there difficulty in obtaining sufficient embedment of the precoated chippings. Tests on asphalt mixtures taken from the surface course have shown that resistance to permanent deformation was improved by a factor of between 2 and 6, and showed that EVA also improved the workability of rolled asphalt, allowing it to be mixed and placed at lower than normal temperature. 1982
Arkansas I-30 Saline County	Accorex (Ref. 36)	Not Available	Placed in August 1983. Overlay. a $^{1}/_{4}$ mile section of surface course with Accorex was constructed. Approximately 150 tons of Accorex modified hot mix surface course was placed. The recommended percentage addition was 0.8% by weight of aggregate. The Accorex was added by placing plastic bags of Accorex into the aggregate filled pug mill and mixing. Then asphalt was added and mixed. The compaction temperatures of the control and test sections were approximately the same. Some clumping of the material was seen before compaction but disappeared after rolling. Three months after construction, measurements showed neglible amounts of rutting. No final conclusions can be drawn from this test. However, it has demonstrated that Accorex can be added to a hot mix in a conventional batch plant and placed on the roadway with little or no problems.

TABLE G13. (continued)
(After Reference 3)

Location	Additives Tested	Pavement Section	Summary of Tests and Results
Projects constructed in 1980 Oklahoma Nevada Wyoming New Hampshire Illinois Arizona Nebraska Iowa Virginia South Carolina	Chemkrete (Ref. 12)	Variety of pavement sections	In each of these projects, with the exception of South Carolina, the sections placed with the Chemkrete modified achieved higher strength stability. However, the Chemkrete sections of these pavements exhibited poor low temperature properties which resulted in excessive cracking. Raveling was also noted in the Chemkrete sections of the pavements in Oklahoma and Virginia.
Projects constructed in 1981 Ohio Pennsylvania California New Hampshire Maine Oregon Georgia Colorado Mississippi	Chemkrete (Ref. 9)	Various	In each of these projects, with the exception of Mississippi, the Chemkrete section achieved higher strength adn stability. Chemkrete Technologies, Inc. (CTI) attributes the cracking problems that developed in the 1981 projects to production, mixing and construcion irregularities. After reviewing the performance of 1981 projects, CTI recommended reducing the concentration to one part Chemkrete and 15 parts asphalt.
Projects constructed in 1982 Idaho California Seiling Oklahoma Enid, Oklahoma West Virginia Hawaii Washington, D.C. Alaska	Chemkrete (Ref. 9)	Various	At the time of the report (May 1983), the construction of the 1982 projects had been completed for 8 to 16 months and each project was performing very well except the project in Enid, Oklahoma, where spot failures developed in the Chemkrete section and required patching immediately after construction, and subsequently the entire Chemkrete section had to be overlayed. <u>COST</u> The increase for Chemkrete modified asphalt is $3.25 per ton of mix, <u>plus</u> freight. This amounts to about a 15% increase.

TABLE G13. (continued)
(After Reference 3)

Location	Additives Tested	Pavement Section	Summary of Tests and Results
Springdale-Big Timber, Montana	Carbon Black (15% by wt. asphalt cement) Control Sections (Ref. 37)	4.8" HMAC 2.4" HMAC 16" base	New construction on IH 90 in May 1983 (I90-7(37)350-U2). Treated asphalt concrete surface course was 4.8-inches thick and placed in two lifts. Carbon black (15%) was metered into a blower using a vane feeder and then pneumatically blown into a drum mix plant at the point of entry of the 200/300 pen asphalt. The control sections contained 120/150 and 85/100 pen asphalts. A specially designed device inside the drum was used to aid in mixing the carbon black with the asphalt. There was some loss of carbon black through the plant as evidenced bly the deposit on the water pond from the wet scrubber. Plant temperature and compaction techniques were same for all mixtures. After two years in service there is more rutting in the 120/150 pen section and more cracking in the 85/100 pen section than in the carbon black section.
Ft. Worth, Texas SH121 (6-8 lanes)	Dow Latex Control Section (Ref. 38)	2" HMAC Fabric 8" CRCP	Overlay placed over CRCP in June 1985. Latex (3% solids) was added in drum mixed as a separate stream behind the asphalt stream. Test and control mixes contain AC-10. Plant temperatures increased about 60°F for latex mixes. Job length about 7 miles. ADT = 70,000. Fabric is 6 oz/yd^2 polyelster. After three months in service latex pavement performing well; control pavement showing flushing and $^3/_4$" ruts.
Harlingen, Texas US 83	Shell Kraton D (SBS) Control Section	1$^1/_2$" HMAC A-R Sealcoat HMAC	Overlay placed over asphalt-rubber sealcoat in June 1985. Test pavement one mile in length (1 transport of binder). Modifier consisted of 60% Kraton 1101 and 40% Kraton 1118 in an extender oil (Dutrex 739). Polymer to oil ratio was 50/50. Modifier preblended with AC-10 prior to delivery. Control asphalt was AC-20. Plant temperature for Kraton mixture about 340°F; for control mixture about 300°F. Rained immediately upon completion of test pavement. Currently no difference in pavements.
Kearn Road near South Bend, Indiana	Styrelf 13 (Ref. 39)	1" HMAC surface course 3" base course with additive prepared subgrade	Placed in July 31, 1984. 5.5% of styrelf was added. The mix on this project seemed to hold its heat for quite a long time. The design asphalt content seemed excessive and possibly the design procedure should be reviewed. The base course mix behaved as would be expected once the asphalt content was reduced. The mix exhibited the expected "stickiness" and appeared to be "tough" under the roller. No mixing problems with the batch plant operation.
Mulberry St. Des Moines Iowa	Styrelf 13 (Ref. 40)	1-2" overlay on a city street	Placed on August 12, 1984. One inch thick at the curb line and two inches thick at the center line. The mix was made in a batch plant. The mix seemed to retain heat for a longer time. The finished pavement looked excellent.
test strip near Vandenburg Air Force Base	Latex rubber (Ref. 41)	aggregate surface chipseal on the alligator cracked pavement	A year old test strip indicated that the rubber additive greatly improved low temperature flexibility of the material and drastically increased the tackiness of the emulsion. No excess chips remained on the surface. A 10-year life expectancy or greater is predicted. The present value of chipseal with latex is smaller than the conventional chip seal. Placed in 1976.

TABLE G13. (continued)
(After Reference 3)

Location	Additives Tested	Pavement Section	Summary of Tests and Results
U.S. Highways 60 and 66 in Potter Co. in Texas	Polyethylene 3M-Asphadur (Ref. 42)	3" HMAC 14" flexible base	The project was originally upgraded to multi-lane in 1951. The roadway consisted of three 11 foot lanes west with a 4 foot concrete median strip. The project was overlaid in 1974 with 70 lb/sq yd of asphalt concrete pavement (type F). The concrete median strip was to be removed and the roadway would consist of one 12 foot and one 15.5 foot lane each direction with a 14 foot continuous left turn lane. Stabilized asphalt concrete pavement at hte rate of 150 lbs/sq yd was placed on nigh traffic bolume intersections. The remainder with 150 lbs/sq yd conventional asphalt concrete pavement. The additive was introduced in the pug mill after the aggregate and asphalt had been mixed. 6% bly weight of the asphalt content was used. The temperature selected for the stabilized mix was 375°F. The cost per sq. yd. for the stabilized asphalt concrete pavement was $3.90 with the stabilizing additive being $1.57 or 40% of the cost. No shoving, rutting or movement observed 5 months after the construction.
Test bay at TRRL (pilot-scale experiment) United Kingdom	Novophalt Polyethylene (Ref. 16)	1.6" HMAC w/Novophalt prepared base	Austrian bitumen, with 7% polyethylene was used. Ten tons of hot mix containing Novophalt were used in placing a 1.6-inch pavement 9 feet wide and 100 feet long. Ten tons of similar asphalt containing 50 pen bitumen were placed as a control. Compaction temperatures ranged from 195°F to 330°F; and density, wheel-tracking rate and embedment of coated chippings during rolling, were all improved with increasing compaction temperature. To achieve the similar densities to control, Novophalt required a compaction temperature 72°F higher than the control. The resistance to permanent deformation was improved at all temperatures with the addition of Novophalt. Wheel-tracking rates were reduced by up to a factor of five found in laboratory tests. The texture-depth values for the asphalt with Novophalt were higher than those for the control at all temperature. Novophalt had to have 284°F to achieve reasonable imbedment of chippings whereas control achieved similar results at 18°F to 36°F lower. Test performed in 1982.
Highway inside Vienna, Austria	Novophalt Polyethylene (Ref. 17)	Not available	A 1200 foot roadway exposed to very heavy traffic. Half of the pavement is made with Novophalt, the other half with normal asphalt. Over the last five years, it has been observed that the Novophalt test pavement shows fewer indentations, ruts and deformations and practically no cracking. Placed in 1980.

TABLE G13. (continued)
(After Reference 3)

Location	Additives Tested	Pavement Section	Summary of Tests and Results
Two viaducts on the Appenine and "Trafori" motorways (Autostrada)	Novophalt Polyethylene (Ref. 13)	Wearing course-dimensions unknown	80/100 pen bitumen was modified with 4% and 7% of polyethylene on the Appenine, and only 4% additive was used in the "Trafori" highway because of the colder prevailing climate. In both operations, the compaction temperature was 320°F or greater. Although the working temperatures were always higher than those specified, the test results were not always in line with those desired. From the creep tests, some sections display some tendency toward visco-plastic deformation. In some cases, the wearing course was observed to creep during the passage of the roller. In these sections there was a drop in the compound modulus and an increase in the deformability. The first achievement was that a practically waterproof pavement was obtained, this being evident from the high compaction and low residual voids observed in the core samples. The second achievement was the compounding of asphalt concretes having high machanical strength. Finally, the bitumen containing additive succeeds in maintaining its physio-chemical properties under thermal stress. This self-protection capacity indicates that the polymer is effectively cooperating with the bitumen in the mix. (1983)

TABLE G14. KENTUCKY'S EXPERIENCE WITH MODIFIED ASPHALTS
(After Reference 3)

Location	Additives Tested	Pavement Section	Approximate Cost per ton HMAC	Summary of Tests and Results
KY 338 Boone County	Petro Fiber (polypropylene)	"Class I" Surface	----	Information not available
US 62 McCracken County	Styrelf	1$^{1}/_{2}$" Overlay	----	Information not available
US 25 Kenton County	Gilsonite	"Class I" Surface	----	A standard Class I surface was modified with 8% gilsonite. The modified mix was placed in the two northbound lanes and the center (left turn) lane. Severe potholing occurred in the surface which was blamed on cool temperatures during construction. The surface was milled and replaced with a similar mix.
KY 15 Perry County Report: KTC-89-52 Study: KYHPR-88-119	Class A surface control	1" wearing course	35.28	Several laboratory tests were conducted to compare performance potential of different modified asphalt systems as compared to a control system. Laboratory tests included: Marshall Stability, Resilient Modulus, Moisture Damage Susceptibility, Tensile Strength, and Freeze-Thaw tests. The polymer modified and Vestoplast systems showed more rutting resistance potential than other mixture systems. Rutting resistance potential was not improved as a result of adding fibers. The Class N mixture did not show any significant distress retarding potential over the convential Class A mix. No significant difference in field performance of the test sections was observed after one year in service.
	Class A surface + polymer	1" wearing course	47.28	
	Class A surface + polyester fiber	1" wearing course	47.69	
	Class A surface + polypropylene fiber	1" wearing course	48.59	
	Class A surface + vestoplast	1" wearing course	36.57*	
	Class N surface	1" wearing course	35.78	

* Does not reflect the cost of Vestoplast.

TABLE G14. (continued)
(After Reference 3)

Location	Additives Tested	Pavement Section	Approximate Cost	Summary of Tests and Results
Hazard Bypass and KY 15, Perry County Report: UKTRP-87-35	AC20 with 6% Kraton Polymer (Shell D4460X)	1" surface wearing course	----	The test section was inspected at four and eight months after construction for rutting, shoving, wash boarding, ravelling, cracking, bleeding, and moisture damage. Control section showed more rutting as compared to the polymer modified section; however, the difference was not very significant, only 2.4 percent. Other modes of distress were not fully manifested at the time of these observations.
Louisa Bypass US 23 Lawrence County study: FAR Task 38	AC20 with 6% Kraton Polymer	1" surface wearing course on top of 12" large-stone asphalt base	----	The polymer modified wearing course was applied over half of the project. At the time of observation, after about 10 months in service, no significant mode of distress was apparent at either the control section or the modified asphalt section.

Appendix H - REFERENCES

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