
KTC-89-52

**EVALUATION OF ASPHALT ADDITIVES
ON PROPERTIES OF CLASS A
SURFACE MIXTURES**

by

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in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
U.S. Department of Transportation

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COMMONWEALTH OF KENTUCKY
TRANSPORTATION CABINET
FRANKFORT, KENTUCKY 40622

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AND
COMMISSIONER OF HIGHWAYS

WALLACE G. WILKINSON
GOVERNOR

July 25, 1991

Mr. Paul Toussaint
Division Administrator
Federal Highway Administration
330 West Broadway
Frankfort, KY 40602-0536

Subject: **IMPLEMENTATION STATEMENT**
KYHPR 88-119, Reinforcement of Asphaltic Concrete Pavements and Bases

Dear Mr. Toussaint:

A number of modified asphalt systems were selected for laboratory and field testing in efforts to identify modified mixtures that would be less susceptible to developing rutting, shoving, fatigue cracking, and thermal cracking. The conclusion was that the modified asphalt systems tend to remedy one mode of distress while having no effect, or possibly undesirable effects, on other modes of distress. Field trial sections have not been in service for sufficient time to provide conclusive evidence in this regard.

None of the modified systems have proved to be the panacea for premature signs of distress that had been claimed by some. It was learned that the key to successful applications lies in matching potential benefits of modified systems with specific design and environmental requirements.

Information gained during this study will be used in a continuing effort to design and construct paving systems having improved performance characteristics and increased benefit-cost ratios. Additional study in this area is being conducted under project KYHPR 90-133.

Sincerely,

O.G. Newman R.E.S.
O. Gilbert Newman
State Highway Engineer

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16. Abstract Various modified asphalt mixture systems were selected for laboratory and field testing. These systems included the following asphalt mixtures: Class A mix, as the control mixture; Class N, which is a coarse mixture; polymerized Class A; polyester fiber; polypropylene fiber; and Vestoplast. Laboratory testing included: Marshall stability, resilient modulus, moisture susceptibility, tensile strength, and freeze-thaw. A field trial section was constructed for long-term performance monitoring.					
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EXECUTIVE SUMMARY

Asphaltic concrete pavements at intersections and on steep ascending grades have been observed to develop severe combinations of rutting, corrugations, shoving, and accelerated fatigue. Those distresses have been associated with movements of heavily loaded vehicles in areas where vehicles are typically travelling at lower speeds such as grades and intersections. Some asphaltic concrete pavements also develop transverse surface cracking not readily associated with traffic loading. These cracks, commonly referred to as thermal cracks, are usually regularly spaced and are associated with temperature cycles and thermal expansion and contraction of pavement layers.

Several modified asphalt mixture systems were selected for laboratory and field testing. These systems included the following asphalt mixtures: Class A mix, as the control mixture; Class N, which is a coarse mix; polymerized Class A mix; polyester fiber reinforced Class A mix; polypropylene fiber reinforced Class A mix; and a new European modified asphalt system called Vestoplast. Laboratory testing included: Marshall stability, resilient modulus, moisture susceptibility, tensile strength, and freeze-thaw. A field trial section was constructed on Kentucky 15, Perry County. Performance of this trial section will be monitored under study KYHPR-85-107, Long-Term Monitoring of Experimental Features. Preliminary field performance data are presented, and plans are underway to continue the field monitoring of these sections.

In general, no modified system has proven to be the panacea that some may claim. The key to a successful application of any asphalt modified system lies in matching potential benefit(s) of the modified system(s) with specific design requirements. Polymerized and Vestoplast mixtures indicated desirable properties with respect to resistance to plastic deformation which is a serious problem on coal haul roads in Kentucky. Compatibility, both chemical and physical, of asphalt and modifier is a critical factor and manufacturer's recommendations should be strictly followed.

INTRODUCTION

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.

During 1988-89, several asphalt modified systems were selected for laboratory and field studies. After careful review of available modified asphalt systems, five modified systems and a Bituminous Concrete Surface Class A control hot mix asphalt (HMA) were selected to be included in this study. Modified asphalt systems were selected by personnel within the Division of Materials, Kentucky Transportation Cabinet. A section of Kentucky Route 15 (Perry County) was designated by the Division of Maintenance for the field trial sections.

The construction of field trial sections was monitored and samples of hot mix were collected by the Kentucky Transportation Center (KTC) personnel. A temporary laboratory was set up at the hot mix plant for sampling purposes. This was done to eliminate the need for reheating and associated asphalt hardening of the transported mix. Shortly after construction, pavement cores were collected and rutting measurement monitoring points were selected. Pavement coring and performance monitoring of the experimental sections are expected to continue for the next two years.

The laboratory testing program was designed to address the susceptibility of the selected modified systems to various modes of pavement distress. Testing included Marshall stability, resilient modulus, moisture damage, tensile strength, and freeze-thaw. These tests were selected because of their link to the actual performance of the pavement.

LITERATURE REVIEW

The asphalt additive market is a very active and dynamic one. New asphalt modifier products are introduced worldwide almost on a daily basis. These products are usually introduced along with a battery of trade literature claiming a wide range of benefits and savings that can be achieved from their use over a wide spectrum of traffic, design, and environmental conditions. Most of this information is based upon manufacturer sponsored research and there is little independent information available on the subject.

Researchers at the Texas Transportation Institute, Texas A&M University, (References 1-2) and others (References 3 through 6) have studied this subject in detail. Haas et al. (Reference 3) suggest that the selection of an asphalt additive should be based upon a sound engineering approach. The schematic representation of their suggested approach is depicted in Figure 1. The synthesis of information reflected in the work by researchers at TTI (References 1-2) indicates that the effectiveness of the additive systems can be best evaluated by procedures that are performance indicators. Their approach is consistent with the current Strategic Highway Research Program's (SHRP,

Reference 7) direction of research. Indeed, measurement of performance indicator parameters is the thrust of this study.

LABORATORY RESULTS

The rationale behind the laboratory testing plan was to conduct a set of laboratory experiments which would best describe the actual pavement performance; that is, performance oriented laboratory tests were selected. This approach proved to be effective for characterization of modified asphalt systems by researchers at the Texas Transportation Institute (Reference's 1-2).

The following sections of the report deal with the specific laboratory tests and associated findings. The laboratory tests described below were conducted on laboratory-compacted specimens.

Marshall Stability Test

Marshall Stability is an indicator of rutting resistance (Reference 8). Asphaltic concrete specimens were compacted at the plant site in accordance with the requirements of the Marshall method ASTM D 1559. These specimens were later tested for the following material properties: Marshall stability, resilient modulus, tensile strength, moisture damage susceptibility, and freeze-thaw.

Two sets of Marshall stability data are reported in Figure 2. First, the data that were reported by Kentucky Department of Highways (KYDOH) based upon specimens that were tested shortly after compaction at the asphalt plant. Second, the data that were obtained from specimens that were tested at KTC three months after compaction. It is believed that the higher stability values associated with the KTC data are results of aging/oxidation of asphalt specimens during the storage period.

Figure 2 depicts the Marshall stability of the modified asphalt mixture systems that were included in this study. Results presented in Figure 2 indicate that the polymerized asphalt mix had a significantly higher Marshall stability than other modified systems. It may be concluded that the polymerized asphalt mix would be the least susceptible to plastic deformation as characterized by Marshall stability.

These findings were later verified by resilient modulus tests; that is, a relatively close correlation between the two test results was observed.

Resilient Modulus Test

Elastic modulus is a measure of a material's responses to load and deformation. Modulus of elasticity relates the forces causing deformation to actual deformation. In pavement technology, the resilient modulus has long been used in lieu of the modulus of elasticity (Reference 9).

Generally, higher moduli indicate greater resistance to deformation. A high modulus asphaltic surface layer will also protect the subgrade from being overstressed and therefore it will reduce the probability of subgrade failure.

Figure 3 depicts the summary of resilient modulus test results. Resilient modulus tests were conducted at three temperatures: 32°F, 77°F, and 104°F; ASTM D4123-87 "diametral" testing procedure was followed. As mentioned in the previous section on Marshall stability, the polymerized asphalt mixture is expected to have the least susceptibility to deformation.

It is important to note that in Figure 3 the resilient modulus data points represent the average of three specimens. Each specimen was tested in two orthogonal directions, results were then averaged to represent the resilient modulus of that particular specimen. Resilient Modulus data reported for 77°F were the average of three laboratory compacted, and three field core specimens. Data reported for the 32°F, and 104°F testing temperatures represent field core specimens only; these data were generated by an overlapping study (KYHPR-90-133: Evaluation of Modified Asphalts).

Moisture Damage Susceptibility Test

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 10) 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 11).

The tensile strength ratio, TSR (Reference 11), which is presented in Figure 4, 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 Vestoplast and the Class N mixtures indicated the least amount of susceptibility to moisture damage (i.e. TSR of approximately 95%). Due to the open graded nature of the Class N mixture, one would expect a high degree of moisture susceptibility. However, this was not evident from the TSR test results.

Moisture susceptibility of the fiber reinforced mixtures may be explained in terms of the unsatisfied asphalt demand imposed by the increase in surface area caused by introduction of fibers. This phenomenon should be addressed and remedied by using a rational mix design (Reference 12), in which some or all of the following may be necessary for a successful fiber reinforced asphalt mix design: using higher asphalt content, adjusting the mineral filler content to accommodate fiber surface area, and adjusting the compactive effort.

Tensile Strength Test

Low temperature cracking susceptibility of the mixtures included in this study was characterized using the tensile strength parameter. Tensile strength was measured using the diametral indirect tensile test (IDT). This test simulates the gradual development of tensile stresses due to temperature cycles in a pavement (Reference 13). If these stresses exceed the tensile strength of the asphaltic course, thermal cracking is likely to occur. Results of tensile strength tests are summarized in Figure 5. These results indicate that the polymerized asphalt mixture demonstrated the highest level of tensile strength among the group of modified asphalt systems that were included in this study. This trend was followed by: Vestoplast, Class A, Polyester, Polypropylene, and Class N.

Freeze-Thaw Test

Durability of the modified asphalt systems was characterized using the freeze-thaw test. The indirect tensile strength was used as an index parameter to establish the freeze-thaw durability of various modified asphalt mixes. The criterion was selected to be the rate at which the tensile strength is diminished due to repeated cycles of freeze and thaw. Most modified systems (polymer, Vestoplast, polypropylene, and Class N) demonstrated reasonable levels of durability; that is, minor drop off in the tensile strength as a function of freeze-thaw cycles. The control mix, class A, showed a severe susceptibility to freeze-thaw damage, while the Vestoplast mixture appeared to be least susceptible to freeze-thaw, Figure 6.

It is interesting to note that the Class N open graded mix did not prove to be highly susceptible to freeze-thaw. A possible explanation may be the stress-relieving nature of large voids that are normally present in Class N mixes.

The apparent gain in tensile strength as a function of freeze-thaw cycles that was demonstrated by the polyester system between cycles 0 and 75 is a test anomaly. That is, polyester modified mixtures are expected to behave similar to other mixtures that were studied in this project with a general downward trend in their durability indices.

FIELD TRIAL SECTIONS

The construction of field trial sections took place during late September and early October of 1988. The construction consisted of a series of control and modified asphalt sections as depicted in Figure 7. 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. At the north end of the project, however, there is an intersection which is not part of the experiment.

The following is the mix design information provided to KTC by the Field Control Bituminous Engineer of the Transportation Cabinet.

The station numbers were obtained from daily tonnage reports at the Resident Engineer's Office. The Class A control mixture used was: 50% Slag #8's, 25% Slag Sand, and 25% Natural Sand in conjunction with various additives. A Class "N" mixture was also used. The Class "N" consisted of 60% Slag #67 and 40% limestone sand.

Class "A" Surface (AC-20 Control), Sta. 0+00 to Sta. 26+00
6.5% A.C. - Unit Weight = 137.9 PCF - % Voids = 5.5%
Stability = 2060 lbs. - Flow = .08 in. - VMA = 18.6%
Max. Specific Gravity = 2.341.

Class "N" Surface, Sta. 26+00 to Sta. 79+00
5.0% A.C. - Unit Weight = 141.0 PCF - % Voids = 5.6%
Stability = 2800 lbs. - Flow = 0.12 in. - TSR = 71%
Max. Specific Gravity = 2.395.

Class "A" Surface Polymerized (Kraton), Sta. 79+00 to 140+17
6.8% A.C. - Unit Weight = 137.8 PCF - % Voids = 6.3%
Stability = 2575 lbs. - Flow = 0.12 in. - TSR = 84%
Max. Specific Gravity = 2.357.

Class "A" Surface (Bonifibers) Polyester, Sta. 140+17 to Sta. 163+40
6.8% A.C. - Unit Weight = 137.8 PFC - % Voids = 5.4%
Stability = 1950 lbs. - Flow = 0.12 in. - TSR = 78%
Max. Specific Gravity = 2.335.

Class "A" Surface (Fiber Pave 3010) Polypropolene,
Sta. 163+40 to 184+18
6.8% A.C. - Unit Weight = 137.2 PCF - % Voids = 5.5%
Stability - 2140 lbs. - Flow = 0.14 in. - TSR = 76%
Max. Specific Gravity = 2.327.

Bridge, Sta. 184+18 to 189+18

Class "A" Surface (Vestoplast), Sta. 189+18 to 234+74
6.5% A.C. - Unit Weight = 143.9 PCF - % Voids = 2.6%
Stability = 2600 lbs. - Flow = 0.12 in. - TSR = 90%
Max. Specific Gravity + 2.367.

Bridge, Sta. 234+74 to 237+40

Class "A" Surface (Fiber Pave 3010) Polypropolene,
Sta. 237+40 to 241+50
6.8% A.C. - Unit Weight = 137.2 PCF - % Voids = 5.5%
Stability - 2140 lbs. - Flow = 0.14 in. - TSR = 76%
Max. Specific Gravity = 2.327.

Class "A" Surface (with Slag), All southbound lanes,
northbound passing and Sta. 241+50 to 273+37, slow lane.
5.4% A.C. - Unit Weight = 141.5 PCF - % Voids = 9.3%
Stability = 2085 lbs. - Flow = 0.08 in. - TSR = 75%
Max. Specific Gravity = 2.501.

These results were obtained mainly from specimens compacted in the field. The mixture designated Class "A" Experimental was: 50% #8's from Elkhorn Stone, 20% limestone sand from Nally & Haydon, and 30% slag sand from Heckett Slag.

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 two additional years. At this time, visual observations indicate that the experimental pavement sections have not yet demonstrated any high severity modes of pavement distress.

The rutting measurements are presented in Figure 6. So far, the results are consistent with the laboratory test data which indicate the polymerized and the Vestoplast systems are least susceptible to rutting. Plans are underway to continue the field monitoring of these experimental sections.

COST ANALYSIS

The most important aspect of any justification for an asphalt modifier is its cost/benefit ratio; i.e., do the benefits of the "added performance" justify a first-cost increase of 30%-40%? The answer is largely unknown and that is the primary reason for this research project and other research activities such as the Strategic Highway Research Program (SHRP) contract A-004 (\$3.5 million, 1989-1992). To answer this question properly, one would be required to do a life-cycle cost analysis which would, in turn, require long-term performance monitoring and engineering economic analysis.

A list of unit costs for the mixtures that were included in this project is given on the following page for the purpose of comparison. It is important to note that the Vestoplast material was donated by the supplier; therefore, the unit cost reported for the Vestoplast modified asphalt mixture is not reflective of the actual cost.

Price Per Ton (\$)	Mixture
35.28	Class A Surface
47.28	Class A Surface with Polymer
47.69	Class A Surface with Polyester Fiber
48.59	Class A Surface with Polypropylene Fiber
36.57	Class A Surface with Vestoplast
35.78	Class N Surface

CONCLUSIONS AND RECOMMENDATIONS

Based upon information presented in this report, the following conclusions are made:

1. In general, the modified systems have not proved to be the panacea that some may claim. The key to a successful application of any modified asphalt system lies in matching potential benefit(s) of the modified system(s) with the specific design and environmental requirements.
2. The polymerized and Vestoplast mixes are more desirable than other systems with respect to resistance to rutting.
3. No significant performance improvement was readily apparent from the two fibrous mixes. Indeed, the rutting susceptibility was greater in fiber reinforced mixtures. It is expected, however, that the fatigue cracking and low temperature cracking modes of distress may be retarded effectively by the application of fiber reinforced mixes. This point will be further investigated under a separate study dealing with characterization of effectiveness of modified asphalt mixture systems in Kentucky (KYHPR-90-133).
4. In evaluating the asphalt additives and modifier systems, one should remember that there is no cure all. Only a well balanced design and sound engineering judgement will result in an optimum design compromise between different modes of pavement distress, traffic load, and environmental factors.
5. One may hypothesize that a combination of asphalt modifier systems may prove to be a possible solution to design situations in which a wide spectrum of distress modes are to be covered. That is, a rutting resistant polymerized system may be reinforced by synthetic fibers for additional gain in resistance to low temperature and/or fatigue cracking.

6. Compatibility, both chemical and physical, of asphalt and the modifier is a critical factor (Reference 14). Manufacturer's recommendations should be followed.

~~The following recommendations are made for proper application of modified asphalt systems:~~

1. Field performance evaluation of the experimental sections should continue for an additional two years.
2. A multi-million dollar research effort has been undertaken by the Strategic Highway Research Program (SHRP). Contract SHRP A-004 deals exclusively with the subject of modified asphalts (Reference 9). It is strongly recommended that the progress of this SHRP research be monitored in order to minimize and hopefully eliminate duplication.

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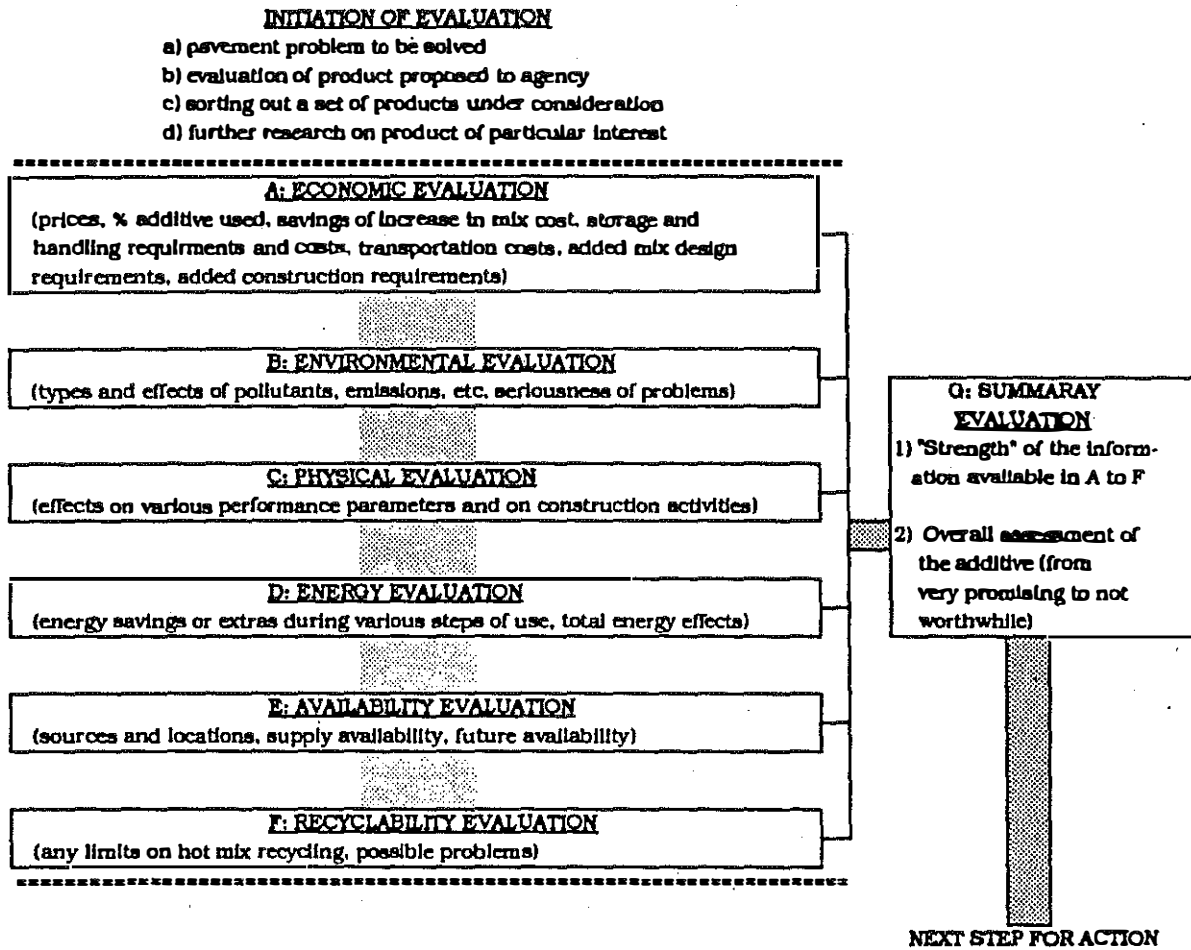


Figure 1. General Framework for Evaluation of Asphalt Additives (after Reference 3).

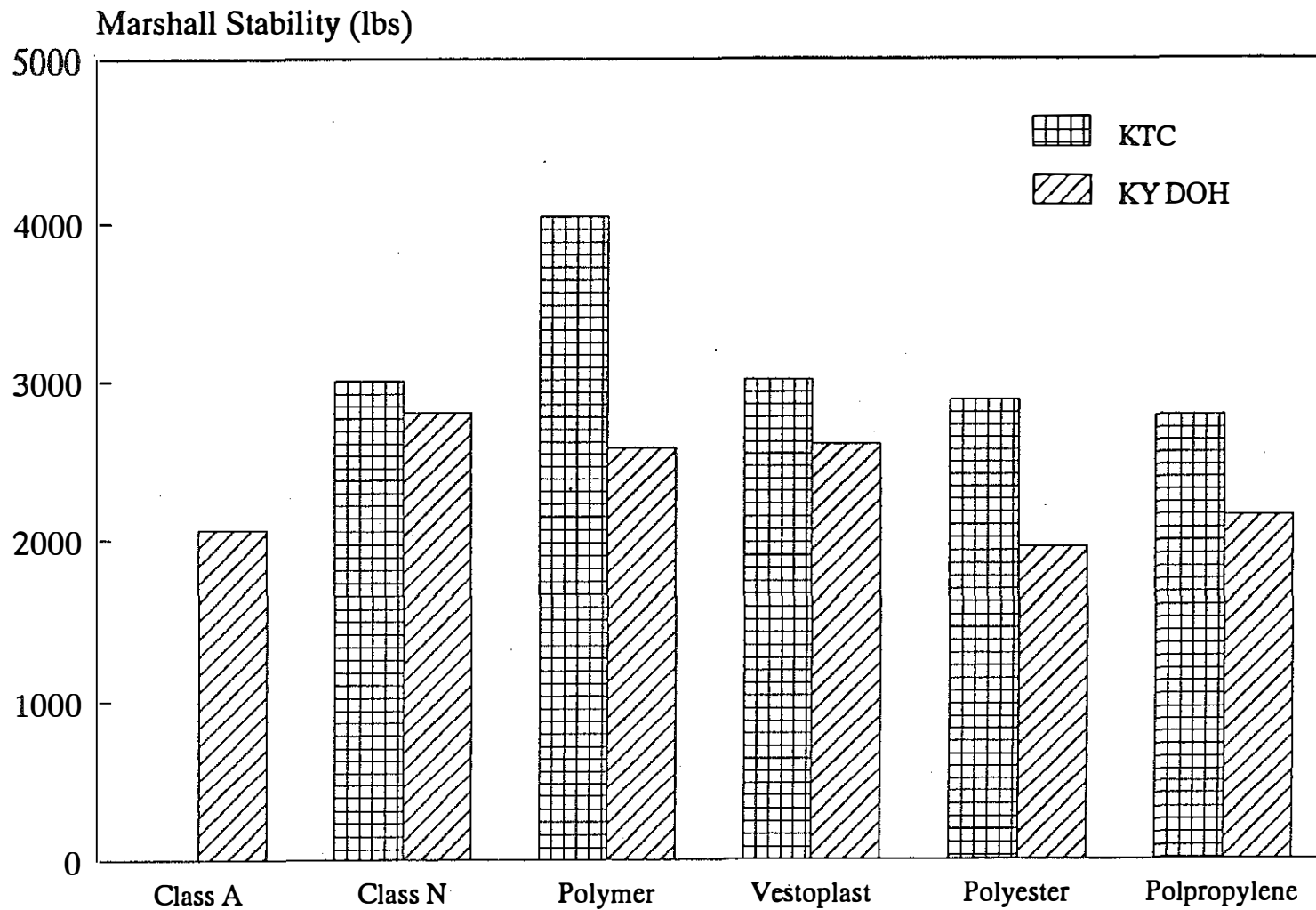


Figure 2. Marshall Stability of Modified Asphalt Mixtures.

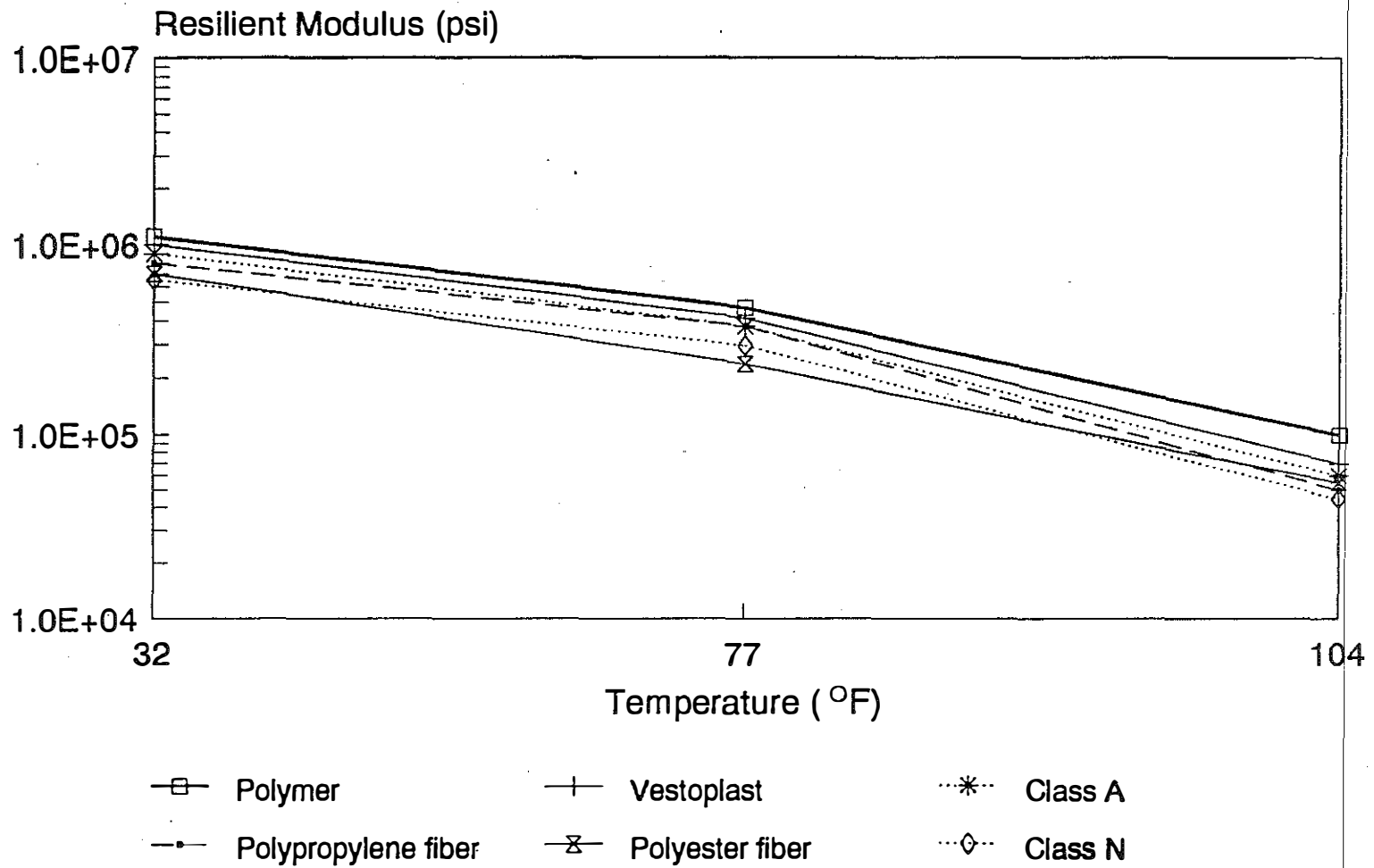


Figure 3. Diametral Resilient Modulus of Modified Asphalt Mixtures.

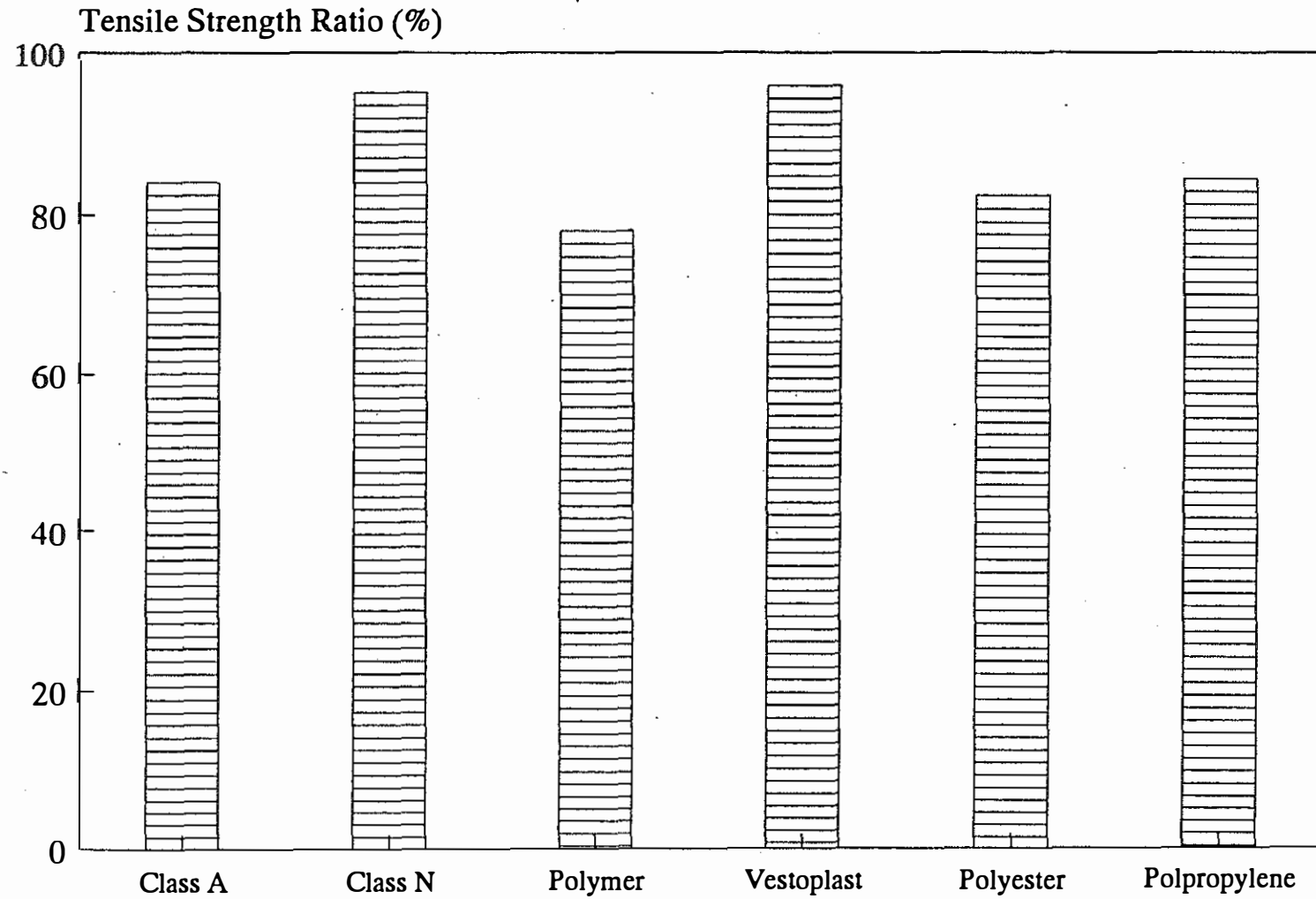


Figure 4. Moisture Damage Susceptibility of Modified Asphalt Mixtures (Ky Method 64-428-85).

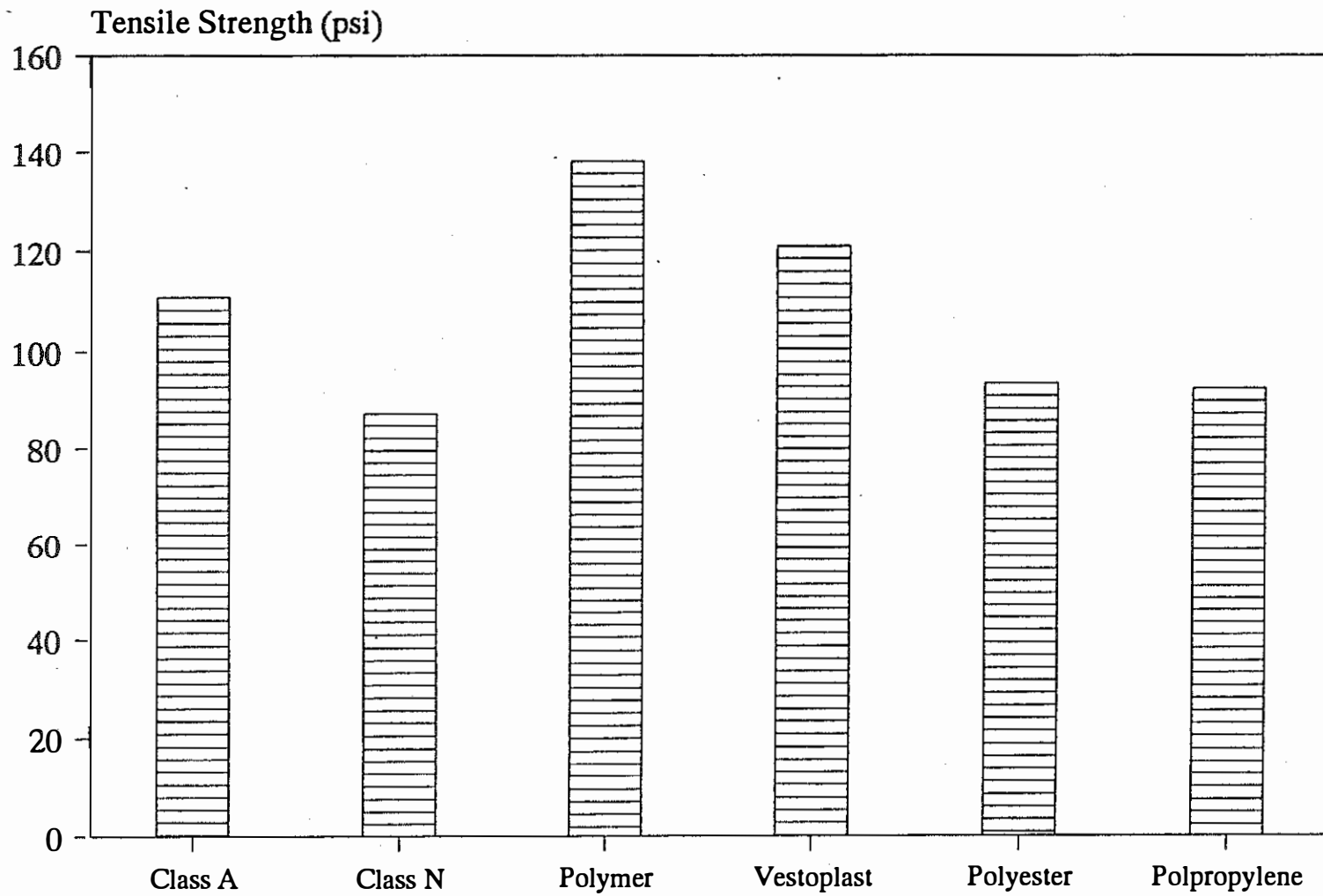


Figure 5. Indirect Tensile Strength of Modified Asphalt Mixtures at 77°F and 2 in/min.

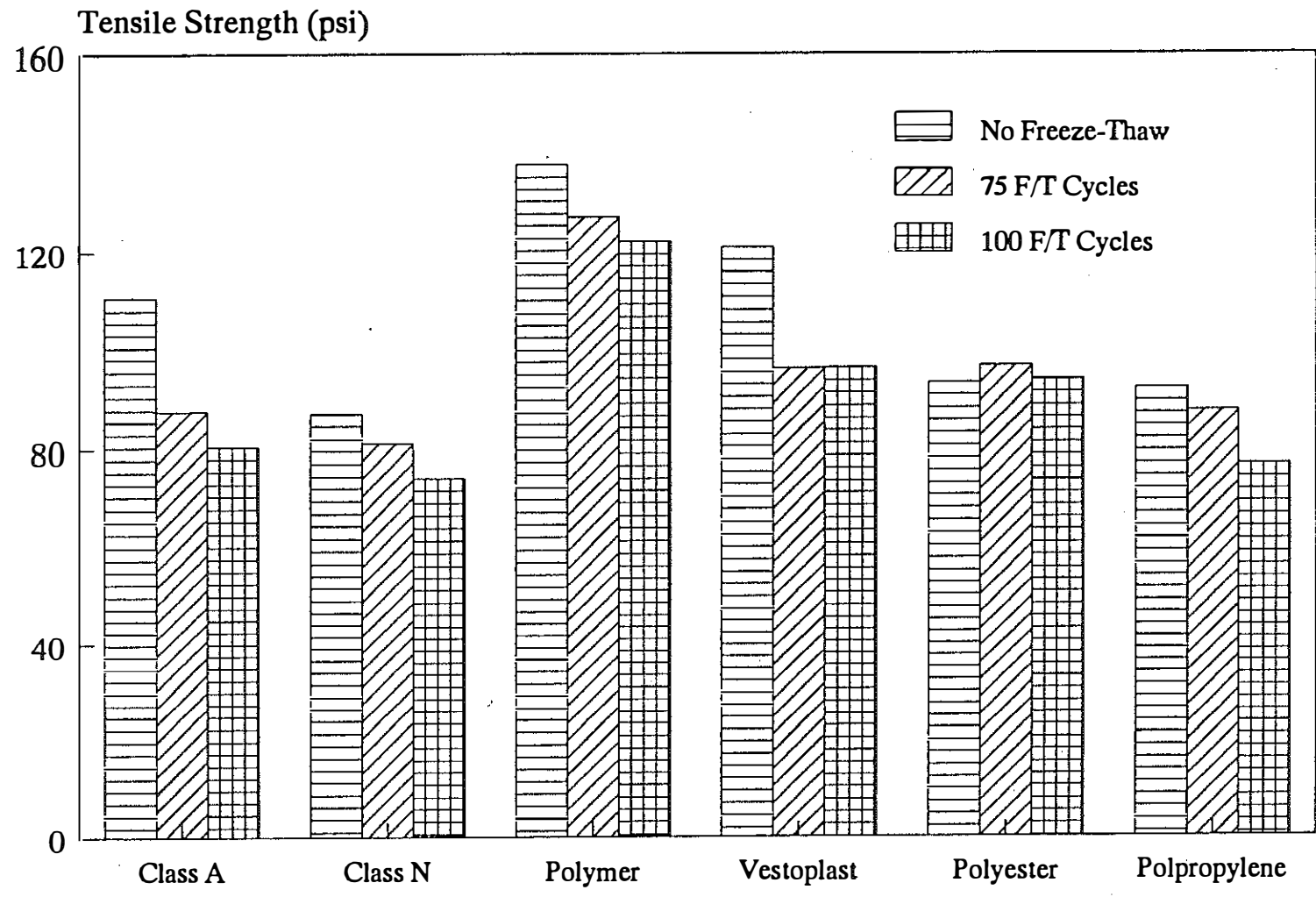


Figure 6. Freeze-Thaw Durability Indices of Modified Asphalt Mixtures.

12' WIDE
BEGIN PROJECT

0+00		BRIDGE END KY 7 OVERPASS
	2600 LF	END CLASS A W/L.S. 8'S
26+00 M.P. 6.5		BEGIN CLASS N
	5300 LF	END CLASS N
79+00 M.P. 7.5		BEGIN POLYMERIZED AC 20S
	6167 LF	END POLYMERIZED AC 20S
140+17 M.P. 8.67		BEGIN POLYESTER FIBER
	2323 LF	END POLYESTER FIBER
163+40 M.P. 9.09		BEGIN POLYPROPYLENE FIBER
	2078 LF	END POLYPROPYLENE FIBER
BRIDGE END 184+18 M.P. 9.49		BEGIN VESTOPLAST
BRIDGE END 189+18 M.P. 9.59		END VESTOPLAST
	4556 LF	BEGIN POLYPROPYLENE FIBER
BRIDGE END 234+74 M.P. 10.45		END POLYPROPYLENE FIBER
BRIDGE END 237+40 M.P. 10.50		BEGIN CLASS A WITH SLAG
241+50 M.P. 10.58		END CLASS A WITH SLAG #8's
	3187 LF	
BRIDGE END 273+37 M.P. 11.138		END PROJECT

Figure 7. Schematic of Field Trial Sections on Kentucky 15, Perry County

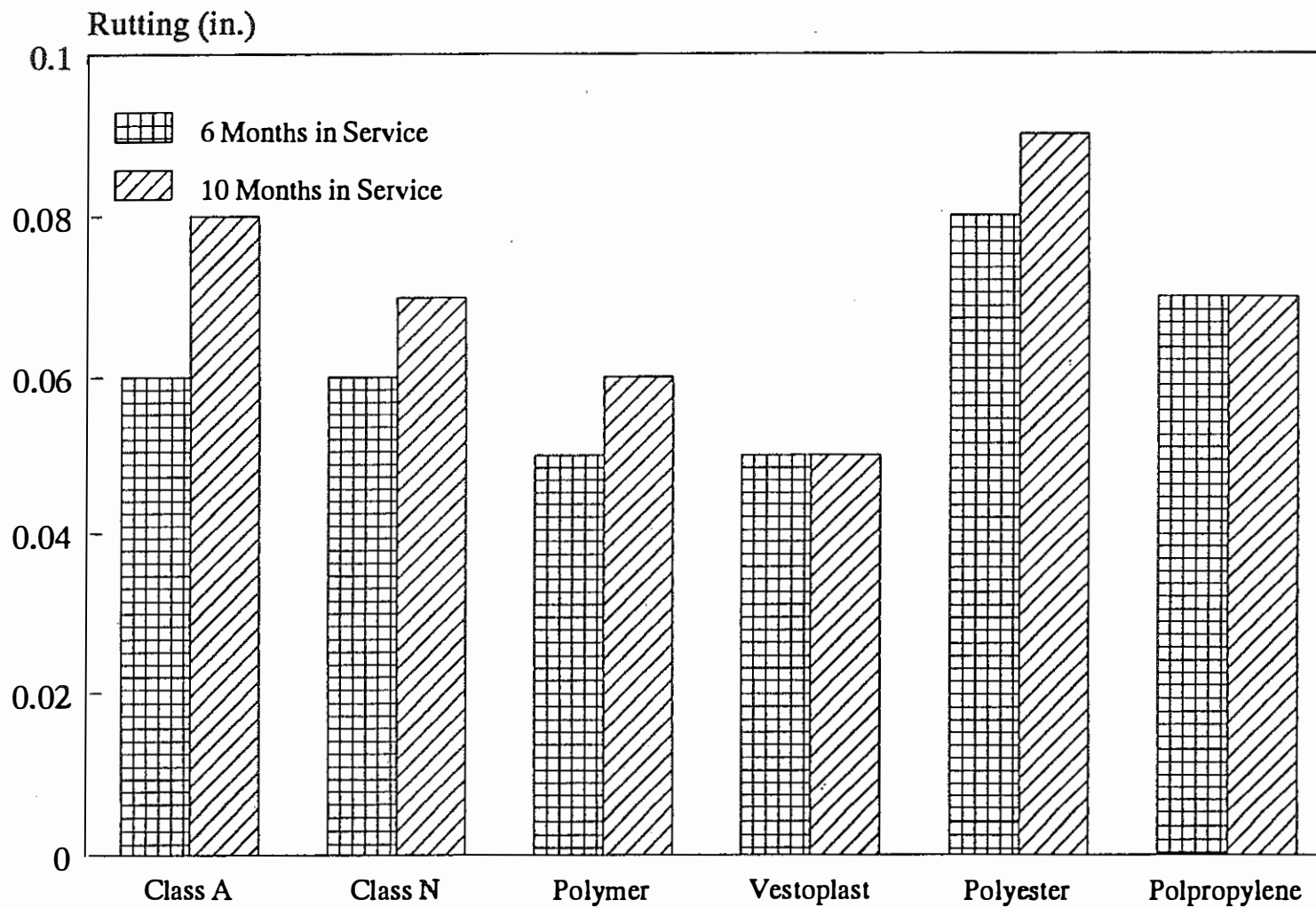


Figure 8. Rutting Measurements of Modified Asphalt Mixtures, Kentucky 15, Perry County.

APPENDIX

Table 1. Marshall Stability Data.

MIXTURE	KTC* MARSHALL STABILITY, lbs. (avg.)	KYDOH** MARSHALL STABILITY, lbs. (avg.)
Class A	-	2,060
Class N	3,000	2,800
Polymer	4,040	2,575
Vestoplast	3,010	2,600
Polyester	2,880	1,950
Polypropylene	2,781	2,140

* Specimens were compacted at the plant and were tested three months later at the KTC laboratory. Some asphalt aging/oxidation is believed to have taken place.

** Specimens were compacted at the plant and were tested shortly thereafter at the KYDOH Division of Materials laboratory. Asphalt aging/oxidation is believed to be minimal.

Table 2. Resilient Modulus Data.

MIXTURE	RESILIENT MODULUS, psi (avg.)		
	32°F	77°F	104°F
Polymer	1,100,000	470,090	100,000
Vestoplast	1,000,000	415,160	70,000
Class A	900,000	375,710	60,000
Polypropylene	800,000	375,700	50,000
Polyester	700,000	237,470	55,000
Class N	650,000	298,010	45,000

Table 3. Moisture Susceptibility Test Data (Kentucky Method 64-428-85).

MIXTURE	TENSILE STRENGTH RATIO, percent
Class A	83.9
Class N	95.0
Polymer	78.0
Vestoplast	95.8
Polyester	82.2
Polypropylene	84.3

Table 4. Tensile Strength Test Data (Indirect Tension at 77°F, and 2 in./min.).

MIXTURE	TENSILE STRENGTH, psi
Class A	110.8
Class N	87.2
Polymer	138.1
Vestoplast	121.0
Polyester	93.4
Polypropylene	92.3

Table 5. Freeze-Thaw Test Data (Indirect Tension at 77°F, and 2 in./min.).

MIXTURE	TENSILE STRENGTH, psi	
	Freeze-Thaw Cycles	
	75	100
Class A	87.7	80.5
Class N	81.3	74.1
Polymer	127.3	122.2
Vestoplast	96.3	96.4
Polyester	96.8	94.0
Polypropylene	87.7	76.8

Table 6. Field Rutting Measurements.

MIXTURE	MIXTURE RUT DEPTH, in.	
	Months in Service	
	6	10
Class A	0.06	0.08
Class N	0.06	0.07
Polymer	0.05	0.06
Vestoplast	0.05	0.05
Polyester	0.08	0.09
Polypropylene	0.07	0.07