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Scott Shuler, Bob M. Gallaway, and Jon A. Epps

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16. Abstract

This report presents a record of asphalt-rubber membrane field performance in Texas. An evaluation of performance is presented for forty-five separate projects in thirteen state highway districts. Approximately 850 lane miles of highways are represented by materials constructed as stress absorbing membranes (asphalt-rubber seal coats) and as stress absorbing membrane interlayers (asphalt-rubber seal coats beneath asphalt concrete overlay). All projects reviewed were constructed between June, 1976 and September, 1981.

A field condition survey was performed at each site and data collected to ascertain pavement surface condition. Four pavement distress modes characteristics of membrane construction are reported. These include flushing, alligator cracking, shrinkage cracking, and raveling. Severity of distress is reported at low, medium and high levels and is further evaluated by calculating distress deduct values for each type of distress. Projects are compared based upon variables of traffic, climate, age, length, substrate, applicator and use (seal coat interlayer). Comparisons are made with performance of asphalt-rubber seal coat and conventional seal coat construction. Data on 148 conventional seal coats throughout Texas were reviewed and a comparison of performance based on the same distress types and environmental variables as with asphalt-rubber is discussed.

17. Key Words
Asphalt-rubber, stress absorbing membrane interlayers, seal coats

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Evaluation of Asphalt-Rubber Membrane Field Performance

by

Scott Shuler

Bob M. Gallaway

and

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Research Study Number 2-9-80-287

Report No. 287-2

Sponsored by the

State Department of

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in cooperation

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United States Department of Transportation

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Texas Transportation Institute

Texas A&M University

College Station, Texas 77843

May 1982

Objectives

The purpose of this investigation was to evaluate the relative performance of asphalt-rubber as a binder in seal coat and pavement interlayer construction. Comparison is made between suppliers of asphalt-rubber seal coats and interlayers and to seal coats constructed with conventional bituminous binders. An objective analysis provides data to fairly compare performance of each system under several field conditions, including traffic, climate, age and others. The results of this study are intended to help provide information concerning the relative merits of asphalt-rubber binders used in seal coat and interlayer construction.

Disclaimer

Acknowledgment

The authors wish to thank the Texas State Department of Highways and Public Transportation district personnel who helped in accumulating the data necessary to compile this report. Special thanks are due those who helped in transporting TTI personnel to field sites and aided in supplying specific data which appear herein.

Abstract

This report presents a record of asphalt-rubber membrane field performance in Texas. An evaluation of performance is presented for forty-five separate projects in thirteen state highway districts. Approximately 850 lane miles of highways are represented by materials constructed as stress absorbing membranes (asphalt-rubber seal coats) and as stress absorbing membrane interlayers (asphalt-rubber seal coats beneath asphalt concrete overlay). All projects reviewed were constructed between June, 1976 and September, 1981.

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Keywords: asphalt-rubber, stress absorbing membrane interlayers, seal coats.

Summary

This report presents a record of asphalt-rubber membrane field performance in Texas. An evaluation of performance for asphalt-rubber is presented for forty-five separate projects in thirteen state highway districts. Approximately 800 lane miles are represented by materials constructed as surface seal coats and as underseals between old pavements and new overlays. All projects reviewed were constructed between June, 1976 and September, 1981.

A field condition survey was performed at each site and data collected to ascertain pavement surface condition was collected. Four distress modes characteristics of membrane construction are reported. These include flushing, alligator cracking, shrinkage cracking, and raveling. Severity of distress is reported at low, medium and high levels and is further evaluated by calculating distress deduct values for each type distress. Projects are compared based upon variables to traffic, climate, age, length, substrate, proprietor and use (surface or underseal). Comparisons are made between products from each proprietor. Also, comparison is made with performance of asphalt-rubber seal coat construction and conventional seal coat construction. Data for 148 seal coats throughout Texas was reviewed and a comparison of performance with asphalt-rubber seal coats based on the same distress types and environmental variables is discussed.

Implementation Statement

Information summarized in this report indicates that asphalt-rubber binders can be effectively used in seal coat construction to reduce alligator cracks and raveling when compared to conventional seal coat performance. However, shrinkage cracking and flushing performance is respectively equal and less desirable than conventional seal coat performance. Surveys of field sites where asphalt-rubber has been applied suggest that great disparity in application occurs during construction which leads to unpredictable performance. This variability in construction practice indicates that more stringent controls be applied to asphalt-rubber construction. Also, it appears desirable to apply seal coat design techniques to determine aggregate spread rates followed by proper binder application rates. The current practice selects binder application rates first and appropriate aggregate quantities for cover are selected afterward. This practice is in conflict with conventional design techniques and may be responsible for a higher incidence of flushing distress on asphalt-rubber projects.

Further research in asphalt-rubber technology is needed to effectively develop a connection between laboratory properties and field performance such that objective construction specifications may be developed with which to exercise the control and design expertise which this study indicates is necessary to effectively utilize this material.

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Preface

Each year about 200 million passenger tires and 40 million truck and bus tires are scrapped. This represents about 2.1 million tons of passenger tires and 1.9 million tons of truck tires annually.

Reclaimed rubber has been successfully blended with asphalt to produce an asphalt-rubber binder for use in pavement construction, rehabilitation, and maintenance. Widespread acceptance of the concept by the engineering community can provide a cost effective and enhanced paving material while utilizing a substantial portion of scrap tires thus converting them to a useful recovered resource.

For definition purposes, asphalt-rubber is a mixture of 15 to 25 percent reclaimed tire rubber reacted with 75 to 85 percent paving asphalt and asphalt modifiers such as extender oils and petroleum solvents. This material should not be confused with the familiar rubberized asphalts that contain 1 to 5 percent of new latex or synthetic rubber.

Experimental sections have been constructed that utilize asphalt-rubber binders for surface treatments, stress absorbing membrane interlayers intended to reduce reflecting cracking in overlays, and as a binder for asphalt concretes and open graded surface courses. Other uses of asphalt-rubber have included crack and joint sealants, roofing products and pond liners. At least 40 states as well as Canada, Australia, and Sweden have constructed experimental sections. There is a general consensus that, when properly formulated and applied, asphalt-rubber is a cost effective binder and, in some cases, is preferred over conventional paving and maintenance materials.

The introduction of granulated rubber into asphalt has been attempted by various investigators in the past with limited success. Charles H. McDonald, Consulting Engineer, Phoenix, Arizona (formerly Materials Engineer with the City of Phoenix, Arizona) is considered to be the father of the asphalt-rubber systems developed in the United States. Mr. McDonald's laboratory work which was initiated in 1963, resulted in the placement of patching materials in the mid 1960's.

These early experiments included the introduction of various forms of rubber (including latex, devulcanized or reclaimed rubber, raw and ground vehicle tire rubber) and various types and percentages of rubber. Because of its lower cost and promising performance in field experiments, the use of ground waste tire rubber was selected for extended studies.

Sahuaro Petroleum and Asphalt Company became interested in the asphalt-rubber product and cooperated in testing for seal coat applications in 1968. From 1968 to 1971, development was directed toward improved procedures for applications. During this time asphalt-rubber test sections were constructed using high boiling point kerosene reacted with the asphalt-rubber mixtures to provide the desired spraying viscosities.

In 1975 Arizona Refining Company (ARCo) began experimental work with asphalt-rubber binder systems. Arizona Refining Company's first experimental section was placed in 1975. The result of the experimental work conducted by McDonald, Arizona Department of Transportation (ADOT), Sahuaro and ARCo has led to the use of asphalt-rubber as a binder system in about 35 states and several Canadian Provinces on over 10,000 lane-miles of roadway.

Of this total mileage, approximately 850 lane miles had been constructed in Texas between June, 1976 and September, 1981.

Two national conferences (1, 2) have clearly shown widespread interest in the application of asphalt-rubber in highway pavements and have addressed both success and failures of experimental projects. These conferences and others have shown the need for additional information on performance, relationships between laboratory developed properties and performance, design techniques for specific applications, specifications and tests for compliance, and construction practices.

Introduction

Asphalt-rubber as discussed in this report consists of a mixture of hot asphalt cement and ground auto or truck tires. The proportion of particulate rubber in the mixture may range from 15 to 25 percent by weight. The ground rubber may be tread, sidewall or whole tire particulate. It may be vulcanized or chemically processed (reclaimed) or combinations of vulcanized and reclaimed. Specifically excluded as part of this study are rubberized asphalt binders which contain 1 to 5 percent liquid latex rubbers.

Two types of asphalt-rubber applications are presented in this report. This first type utilized asphalt-rubber as a binder for surface chip seal coat construction. This application is similar to conventional seal coats except the binder exhibits elastomeric properties. The second utilizes the asphalt-rubber binder for a chip seal coat, but, after construction of the chip seal, an asphalt concrete overlay is applied to the chip seal surface. In this application, the asphalt-rubber seal coat or interlayer as this construction is called, acts as a crack attenuating layer sandwiched between an existing pavement and the new overlay.

Asphalt-rubber seal coats and interlayers have been constructed in Texas since June, 1976. Since then, 29 seal coats and 16 interlayer projects are divided among thirteen highway districts and cover 852 lane miles. This mileage is further divided into 498 lane miles of interlayer construction and 354 lane miles of seal coat construction.

Distribution of asphalt-rubber projects around the state is shown in Figure A-1, Appendix A. More specific information regarding locations appears in Table 1.

Two suppliers provided asphalt-rubber binders for the forty-five projects evaluated. These suppliers will be identified as Product A and Product B for convenience. Product A is asphalt-rubber supplies by Sahuaro Petroleum and Asphalt Company of Phoenix, Arizona. In general, this product consists of vulcanized tread tire rubber, asphalt cement and kerosene. Product B is asphalt-rubber manufactured by Arizona Refining Company of Phoenix, Arizona. In general, this product is a combination of vulcanized and reclaimed whole truck and bus tire, asphalt cement and an extender oil derived from an asphalt maltene fraction. Mixture preparation varies between suppliers but generally, temperatures for mixing is controlled between 30 and 60 minutes.

Construction of asphalt-rubber chip seals and interlayers follows the same techniques used in conventional seal coat application with two primary differences. Spray temperatures are elevated to approximately 375°F and application rates differ for both binder and aggregate chip. Application of the binder has been recommended by the two proprietors at between 0.55 and 0.60 gallons per square yard. Chip spread rates should vary depending upon grade of aggregates used and traffic conditions. Larger aggregates have been recommended to compensate for high asphalt application rate. Recent changes in asphalt-rubber manufacturing techniques, however, have made continued use of these high binder rates questionable.

Performance comparison is made between Product A and B asphalt rubber seal coats and interlayers to evaluate relative proprietary qualities. A comparison of asphalt-rubber chip seal to conventional asphalt cement chip seal performance is made to ascertain relative binder qualities. Further comparisons may then be made of performance for each asphalt-rubber product to conventional materials.

Method of Evaluation

Performance of asphalt-rubber sections was evaluated visually by recording the amount and degree of four distress modes; flushing, alligator cracking, transverse and longitudinal shrinkage cracking and raveling (3). Conventional seal coat performance was evaluated by reviewing data obtained from the Texas Transportation Institute Flexible Pavement Data Base Project 2284. This project is in progress and is designed to survey approximately 350 random pavement sections throughout Texas with which to build a foundation for future pavement management techniques. Without this information, a comparison of asphalt-rubber and conventional construction would have been considerably more difficult.

The performance of each pavement was compared by judging the amount and severity of each type of distress observed. This report presents these data in two ways. The percent of each level and type of distress is compared for each type facility. This gives a subjective indication of performance. Each facility is also rated using a technique described by Epps, et al. (3) where deduct points are assigned to various types of distress. A description of each distress mode appears in the

Table 1. Location of Asphalt-Rubber Membrane Projects in Texas.

District	Project No.	Type	Location
3	1	A-SAMI	US 287, Clay Co. from Henrietta to Bellvue
5	2	A-SAM	SH 114 Hockley Co. from Levelland to Smyer
	3	B-SAM	Loop 289, Lubbock
	4	A-SAMI	US 60, Parmer Co. from Farwell to Bovina
7	5	A-SAM	US 287, Tom Green Co. 2 mi. N. of Carlsbad
	6	A-SAM	SH 208, Tom Green Co. Sta. 205-320
	7	A-SAM	SH 208, Tom Green Co. Sta. 470-545
	8	B-SAM	Loop 306, Tom Green Co. from SW Blvd to US 67 WB side
	9	A-SAM	Loop 306, Tom Green Co. from SW Blvd to RM 584 EB side
	10	B-SAM	US 87, Tom Green Co. Sta. 165 to Sta. 20 WB Sta. 130 to Sta 237 FB US 277 to FM 1223.
	11	A-SAM	US 87, Concho Co. through Eden
	12	A-SAMI	IH 10/US 290, Crockett Co. from Sutton C/L to Taylor Box Rd., 2 mi. E. Ozona
	13	A-SAMI	IH 10/US 290 Kimble Co. from Kerr C/L to 9.7 mi. NW toward Junction
9	14	A-SAM	SH 22, Hill Co. from E. side Whitney dam NE 2 mi.

Table 1. Continued.

District	Project No.	Type	Location
11	15	A-SAM	US 259, Nacogdoches Co. from US 59 to SH 204
15	16	A-SAM	IH 35/US 81, Comal Co. from Hays C/L to FM 306
	17	B-SAM	IH 10/US 87, Bexas Co. from Balcones Cr. to Loop 345
	18	A-SAMI	IH 37 Bexar Co. from IH10 to 2.5 mi. south
17	19	B-SAM	SH 21, Brazos Co. from Loop 158 to 2 mi. W.
	20	B-SAM	US 79, Milam Co. from Milano to 3 mi. E.
	21	B-SAM	US 79, Leon Co. from Marquez to Jewett
	22	A-SAMI	SH 6/US 190, Robertson Co. from FM 391 to Brazos C/L
	23	A-SAMI	SH 36, Washington Co. from Yegua Cr. to Loop 283 Brenham.
	24	A-SAMI	IH 45, Madison Co. from US 75 to Madison Walker C/L
19	25	A-SAM	US 80, Harrison Co. from Gregg C/L to 2.3 mi. W. FM 450 - WB
	26	A-SAM	SH 43, Marion Co. from 0.3 mi. N. Big Cypress Cr. Br. to FM 805
20	27	A-SAMI	US 59, Liberty Co. from Montgomery C/L 4.3 mi. N.

Table 1. Continued

District	Project No.	Type	Location
20	28	A-SAMI	IH 10, Chambers Co. from E. side Old and Lost R. Br. to SH 61
	29	A-SAMI	IH 10, Jefferson Co. from 0.6 mi. SW FM 365 W. 6 mi.
21	30	A-SAM	US 83, Hidalgo Co. from US 281 to FM 907
	31	B-SAM	US 83, Hidalgo Co. from FM 907 to FM 493
	32	A-SAM	US 83, Cameron Co. from Hidalgo C/L to FM 2556
	33	B-SAM	US 83, Cameron Co. from FM 2556 to 1 mi. E.
	34	B-SAM	SH 48, Cameron Co. from Loop 415 to SH 4 EB
	35	A-SAM	SH 48, Cameron Co. from SH 4 to Loop 415 WB
	36	A-SAM	US 83, Hidalgo Co. from Loop 374 to FM 1016, WB[1]
	37	B-SAM	US 83, Hidalgo Co. from Loop 374 to FM 1016, EB[2]

[1]At Loop 374 Product A is in WB lanes. A and B products alternate at 1.0 mi. intervals for remainder of project.

[2]At Loop 374 Product B is in EB lanes. B and A products alternate at 1.0 mi. intervals for remainder of project.

Table 1. Continued.

District	Project No.	Type	Location
	38	B-SAMI	Spur 115, Hidalgo Co. from S. of Hackney Foodway 1.3 mi. S.
	39	A-SAMI	Spur 115, Hidalgo Co. from 1.3 mi. S. of Hackney Floodway S. 1.3 mi.
	40	B-SAM	FM 491, Hidalgo Co. in Mercedes
22	41	A-SAM	US 90, Uvalde Co./Kinney Co. from Uvalde to W. C/L to 4 mi. W. Uvalde/Kinney C/L
24	42	A-SAMI	IH 10, Hudspeth Co. from MP 101 to MP 106
	43	A-SAMI	IH 10, Judspeth Co. from LP 120 to MP 126
25	44	B-SAM	US 62/US 70, Motley Co. from Floyd C/L to Matador.
	45	B-SAMI	US 82, Knox Co. from King C/L to Benjamin

Performance Evaluation section of this report. Deduct points assigned for each level of severity are shown in Table 2. The extent and degree of each of these types of distress are noted in the appropriate location on the rating form shown as Table 3 for each section evaluated (4). For example, if 25 percent of the pavement contains moderate flushing, the number "2" is placed under the moderate column of the flushing portion of the form. If no flushing existed, a zero is placed in the slight column.

The extent of distress for raveling, flushing and alligator cracking is defined as a percent of the lane area displaying this type of distress. If a single wheel path illustrates a particular type of distress continuously, this is normally considered to be about 20 to 25 percent of the area. If two wheel paths illustrate a particular type of distress continuously, this is normally 45 to 50 percent of the area. If a single wheel path has discontinuous distress, it may often be less than 15 percent. The above percentages are based on the fact that a typical highway wheel path is about 3 feet in width.

Longitudinal and transverse cracking are recorded in terms of lineal feet of crack per station per lane and number per station, respectively. A single continuous crack along a highway would indicate that the longitudinal crack length is in excess of 100 feet. Similarly, two continuous cracks along a highway would indicate that the longitudinal crack length is in excess of 200 feet.

Factors Considered by Analysis

Since, for a given pavement, performance varies with traffic and environmental conditions, several independent variables were studied to help explain differences in performance. The difference in performance between suppliers of the asphalt-rubber was of interest since the products supplied by these companies differ substantially in production methods and raw materials used. The type of application, whether a seal coat or underseal was studied to determine the distribution of each type of construction around the state and to evaluate the relative merits of each as a maintenance tool. For each type of application and product applied, other variables were studied to evaluate performance. These included average daily traffic, accumulated lifetime traffic, age, length, substrate, and climatic factors. Average daily traffic was evaluated per lane at three levels; low, 0 to 500 vehicles per day; moderate, 501-1,000 vehicles per day; and high, greater than 1,001 vehicles per day. The levels of traffic volume were selected based on previous study of relative low, medium and high volume (5). Accumulated traffic was measured at three levels: less than 1 million, and over 2 million lifetime vehicles. Facility age was studied at three levels of 0 to 2 years, 3 to 4 years, and 5 to 6 years. Project length was reviewed at three levels of 0 to 3, 4 to 6 and 8 to 56 lane miles. It was desirable to maintain equivalent sample sizes for each level of independent variable. To do this, at times the levels of independent variable became unequal. Project length was not considered a variable for conventional seal coat construction since

Table 2. Deduct Values for Flexible Pavements

Type of Distress	Degrees of Distress	Extent or Amount of Distress (1)	(2)	(3)
Rutting	Slight	0	2	5
	Moderate	5	7	10
	Severe	10	12	15
Raveling	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Flushing	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Corrugations	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Alligator Cracking	Slight	5	10	15
	Moderate	10	15	20
	Severe	15	20	25

Deduct Points for Cracking

Longitudinal Cracking

	Sealed (1)	(2)	(3)	Partially Sealed (1)	(2)	(3)	Not Sealed (1)	(2)	(3)
Slight	2	5	8	3	7	12	5	10	15
Moderate	5	8	10	7	12	15	10	15	20
Severe	8	10	15	12	15	20	15	20	25

Transverse Cracking

	Sealed (1)	(2)	(3)	Partially Sealed (1)	(2)	(3)	Not Sealed (1)	(2)	(3)
Slight	2	5	8	3	7	10	3	7	12
Moderate	5	8	10	7	10	15	7	12	15
Severe	8	10	15	10	15	20	12	15	20

Table 3. Maintenance Rating From for Flexible Pavements.

DISTRICT NO. ☐☐

RATERS ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

DATE MONTH ☐☐ DAY ☐☐ YEAR ☐☐☐☐

LOCATION		FOREMAN NO.		
		HIGHWAY CLASS		
		COUNTY NO.		
		HIGHWAY NO.		
		CONTROL		
		SECTION		
		FROM		
		TO		
		LANE		
		MAYS METER		
PAVEMENT	RUTTING	SLIGHT, MODERATE, SEVERE	% AREA	(1) 1-15, (2) 16-30, (3) > 30
	RAVELING	SLIGHT, MODERATE, SEVERE	% AREA	(1) 1-15, (2) 16-30, (3) > 30
	FLUSHING	SLIGHT, MODERATE, SEVERE	% AREA	(1) 1-15, (2) 16-30, (3) > 30
	CORRUGATIONS	SLIGHT, MODERATE, SEVERE	% AREA	(1) 1-15, (2) 16-30, (3) > 30
	ALLIGATOR CRACKING	SLIGHT, MODERATE, SEVERE	% AREA	(1) 1-5, (2) 6-25, (3) > 25
	LONGITUDINAL CRACKING	SLIGHT, MODERATE, SEVERE	LIN FT PER STA/LN	(1) 10-99, (2) 100-199, (3) > 200
	TRANSVERSE CRACKING	SLIGHT, MODERATE, SEVERE	NO PER STA	(1) 1-4, (2) 5-9, (3) > 10
	CRACKS	(1) SEALED (2) PARTIALLY SEALED (3) NOT SEALED		
	PATCHING	GOOD, FAIR, POOR	% AREA	(1) 1-5, (2) 6-15, (3) > 16
	FAILURES / MILE			(1) 1-5, (2) 6-10, (3) > 10
SHOULDER	PAVED	RIDE, CONTRAST, PAVEMENT EDGE, SHOULDER EDGE, CRACKS, RAVELING, VEGETATION		
	UNPAVED	PAVEMENT EDGE, RUTTING, CORRUGATIONS, LOOSE ROCK		
ROADSIDE AND DRAINAGE		LITTER, MOWING, VEGETATION, SLOPE EROSION, CULVERTS, DITCHES, OUTFALL CHANNELS, ROADSIDE DRAINAGE		
TRAFFIC SERVICE		GUARDRAILS, SIGNS, DELINEATORS, STRIPING, AUXILIARY MARKINGS		
OTHER				

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80

the lengths of the original projects were unknown. The substrate for each construction type was classified as thin flexible, thick flexible or rigid. A thin flexible substrate consists of one or more seal coats with no hot-mixed asphalt concrete in the underlying pavement layer. A thick flexible substrate is any in which asphalt concrete constitutes the underlying pavement layer. A rigid substrate consists of portland concrete. The locations of the projects were classified by three minimum annual temperature levels and two rainfall categories. Minimum annual temperature levels were, -26°F to -10°F, -10°F to +5°F and +5°F to +20°F. Rainfall was classified as greater or less than 35 inches per year (6).

The following discussion serves to review the condition of the asphalt-rubber projects in Texas and compares performance between suppliers and between asphalt-rubber and asphalt cement as binders in seal coat construction.

A visit to each site listed in Table 1 provided data necessary to evaluate the relative performance of each project. Evaluation techniques previously described were used to determine the physical condition of each pavement. This process allowed further comparison of asphalt-rubber performance with conventional seal coats already evaluated within the state using these same evaluation techniques.

Five of the forty-five projects evaluated by this study are part of the FHWA Demonstration Project 37, a series of controlled test sections throughout the country. The remaining forty projects however, were constructed as routine maintenance projects without unusual benefits which sometimes accompany custom experimental pavement sections.

The results of this study therefore, should give a more realistic evaluation of asphalt-rubber materials used as day-to-day construction materials. In addition, it should be noted that, to date, no Texas construction specification exists by which maintenance personnel may routinely control construction on such projects. The specifications for asphalt-rubber come from specific aspects of the supplier of the specific products. Engineers and inspectors are then controlling projects based on directions which originated from the contractor. Except for some construction methods which are similar to conventional seal coat construction, many of the critical asphalt-rubber seal coat operations are alien to the experienced field inspector.

Potential gaps in the control of asphalt-rubber projects exist which will be difficult to close without construction specifications in which pavement engineers have confidence.

Performance Evaluation

The service performance of the asphalt-rubber membranes is presented by observing the effects of several independent variables on four typical distress modes. These distress types are flushing, alligator cracking, shrinkage cracking (longitudinal and transverse), and raveling. A description of each of these distress types as considered by this analysis are as follows:

Alligator cracking is interconnected cracks forming a series of small blocks resembling an alligator's skin or chicken wire. They are often associated with pavements that deflect excessively under traffic loads. The excessive load associated deflection is due to a weak base, subbase or subgrade pavement layer(s) and/or improper design and/or construction.

Evidence based on experiemental test roads (7) suggests that this type distress can be prevented or delayed in overlays of pavements exhibiting alligator cracks if an asphalt-rubber interlayer is placed between the distressed pavement and the overlay. Other reports (8, 9) indicate better performance of asphalt-rubber seal coats placed on alligator cracked pavements than conventional seal coats.

Shrinkage cracking is considered by this report to be cracks in the parallel and transverse to centerline pavement directions caused by expansion and contraction of the pavement during periodic temperature changes and/or moisture changes. Shrinkage cracks in rigid base course, portland concrete or bituminous pavements which have reflected through to overlays will be considered shrinkage cracks in the overlay, as well. This mode of distress is manifested in both asphalt-rubber seal coats and overlays with interlayers. Past research indicates that retarding growth rates of reflection cracks by use of asphalt-rubber interlayers may be inappropriate when overlays are placed on rigid substrates (7). Slab spacing appears to be the key variable which determines rate of success for this application.

Raveling is the progressive loss of surface material by weathering and/or traffic abrasion. In asphalt concrete mixtures the fine aggregate usually wears away first, leaving coarse aggregates in relief. As erosion continues, larger particles eventually break free and the pavement may become rough and jagged in appearance. Raveling is caused by poor construction methods, inferior aggregates, or poor mix design (inadequate) binder). Raveling occurs in chip seal coat construction when aggregates are progressively lost from the seal coat surface. This loss is caused by inadeqaute adhesion of the aggregates and binder. Causes of adhesion loss include improper chip embeddment depth, wet aggregate, cold binder at compaction, and/or combinations of these. In addition to these reasons, asphalt-rubber seal coats may ravel due to an inadequate reaction period or improper blending of rubber particles and asphalt. If the rubber particles are not adequately reacted during the asphalt and rubber mixing period, rubber particles may remain as solid constituents in the mixture. These solid particles then act to impair the adhesive properties of the binder. This condition leads to chip loss due to inadequate cementing capacity of the asphalt-rubber. If blending is not thorough, segregation of the rubber in the mixture may occur and by inadequate dispersion, high rubber concentration will be present at specific locations in the mix leading to inadequate cementing action.

Flushing or bleeding is the presence of excess asphalt at the pavement surface. Pavement mixes rich in asphalt, improperly constructed seal coats, or too heavy a prime or tack coat may contribute to bleeding or flushing. Heavy traffic and/or high traffic volumes may force asphalt to the surface of the pavement in hot weather. This condition may occur in either asphalt-rubber seal coats or in overlays of the interlayers. Due to high asphalt-rubber binder application rates, as suggested by proprietors, aggregate spread rates were supposed to be adjusted accordingly. However, even using large size aggregates, these high binder quantities (0.55 to 0.60 gsy) often are excessive and lead to eventual flushing problems. Bleeding of overlays applied over asphalt-rubber interlayers may occur due to the presence of diluents which act to soften the asphalt concrete binder. This softening leads to easier movement of the binder to the pavement surface under the application of traffic.

Other current modes of distress or indications of previous distress observed during inspection included rutting, and corrugations. These distress types did not predominate and do not represent distress typically induced by seal coat application. Analysis will therefore not include modes of distress other than the four types previously defined.

The independent variables studied to determine differences in asphalt-rubber performance and between asphalt-rubber and conventional seal coat performance are summarized in the outline below:

Independent Variables

A. Material Supplier

1. Product A
2. Product B

B. Application

1. SAM
2. SAMI
3. Conventional Seal Coat

C. Lane Traffic, vpd

1. 0-500
2. 501-1,000
3. 1,001 +

D. Accumulated Traffic, vehicles

1. 0-1,000,000
2. 1,000,001 - 2,000,000
3. 2,000,001 +

E. Age, years

1. 0-2
2. 3-4
3. 5-6

F. Length, lane miles

1. 0-4
2. 5-7
3. 8-56

G. Substrate

1. Thin Flexible
2. Thick Flexible
3. Rigid

H. Location

1. Temperature - annual minimum

    a. -26°F to -10°F
    b. -10°F to +5°F
    c. +5°F to +20°F

2. Rainfall, annual inches

    a. Greater than 35
    b. Less than 35

These variables were selected for study based upon experience with conventional seal coat and overlay construction and the factors which affect performance of these facilities. Groupings for each variable were selected to provide approximately equal sample sizes. Therefore, variable subcategories may not always contain an equal spread of the parameter under consideration.

A statistical analysis of these data is desirable due to the considerable number of combinations possible between independent and dependent variables. This type of analysis was made. However, due to some very small sample sizes, significance of results must be carefully interpreted to avoid erroneous conclusions. Analysis will also be accomplished in a somewhat more subjective manner by observing trends which appear in the data due to changes in material response.

The performance of each project is summarized in Appendix C, Tables C-1 through C-13, by highway district. The data analysis to follow uses the information contained in these tables and in Tables D-1 through D-19, Appendix D, to develop relationships between the independent variables and the related distress modes. A summary of conventional seal coat performance obtained from the Flexible Pavement Data Base is contained in Appendix E, Tables E-1 through E-13.

Analysis

The analysis of asphalt-rubber performance will be presented by reviewing effects of separate independent variables, then by observing interactive effects of multiple variables. The objective comparison of performance between construction methods was accomplished by obtaining a mean and standard deviation of deduct values assigned to each distress type, level of severity and area of extent along the project (6). These deduct values give an indication of the overall level of severity of each distress mode. This deduct value is then used to compare performance of asphalt-rubber for Product A versus Product B and for asphalt rubber versus conventional construction under similar environmental conditions. The results of this comparison appear as tables in an Appendix to this report identifying statistical differences when they exist, between deduct value means. Significance is tested at the 0.05 alpha level using analysis of variance techniques (ANOVA).

Several performance comparisons may be made between suppliers of asphalt-rubber. Product A was compared to Product B in seal coat and interlayer construction, all asphalt-rubber seal coat projects were compared to conventional seal coat projects and Products A and B were compared separately to conventional seal coats. A comparison of this type may be misleading, unless the distribution of data from each source of comparison is equivalent for each independent variable. The distribution of these data is approximately equivalent except for the traffic and climate parameters. By review of Figures A-2 and A-3 it may be seen that conventional seal coats tend to be built on pavements carrying relatively low traffic volumes and low accumulated traffic. Conversely, a higher proportion of asphalt-rubber is used on high traffic volume pavements. However, the proportion of accumulated traffic over the life of the pavements is relatively equal for asphalt-rubber, indicating the high traffic volume facilities are also the newest facilities. The climates where these pavements are found also varies. Figure A-4 depicts the relationship between asphalt-rubber and conventional construction relative to thermal climate. As seen here, each type of construction has approximately equal proportion in the moderate temperature region (-10°F to +5°F annual minimum). However, project proportion is reversed in cold and hot climates (-26°F to -10°F and +5°F to +20°F, respectively). Conventional seal coats tend to be located in cold regions while asphalt-rubber projects tend to hot regions. The proportion of projects in climates having over 35 inches rainfall per year versus those less than 35 inches per year is approximately equivalent as seen in Figure A-5.

A performance comparison of asphalt-rubber seal coats with conventional seal coats is shown in Figure A-6. This figure and the comments shown below assume that construction and environmental conditions all equal for both conventional and asphalt-rubber projects. As will be shown, these operating conditions are not equal. Figure A-6 is provided to give a very general view of overall performance. Data to produce Figure A-6 are included in Table F-1, Appendix F. Review of Figure A-6 indicates the following by percentage basis:

* Flushing - high severity flushing occurs more often in asphalt-rubber seal coats than in conventional

* Shrinkage Cracking - both types of seal coats exhibit similar performance

* Alligator Cracking - conventional seals exhibit low and medium severity more often but similar high severity

* Raveling - conventional seals produce low and medium severity more often, asphalt-rubber, high severity more often

* No Distress - asphalt-rubber displays approximately twice the proportion of projects as conventional at 7 percent to 3 percent, respectively.

These preliminary conclusions must be tempered with the knowledge that asphalt-rubber tends to be found on more high traffic volume pavements and in hotter climates than conventional seal coats. Analysis in this report will be done both on a percentage basis and statistically to give an equivalent picture of performance due these variations in operating environment.

General Performance Comparison

Performance variations between Products A and B for seal coat and interlayer construction will be reviewed next. The distribution of Product A and Product B among the independent variables may be summarized best by observing Figures A-7 and A-8. Figure A-7 indicates an approximately equal distribution between Product A and B in seal coat construction for all independent variables, except that a higher proportion of Product B is found in areas of high traffic volume than Product A. Trends in the interlayer distributions are similar as seen in Figure A-8. Comparisions of general performance between the two suppliers of asphalt-rubber are presented in Figures A-9 and A-10 for seal coat and interlayer construction, respectively. Review of Figure A-9 indicates a higher potential for Product B to flush compared to Product A. However, after reviewing the tables in Appendix B, no statistically significant difference is evident between Product A or B for flushing. Product A leads to a higher percentage of raveling, alligator and shrinkage cracking than Product B according to Figure A-9. The trend toward alligator cracking in Product A is relatively low. Interlayer performance is summarized in Figure A-10. Product A tends to flush more, Product B to crack more.

Comparision of general performance between conventional seal coats and the two suppliers of asphalt-rubber seal coats is left to the reader. By review of the figures previously examined and by accounting for differences in performance between asphalt-rubber supplies, a general comparison of performance between Product A or Product B and conventional seal coat performance is easily accomplished.

Detailed Performance Comparison

To help simplify discussion of the following analysis, asphalt-rubber performance will be compared between Products A and B first. Overall asphalt-rubber to conventional seal coat performance will then be compared. This will allow the reader to more easily evaluate the performance of each rubber product to that of conventional seal coats.

Recall the Product A asphalt-rubber consists of vulcanized rubber asphalt cement and kerosene, Product B consists of combined vulcanized and reclaimed rubber, asphalt cement and liquid diluent. Conventional seal coats consist of asphalt cement or liquid asphalts to which uniformly graded aggregate chips are applied.

Effect of Lane Traffic Volume - Subjective Analysis

The proportion of each product in the three traffic volume categories differ. No asphalt-rubber projects exist where lane traffic is below 500 vehicles daily. A higher proportion of asphalt-rubber projects exist in the 1,000 + ADT category than in the conventional seal coat group. At lane traffic of 501-1,000 ADT a higher proportion of Product A to Product B exists at approximately a 2 to 1 ratio. This trend reverses at over 1,000 ADT as more Product B projects exist at this level.

Figures A-11 and A-12 in Appendix A depict performance of asphalt-rubber for lane traffic of medium and high volume. The principal distress apparent here is flushing, shrinkage cracking and raveling. Product A exhibits these distress modes at medium and high traffic levels. Product B exhibits no apparent distress at medium traffic but displays flushing at high traffic volumes. In general, Product B performs with less cracking and raveling distress than A at either traffic category.

Performance of asphalt-rubber and conventional seal coats is summarized in Figures A-3, A-4 and A-5. Figure A-3 is a review of conventional seal coat performance only.

Figure A-4 shows asphalt-rubber having a higher tendency to flush under 501-1,000 ADT than conventional seal coats. This figure also indicates asphalt-rubber has a higher propensity for shrinkage cracking high severity raveling and numbers of projects with no visible distress. Figure A-5 indicates conventional seal coats tends to flush, crack and ravel more than asphalt-rubber on roads with 1,000 + ADT.

Therefore, by review of distress on all projects on a percentage basis, the following conclusions may be stated:

1. Product A displays more flushing, cracking and raveling than Product B on 501-1,000 and 1,000 + ADT pavements for seal coat construction.
2. Asphalt-rubber seal coats tend to flush, crack and ravel more than conventional seal coats at 501-1,000 ADT.
3. Conventional seal coats tend to flush, crack and ravel more than asphalt-rubber at 1,000 + ADT.

Effect of Lane Traffic Volume - Statistical Analysis

The above conclusions have been verified statistically, the results appear in Appendix B. The tables in Appendix B contain the resultant data after deduct values were calculated for each distress type for all independent variables.

The tables in Appendix B contain mean deduct values for the distress types shown under various conditions. The tables indicate when a statistically significant difference exists between suppliers. (Product A, B and Conventional, C) and between levels of the independent variable studied, e.g., low, medium or high ADT volume traffic. For example, Table B-1 depicts the mean flushing deduct values for suppliers A, B and C under low, medium and high volume ADT. The table indicates that no significant difference exists among Products A, B, or C in the medium and high level columns as denoted by the letters 'NS'. Also, no significant difference exists between medium and high ADT for either Products A or B. However, significant difference does exist between low and medium ADT for conventional seal coats as denoted by the letters 'L/M' in the third row of the table. This means that medium ADT contributes to significantly higher flushing deduct values than low ADT in conventional seal coats. Notice that high ADT develops a slightly lower mean deduct value than medium ADT but is not enough lower to make it significantly different from low ADT or medium ADT. By altering the alpha level of the test static from 0.05 to 0.10 or higher a significant difference could possibly be shown between low ADT and high ADT.

Tables B2, B3 and B4 compare mean deduct values for thermal cracking, alligator cracking and raveling as related to ADT. Review of Table B2 indicates a difference between Product A and Product B and C for thermal cracking. No significant differences exist for alligator cracking as shown in Table B3. Table B4 indicates a difference between Product A and C for raveling in high ADT pavements and also indicates that Product C tends to ravel more on low ADT than high ADT pavements.

There was no difference between asphalt-rubber and conventional performance for 501-1,000 ADT and conventional seal coats tend to perform better than some asphalt-rubber seal coats for 1,000 + ADT.

The results of the statistical analysis suggest that conclusions based on percent distress are only significant for shrinkage cracking where ADT is a variable. Product A displays significantly higher shrinkage cracking distress than either Product B or C on high ADT facilities.

<u>Effect of Accumulated Lifetime Traffic</u> - Subjective Analysis

Flushing is the predominate distress for asphalt-rubber under all three levels of lifetime traffic. Product B flushes more than Product A at all traffic levels. The other distress modes are generally manifested in Product A with shrinkage cracking being most prevalent in low traffic pavements. Figures A-16, A-17 and A-18 depict this relative performance under accumulated traffic. Figures A-19, A-20, A-21 show the relative performance of conventional and asphalt-rubber seal coats. These figures suggest the following:

1. Flushing is the predominate mode of distress for all seal coats.
2. Asphalt-rubber seal coats flush more than conventional seal coats at all traffic levels

3. Shrinkage cracking is more prevalent in asphalt-rubber seal coats for low accumulated traffic than for high accumulated traffic.

4. The proportion of shrinkage cracking is approximately equal for all levels of accumulated traffic on conventional seal coats.

Effect of Accumulated Lifetime Traffic - Statistical Analysis

A statistical comparison of the deduct values indicates no significant difference between performance of any products other than for raveling distress. Table B-8 indicates significantly higher raveling for Product A seal coats than conventional seal coats on pavements with medium and high accumulated traffic.

Table B-5 indicates that Product B has significantly higher flushing distress for high versus medium accumulated traffic. No evidence in Tables B-5 through B-8 indicates that conventional seal coats flush, crack or ravel more than asphalt-rubber as accumulated traffic levels increase from under 1 million to over 2 million as suggested by the figures of Appendix A.

Effect of Construction Year - Subjective Analysis

The age parameter is used to determine if asphalt-rubber formulations have changes relative to performance since 1976. The changes made to each product by the two suppliers over the six-year analysis period are not specifically known for each project, but if major formulation changes have been made, effects on performance may appear in the analysis.

Three categories are studied to analyze the age parameter. The newest projects, those built between November 1979 and November 1981, are presented as 0 to 2 years old. The 3 to 4-year projects were built in the preceeding two-year period and the 5 to 6-year projects, the two-year period before that. Figures A-22 through A-27 should be referred to for the following discussion.

Distress occurring in the 0 to 2-year projects were primarily flushing and shrinkage cracking. Flushing was approximately in equal proportions for both products at all three distress severity levels, shrinkage cracking was primarily manifested in Product A. The 3 to 4-year old projects display less distress in general than the newer projects; except that Product B displays a higher percentage of high severity flushing in the 3 to 4-year old category than 0 to 2-year. Product A projects in the 5 to 6-year old category display no raveling distress, while 40 to 50 percent of the Product A projects 0 to 2 and 3 to 4-year old display severe raveling distress. This could signal a possible change in the methods used to formulate the Product A asphalt-rubber since if the product were manufactured in the same way since 1976 it would be more likely to see a higher percentage of raveling on the older, rather than newer projects. A similar occurrence exists for projects having no distress. Nearly 40 percent of the 5 to 6-year old Product A projects display no distress. while none of the younger Product A projects display no distress. No Product B projects fell in the 5 to 6-year category. However, Product A appears to have a consistent problem with flushing and shrinkage cracking. Figures A-22, A-23 and A-24 should be reviewed for a detailed comparison.

Conventional seal coats generally display a tendency for low severity distress rather than high. This appears to be true for all time periods by review of Figures A-25, A-26 and A-27. Asphalt-rubber seal coats display approximate equal likelihood for low as high severity distress. Flushing distress is more pronounced in conventional seal coats at low severity, but occurs more often in asphalt-rubber at medium and high severity. Asphalt-rubber shows less tendency to low severity thermal cracking but is approximately equal to conventional seal coats at medium severity and high severity. Generally, age seems to have little effect on any of the parameters with respect to conventional seal coats. Similar trends appear for each time period in each distress type. Asphalt-rubber tends to flush and crack more for the 5 to 6-year old projects than any other. Flushing in 0 to 2-year old asphalt-rubber projects appears greater than 3 to 4-year old projects.

It seems illogical that newer asphalt-rubber projects would perform less well than older projects unless formulations of asphalt-rubber have changed, or construction procedures have become less stringent.

Effect of Construction Year - Statistical Analysis

The statistical analysis of projects by age appears in Tables B-9 to B-12, Appendix B. Table B-9 indicates no significant difference between products regarding flushing, however, Product B displays significantly higher flushing for 3-4 year projects than 0-2 year old projects.

Product A shows more severe shrinkage cracking than either Product B or C for 0-2 year projects, but no difference is shown for older projects, suggesting that Product A reaches a given level of shrinkage cracking earlier than Product B or C. Product A displays significantly higher alligator cracking than Product B for the 0-2 year material. However, Figure B-11 indicates no statistically significant difference between Product A and conventional seal coat alligator cracking performance for 0 to 2-year old projects, although the deduct values of 25 and 11.5, respectively, suggest otherwise. This apparent discrepancy is caused by sizable differences in sample size between the Product A sample and the conventional seal coat sample. In this case, the Product A sample consisted of one project, while the conventional seal coat sample contained ten projects. The large difference in sample sizes together with a sample of a single project for one population, results in no statistical difference between numbers which appear to be significantly different in absolute value.

A similar apparent discrepancy exists for Product A and conventional seal coat alligator cracking performance for the 3 to 4-year old projects. Product A appears to have a much smaller deduct score (5) than conventional seal coat deduct score of 12.3. However, no statistical difference exists. This again is caused by a sample size of one in the case of Product A, and a sample size of eleven for the conventional material.

When apparent discrepancies like those discussed above appear in the data due to sample sizes of one they will be indicated such that an understanding of the cause may be more obvious to the reader. This may indicate that Product A tends to alligator crack earlier than Product B but performs similarly to conventional seal coats for this distress type.

Raveling performance is significantly worse for Product A than conventional seal coats in 0 to 2 and 3 to 4-year age groups. No raveling occurs in Product B systems for any age group. Also, Product A seal coats show no significant raveling performance difference between age groups, i.e., 0 to 2 year versus 3 to 4-years. No significant difference in performance exists for conventional seal coats throughout the years, as well.

Effect of Substrate - Subjective Analysis

Three types of substrates were considered for analysis. Thin flexible is considered as substrate consisting of single or multiple seal coats over prepared bases and subgrades. Thick flexible is plant-mixed asphalt concrete over prepared base course and subgrade, and rigid is any type of portland concrete pavement section. Only one conventional seal coat was built over a rigid substrate and no asphalt-rubber sections were constructed over this type. Therefore, no analysis of seal coats over a rigid substrate is presented. Four interlayer projects were built over rigid pavements, and a section of this discussion will be devoted to this performance analysis.

Figures A-28 through A-32 will be used as reference for the following discussion. Asphalt-rubber Products A and B flush more over thick flexible substrates than thin flexible substrates as shown on Figures A-28 and A-29. Product B exhibits a higher proportion of flushing than A over thin substrates. Shrinkage cracking, alligator cracking and raveling occurs mainly in Product A and show no trend for either substrate type. Figures A-30 and A-31 summarize performance of asphalt-rubber and conventional seal coats over thin and thick flexible substrates, respectively. Flushing occurs in conventional seal coats over thick substrates more often than thin. Shrinkage cracking appears to be unaffected by the flexible substrate type for asphalt rubber. Approximately 20 percent of all projects exhibit shrinkage cracking where constructed over seal coats or asphalt concrete. Conventional seal coats appear to exhibit more shrinkage cracking over asphalt concrete substrates than over other seal coats. Alligator cracking does not appear to be a significant problem in conventional seal coats with less than 10 percent of all projects exhibiting any one level of severity. This is not necessarily true of asphalt-rubber, as approximately 20 percent of all projects exhibit alligator cracks when constructed over thin flexible pavements. Review of Figure A-28 indicates the alligator cracking occurring only in the Product A material.

A comparison of interlayer projects built over thick flexible and rigid substrates with the Product A material is presented in Figure A-32. A comparison to Product B performance is omitted due to lack of data for Product B interlayer construction. For example, only one project exists for Product B interlayer construction over a thin flexible substrate. Therefore, the performance of Product B is difficult to fairly evaluate. Review of Figure A-32 indicates that cracking due to construction over rigid pavements may be less prevalent than for construction over flexible pavements for medium severity shrinkage and low severity alligator cracking. However, a review of Tables C-1 to C-13, Appendix C, indicates that all interlayer construction over rigid substrates is less than 2 years old. Therefore, the age of these projects may not have allowed the medium or high severity cracks to manifest themselves. A higher proportion of low severity shrinkage cracks appears in interlayers constructed over rigid pavements than those constructed over thick flexible pavements. This result seems to be consistent with performance reported for other installations (7).

Effect of Substrate - Statistical Analysis

Tables B-13 to B-16 will be referred to regarding statistical analyses. Although a difference among products appears evident from the previous review of Appendix A regarding flushing distress, no significant difference is detected as shown in Table B-13 between products or within Products A and B. A difference does appear within conventional seal coats, as less flushing occurs over thin flexible and rigid substrates than over thick flexible. This same conclusion was previously mentioned based on data from Appendix A.

Product A displays significantly more shrinkage and alligator cracking than conventional seal coats over thin substrates and more raveling than conventional seal coats over either thin or thick flexible substrates.

Review of distress appearing on interlayer construction indicates no significant differences between suppliers, however Table B-14 shows that Product B has higher severity shrinkage distress over rigid pavements than thick flexible pavements. A very limited supply of data was available with which to develop the Product B interlayer results appearing in Table B-14, however. Therefore, more information regarding interlayer performance over rigid and thick flexible substrates is desirable.

Effect of Climate - Subjective Analysis

Locations for study were selected based on minimum annual temperature ranges and annual rainfall (6). These areas of the state are shown on Figures A-33 and A-34. Three thermal and two moisture related climates were selected for study. Figures A-35 through A-39 will be used as reference in the following discussion.

In the hot climate zone labeled T1 flushing and some shrinkage cracking distress occur. Product A and B flush approximately equally in this climate and Product A displays some moderate severity shrinkage cracking. The moderate climate, Zone T2, indicates Product B more susceptible to flushing than A. Product A displays an increased tendency to crack and ravel in the moderate climate in the hot climate. The coldest climate, T3, shows no flushing distress, but Product A displays severe shrinkage and alligator cracking while Product B displays low severity shrinkage cracking.

The following discussion concerns the performance of asphalt-rubber in two climates with different levels of annual rainfall. Zone R1, shown in Figure A-34, is considered a dry climate, with less than 35 inches of rainfall annually. Zone R2, is considered a wet climate with over 35 inches of rainfall annually.

Flushing distress in the dry climate is approximately equal for both products. In the wet climate severe flushing occurs more often for Product B than Product A. Product A displays approximately equal flushing potential in wet and dry climates, approximately 35 percent of all projects. Cracking is a problem with Product A in both wet and dry climates but appears more significant in the wet climate. Raveling occurs for Product A only in the dry climate.

Figures A-40 through A-44 will be referred to for the following discussion comparing asphalt-rubber and conventional seal coat performance. The relative performance of asphalt-rubber in hot climates appears better than conventional seal coats while in moderate climates performance is nearly equal. More flushing occurs with conventional seal coats in the colder climates than with asphalt-rubber seal coats. Shrinkage and alligator cracking occur more often in asphalt-rubber than conventional seal coats in cold areas.

The performance of both systems in dry climates are similar, although conventional seal coats tend to crack and ravel more than asphalt-rubber. Wet climate performance for conventional seal coats is similar to dry climate, but asphalt-rubber seal coats display a higher proportion of shrinkage cracks and much higher severe flushing than conventional seal coats in the wet climate.

Performance of interlayer projects in the various climates may be observed in Table F-10, Appendix F. The best performance is in cold and dry climates for Product A. Flushing is the most prevalent distress with shrinkage cracking occurring in both Products A and B primarily in hot and wet climates for Product A and hot, moderate and dry for Product B.

Effect of Climate - Statistical Analysis

The wet or dry climate analysis shown in Tables B-17 to B-20 does not detect statistically significant differences between products or within products for any distress type except raveling. Here, as Table B-4 shows, Product A ravels to a significantly greater extent than conventional seal coats in areas where average annual rainfall is less or more than 35 inches.

For the hot, moderate and cold climates the analysis detects more differences than the rainfall factor. Tables B-21 through B-24 depict this. As the previous subjective analysis indicated statistically, conventional seal coats display significantly greater flushing distress in cold climates than in hot or moderate regions. Also, Product A seal coats display more flushing in moderate climates than conventional seal coats.

Shrinkage cracking is more severe in Product A seal coats than in B or C in cold climates and Product A displays a significant increase of shrinkage cracking in cold versus moderate climates.

Alligator cracking is unaffected by rain climate as suggested by Table B-23, no significant differences appear between products or within products in areas of different rainfall.

Significantly greater raveling distress occurs in Product A seal coats than conventional seal coats in both hot and moderate climates.

Effect of Project Length - Subjective Analysis

Project length was chosen as a performance indicator because it has been suggested by asphalt-rubber suppliers that a sufficient length of pavement is required to obtain acceptable performance. Length of conventional seal coat projects is not recorded in the random sample data base, therefore, analysis will be confined to asphalt-rubber construction.

Figures A-45 through A-47 contain graphical comparisons of Product A and Product B performance related to project length. Flushing remains the most significant mode of distress in all three lengths of projects considered. Product B performs slightly better than A on projects of 0 to 3 lane miles, and better overall on 4 to 6 and 8 to 56 lane mile projects with respect to distress other than flushing. Product A flushes less than three lane miles. In general, no obvious trends appear in the data which suggest that project length is a significant factor in determining performance and within reason this is the way it should be.

The distribution of projects with respect to length indicates that 74% of asphalt-rubber seal coat construction is performed on projects of less than ten lane miles, with 34% constructed between 2 to 4 lane miles. Interlayer construction is evenly distributed over the range of lengths up to fifty-six lane miles. Interlayer performance does not appear to be related to project length as may be seen by review of Table F-12, Appendix F. The distribution of products with respect to length for seal coat and interlayer construction can best be seen in Figures A-48 and A-49.

Effect of Project Length - Statistical Analysis

The length of projects used to measure performance differences appeared an inconclusive measure from the previous analysis. Review of Tables B-25 through B-28 confirms this, as few statistically significant differences appeared in these data. Table B-25 depicts a difference in flushing between 0 to 4 lane miles and the other two length categories. Except for this results, project lenght appears a poor indicator of performance with respect to the distress modes studied here. This finding was not unexpected.

Conclusions

1. Flushing

   a. Flushing distress occurs more often with asphalt-rubber seal coats than conventional seal coats at a ratio of 99 percent of all asphalt-rubber projects and 74 percent conventional projects.

   b. The incidence of low, medium or high severity flushing is approximately equal with asphalt-rubber, while low severity flushing occurs more often than medium or high severity in conventional seal coats.

   c. Product A asphalt-rubber seal coats display a significantly higher level of flushing than conventional seal coats in climates having minimum annual temperature (MAT) levels of -10°F to +5°F, considered a moderate climate by this study.

   d. Product B displays a significantly higher level of flushing for seal coats 3-4 years old than 0-2 years old.

   3. Product A displays a significantly higher level of flushing than Product B on interlayer projects receiving lifetime accumulated traffic volumes in excess of two million vehicles.

2. Shrinkage Cracking

   a. Shrinkage cracking appears in both asphalt-rubber and conventional seal coats at approximately the same proportion, occuring in about 50 percent of all projects.

b. Product A seal coats display a significantly higher level of shrinkage cracking than Product B or conventional seal coats under the following conditions:

   ADT over 1,000 per lane

   Pavements less than 2 years old

   Cold climates with minimum annual temperatures (MAT) from -26°F to -10°F.

c. Product A seal coat construction display significantly more shrinkage cracking on cold climates (-26°F to -10°F MAT), than in moderate climates (-10°F to +5°F MAT).

d. For interlayer construction, Product B displayed more shrinkage cracking than Product A on facilities with low accumulated lifetime traffic (0-1 million vehicles).

e. Product B interlayer construction displayed a significantly higher level of shrinkage cracking on pavements with high accumulated lifetime traffic (over 2 million vehicles) than on pavements with low accumulated lifetime traffic (0-1 million vehicles).

f. This result may indicate that deflection, rather than shrinkage, is the cause of these failures and that shrinkage, per se, may be controllable, while excess deflection may not.

3. Alligator Cracking

   a. With all other environmental factors equal, overall alligator cracking appears in conventional seal coats at approximately twice the frequency as asphalt-rubber seal coats. This distress occurs in 20 percent of conventional seal coats studied and 9 percent of asphalt-rubber.

b. Product A displays a significantly higher level of alligator cracking than Product B for pavements less than three years old.

c. Product A seal coats display a significantly higher level of alligator cracking than conventional seal coats when constructed as additional layers in existing single or multiple seal coat systems.

4. Raveling

a. Raveling appears in approximately 44 percent of the conventional seal coats studied and 17 percent of the asphalt-rubber seal coats.

b. Product A seal coat construction displays a significantly higher level of raveling distress than conventional seal coats under the following conditions:

    High lane ADT (over 1,000)

    Medium and High Accumulated Traffic (1,000,001-2,000,000 and >2,000,000)

    Less than three years old

    Thin or thick flexible substrates

    Hot or moderate thermal climates (+5°F to +20°F and -10°F to 5°F MAT, respectively).

c. Raveling in Product A seal coats is probably not due to embedment depth, due to high binder application rates but related to a tougher asphalt-rubber binder or inadequate reaction unless rubber particles are sufficiently digested in the asphalt of rubber and asphalt. The adhesive qualities needed to prevent chip loss on high volume facilities at high ambient temperatures are not developed. In addition, the increased toughness characteristic of asphalt-rubber binders leads to decreased wetting of aggregate particles, and potential higher chip loss.

5. No Distress
   a. Proportion of projects displaying none of the four types of distress studied here are 7 percent for asphalt-rubber and 3 percent for conventional seal coats.

6. This analysis indicates that asphalt-rubber seal coats may perform better than conventional seal coats for alligator cracking and raveling performance, equally for shrinkage cracking, and worse for flushing performance. But, it must be realized that asphalt-rubber does not exist as two specific formulations. In fact, although this report assumes the two products of asphalt-rubber have constant properties from project to project, the contractors have changed material formulas through the years, between projects, and possibly within a given project making a simple comparison of 'Product A' with 'Product B' difficult. For this reason further investigation of materials and construction methods used on each project is desirable before a true objective analysis can be completed.

7. The improved alligator cracking and raveling performance of seal coat manufactured with asphalt-rubber and poorer flushing performance should not be a startling conclusion. The relatively high application rates for the binder should lead to the increased incidence of flushing distress due to high theoretical embedment depths. The increased embedment depth leads to a lower potential for raveling distress

in asphalt-rubber seal coats compared with conventional seal coats. The increased flexibility of the binder due the increased thickness (application rate) and presence of rubber should lead to an increase in failure strain. This characteristic aids in reducing alligator cracking but evidently is not adequate to resist strains induced by shrinkage.

8. The present performance of asphalt-rubber suggests that improved efforts at design of these new systems may alleviate the problems described here. Much of the current technology in asphalt-rubber seal coats has developed beginning with a constant binder quantity, more or less, and determining the quantity of aggregate to provide cover (albeit without consideration for aggregate grading or maximum size). Conversely, conventional seal coat design has begun by determining the quantity of aggregate for a one-stone cover of unit area, and designing the appropriate quantity of binder to provide some ideal embedment depth, given voids quantities, surface texture, traffic and, losses. By refining the techniques used to construct asphalt-rubber seal coats it may be possible to tune the construction technique such that one desirable attribute is not gained at the expense of another.

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Appendix A

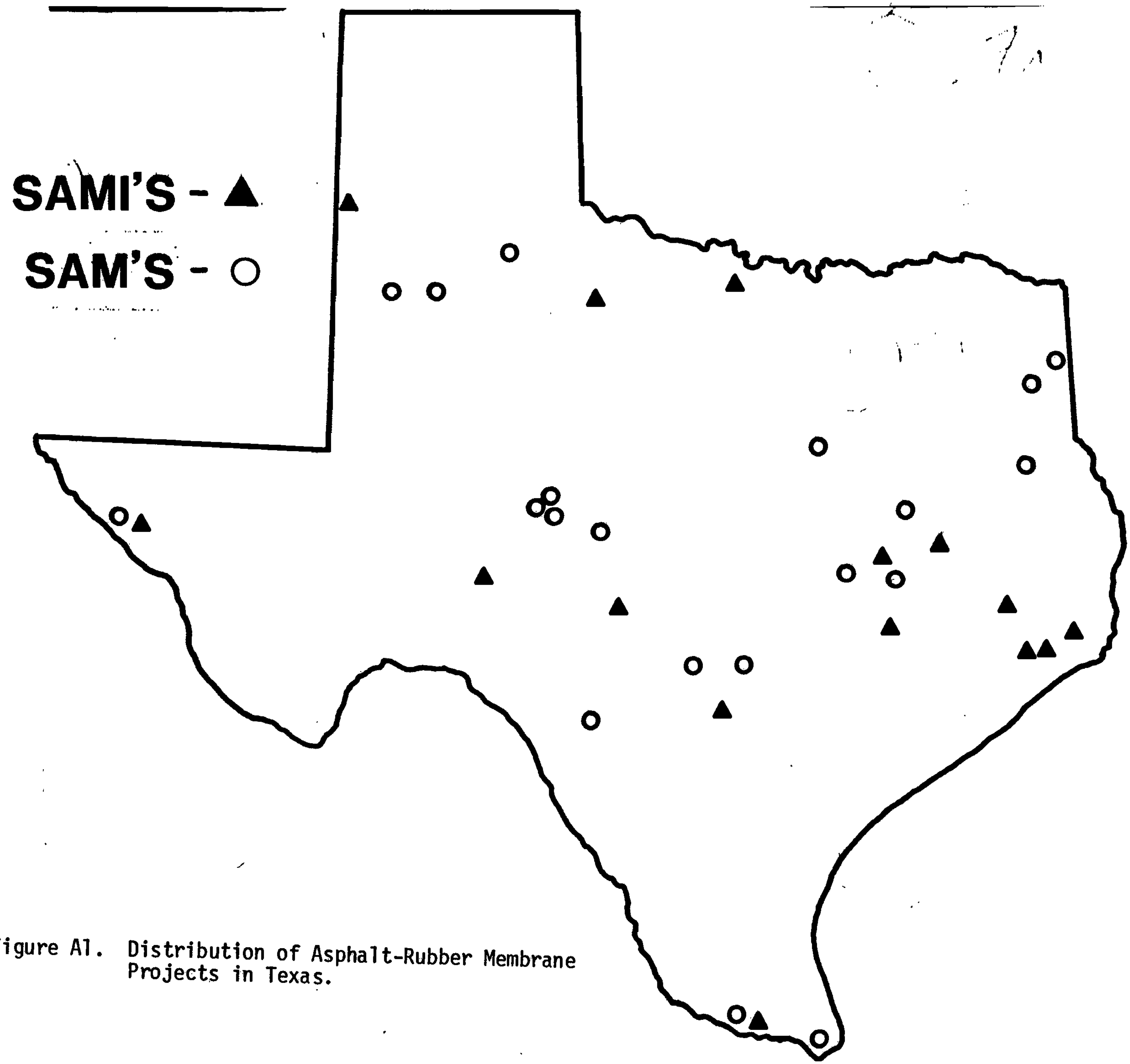


Figure A1. Distribution of Asphalt-Rubber Membrane Projects in Texas.

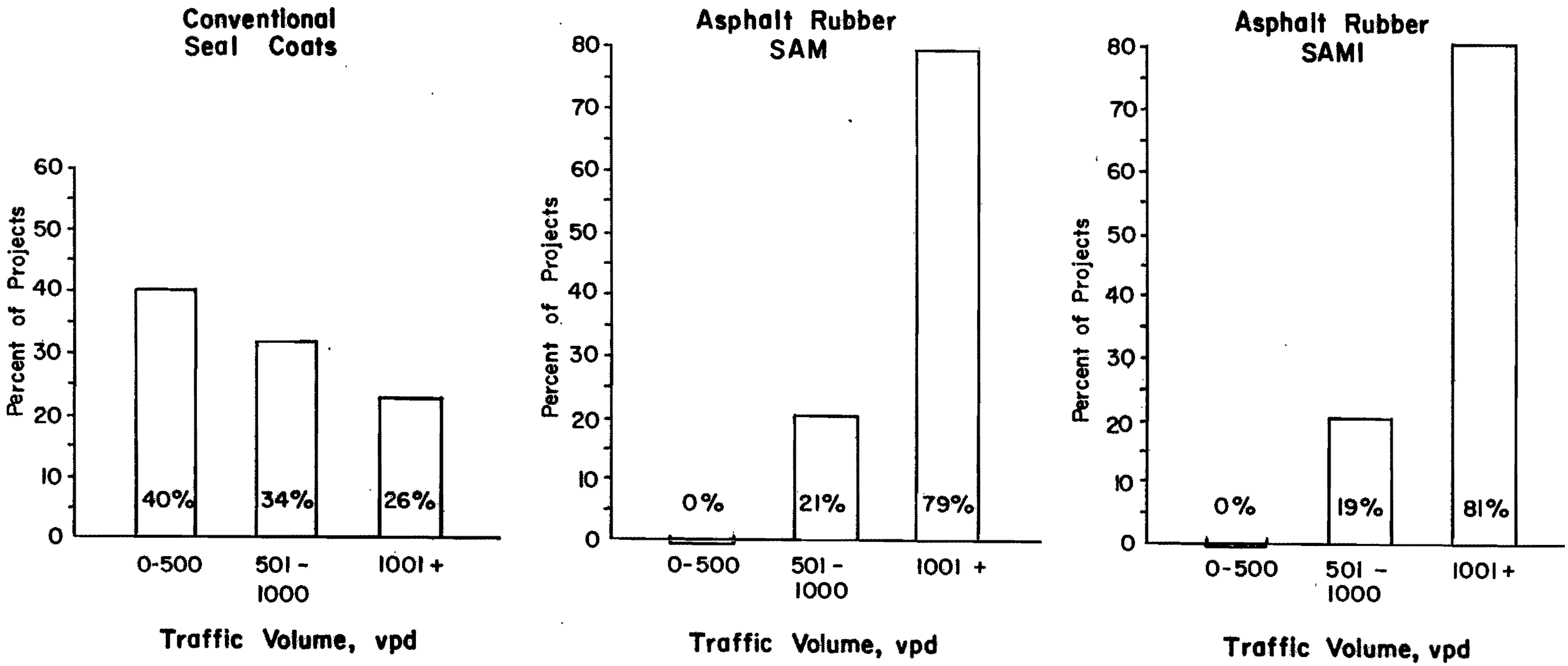


Figure A2. Project Distribution Related to Traffic Volume.

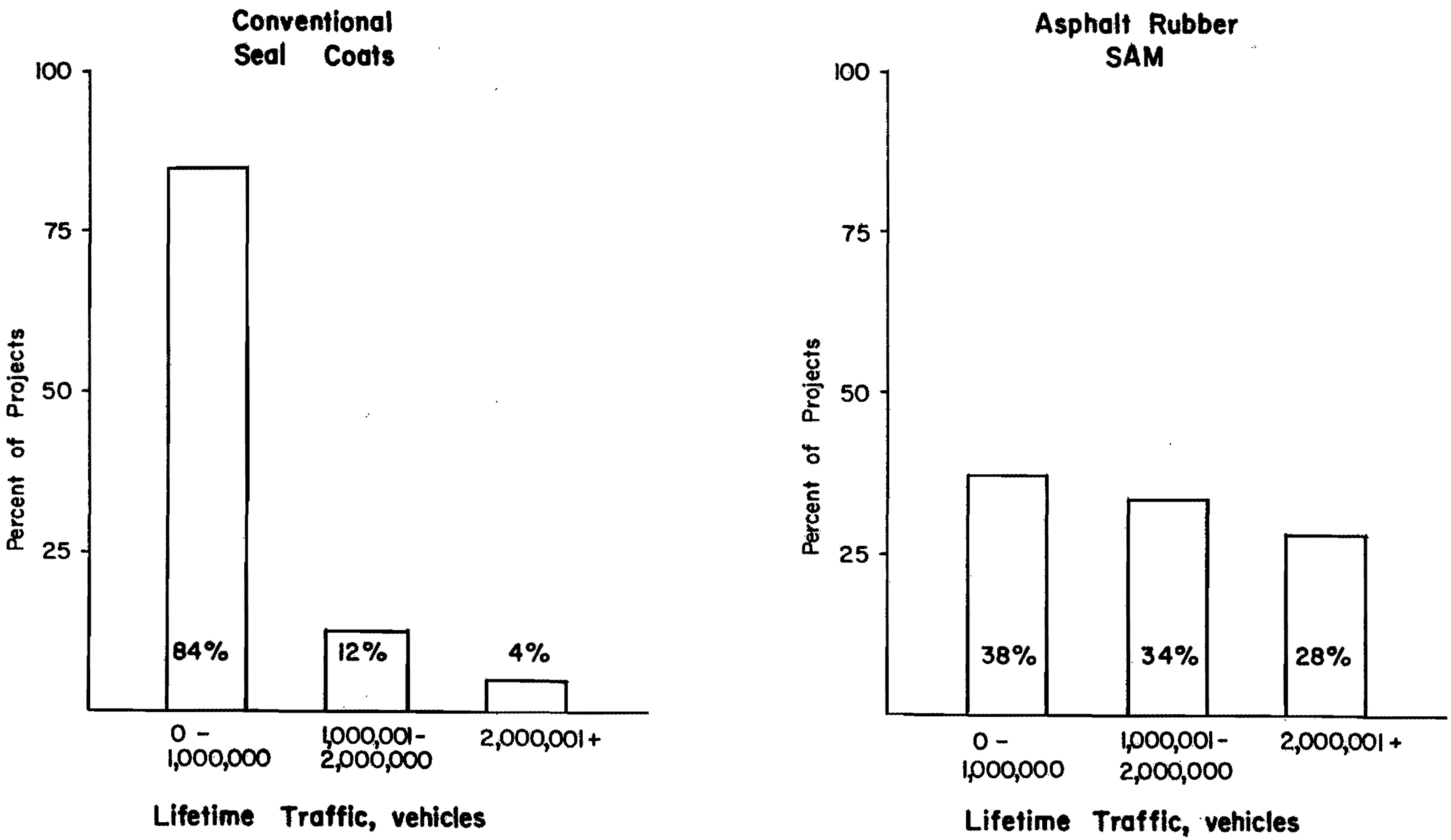


Figure A3. Project Distribution Related to Accumulated Traffic.

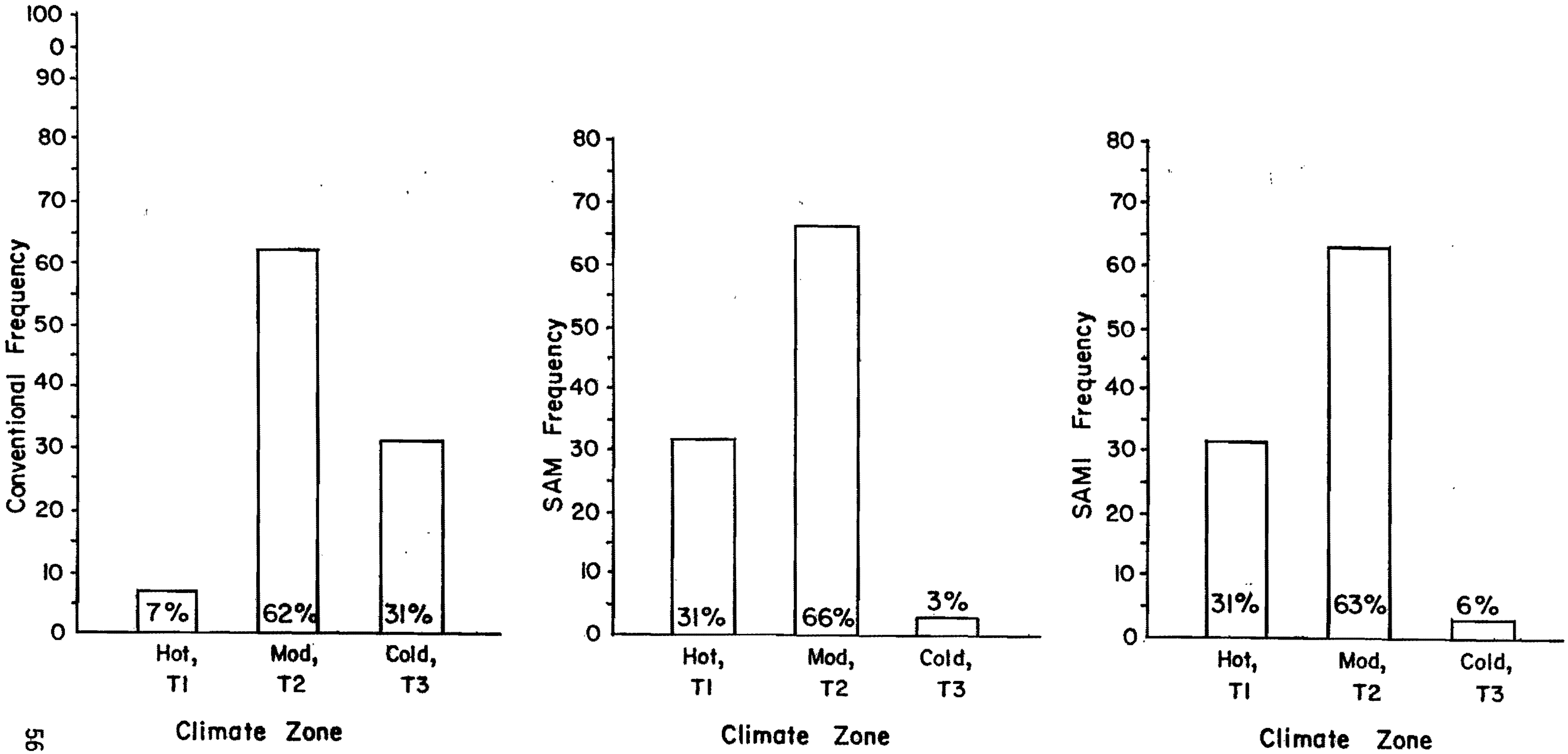


Figure A4. Project Distribution Related to Thermal Climate.

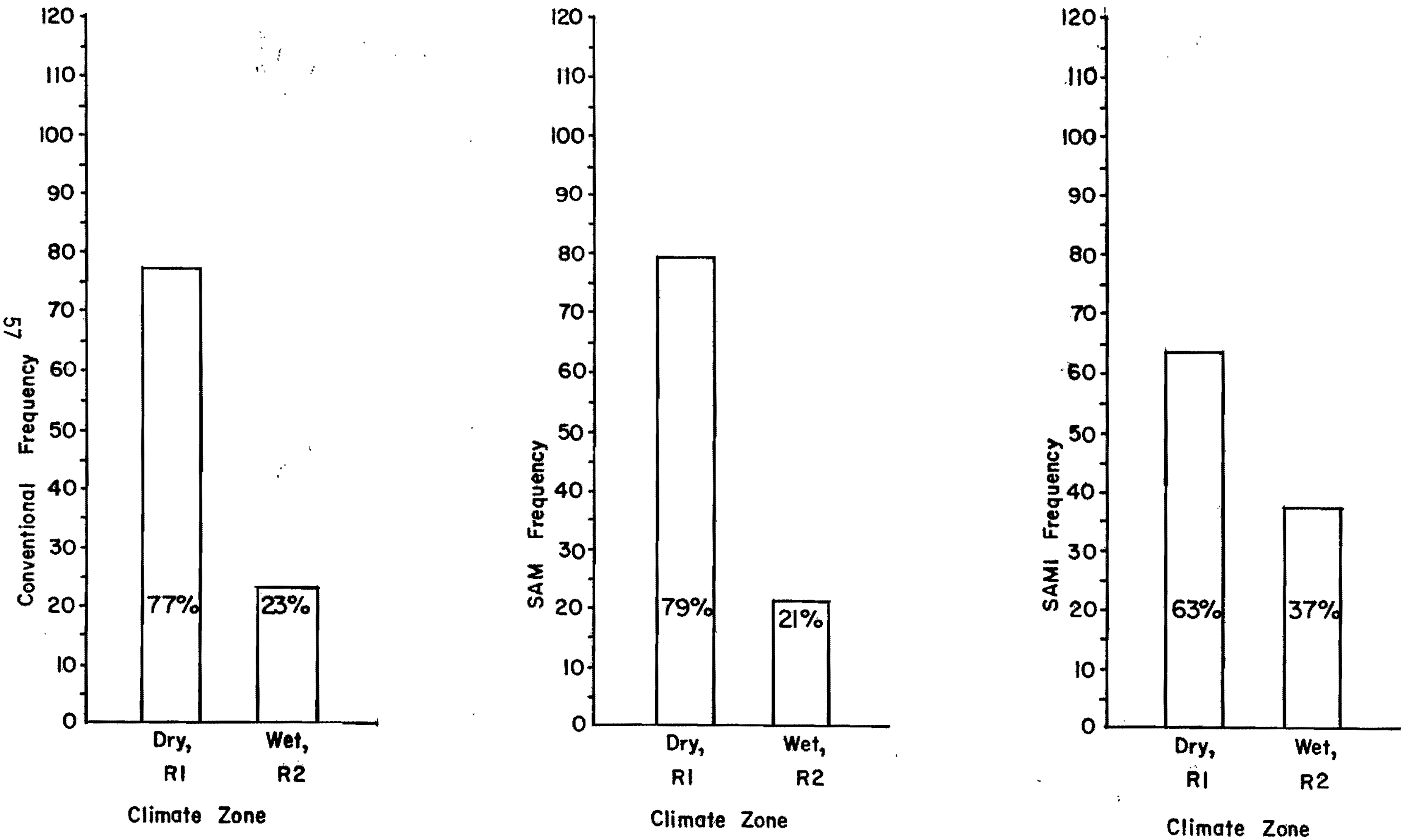


Figure A5. Project Distribution Related to Rain Climates.

All Seal Coats

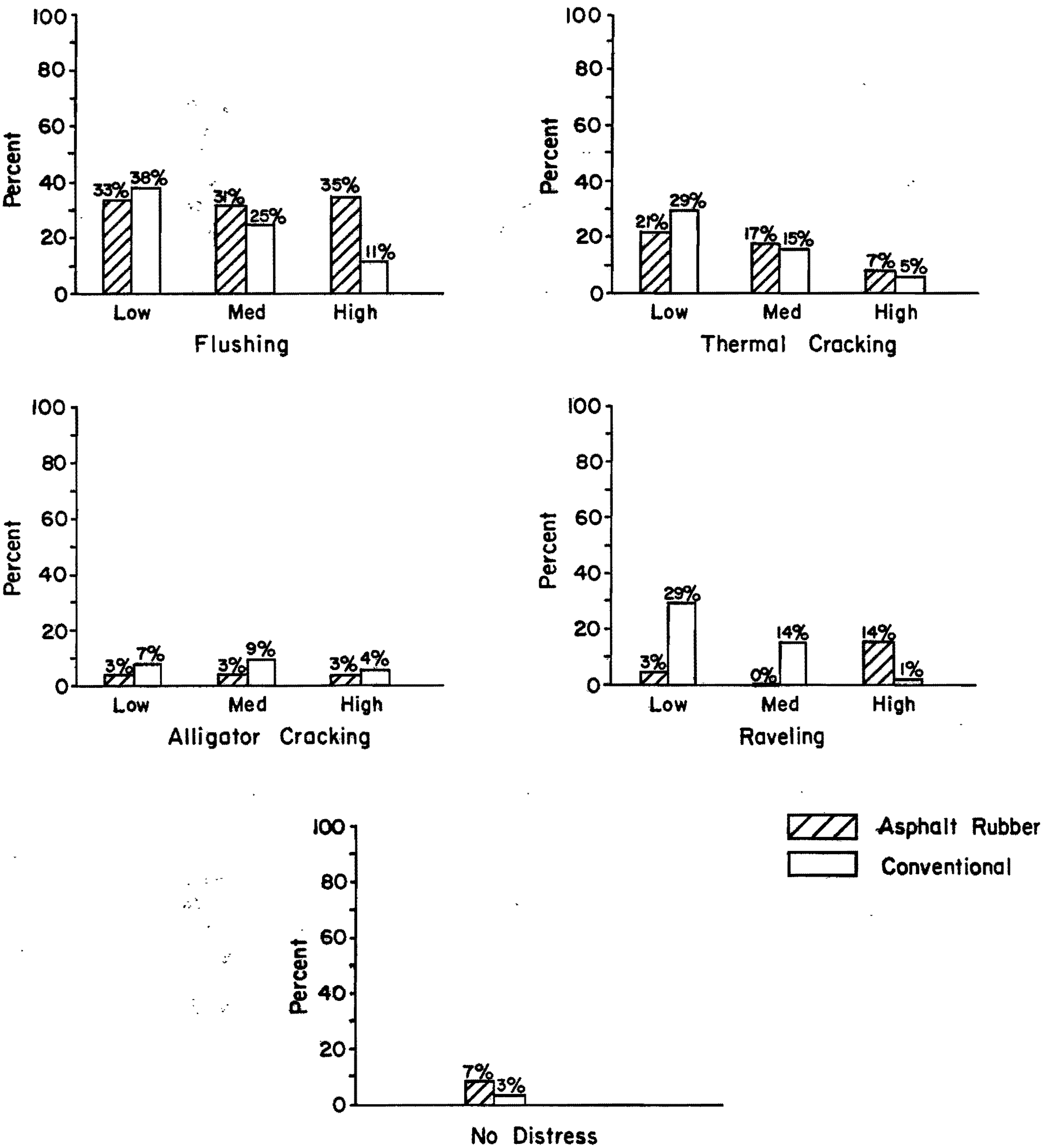


Figure A6. Overall Performance of All Seal Coats.

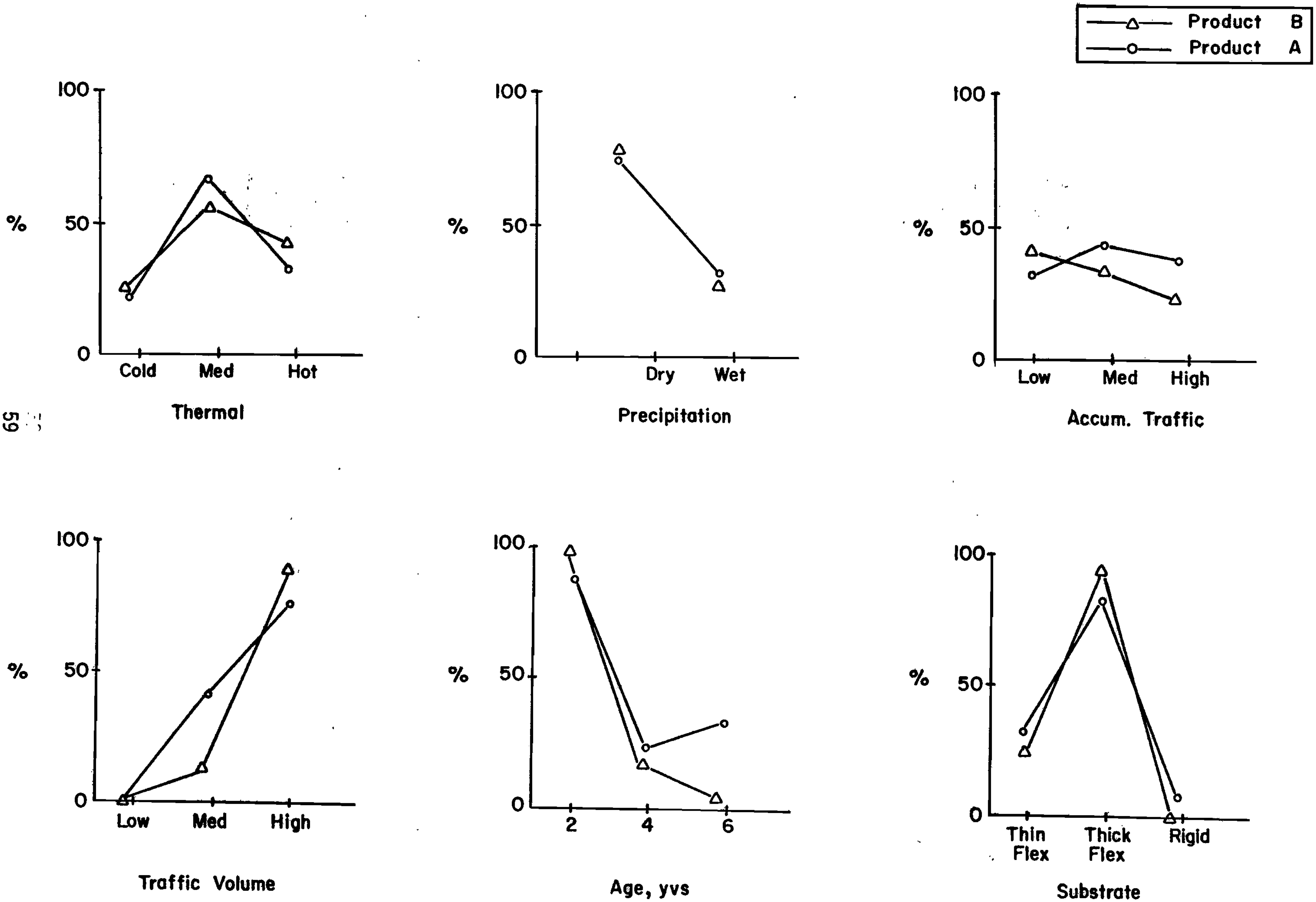


Figure A7. Distribution of SAM Construction.

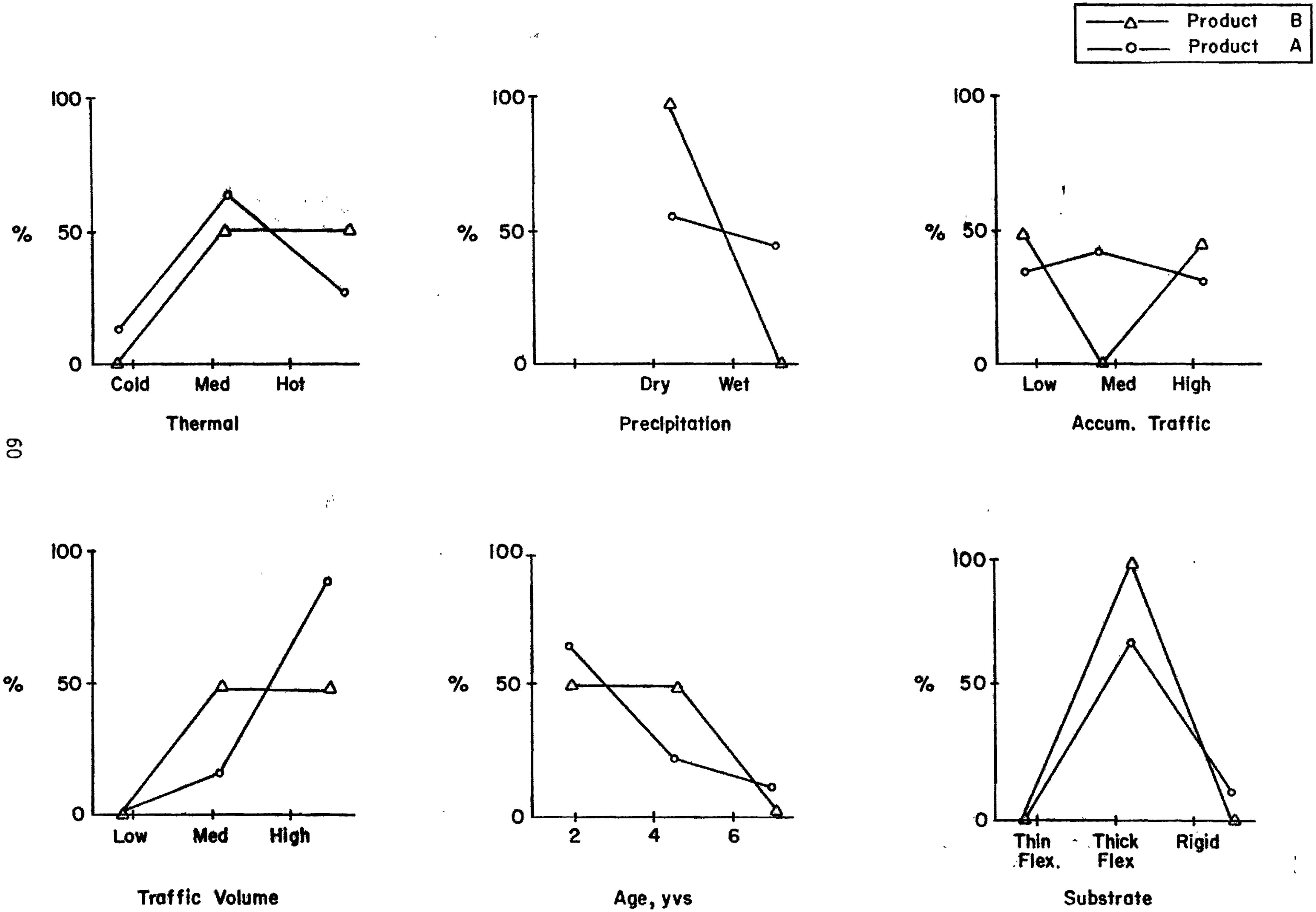


Figure A8. Distribution of SAMI Projects.

All Asphalt-Rubber
Seal Coats (SAM)

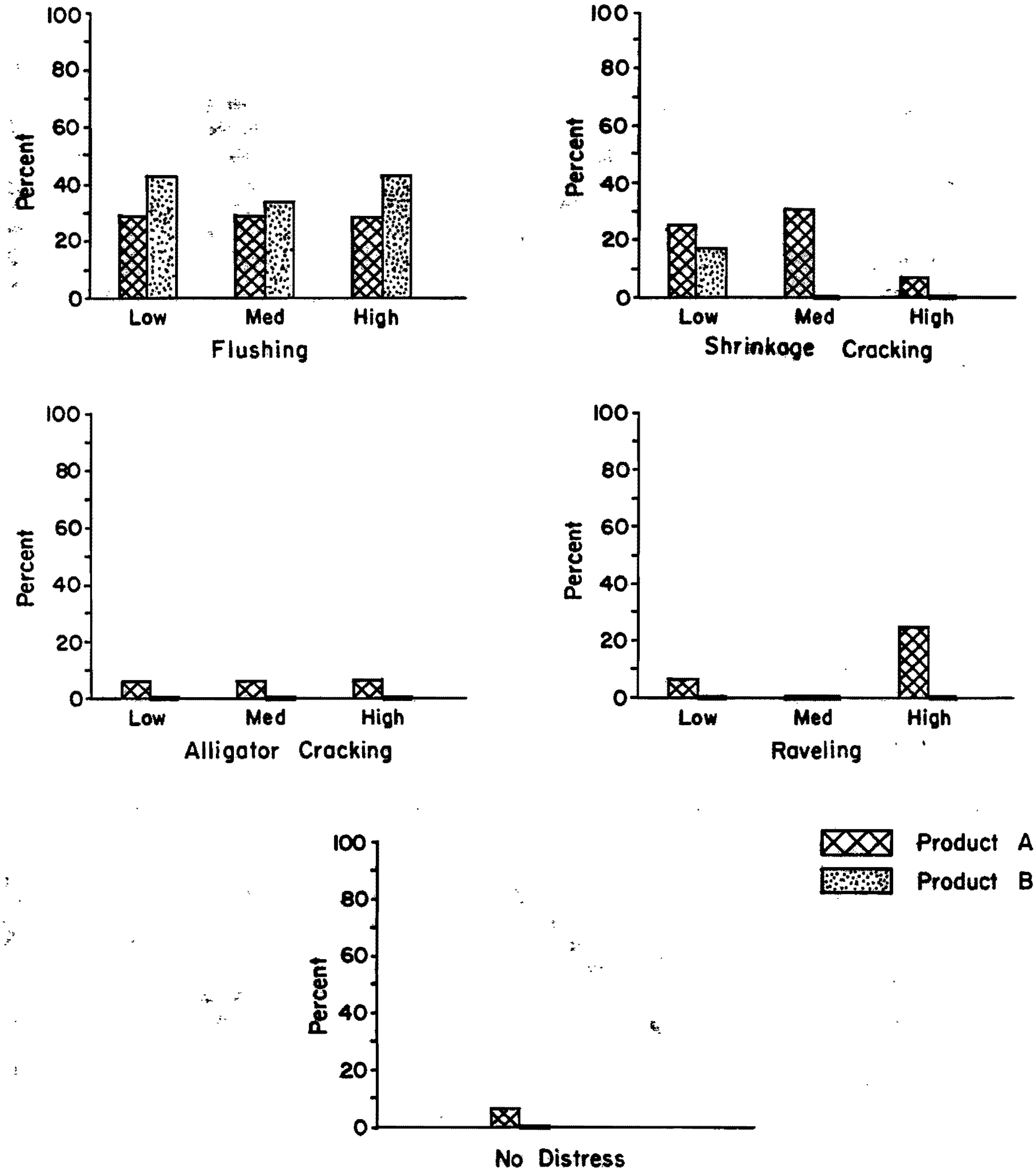


Figure A9. Overall Asphalt-Rubber SAM Performance.

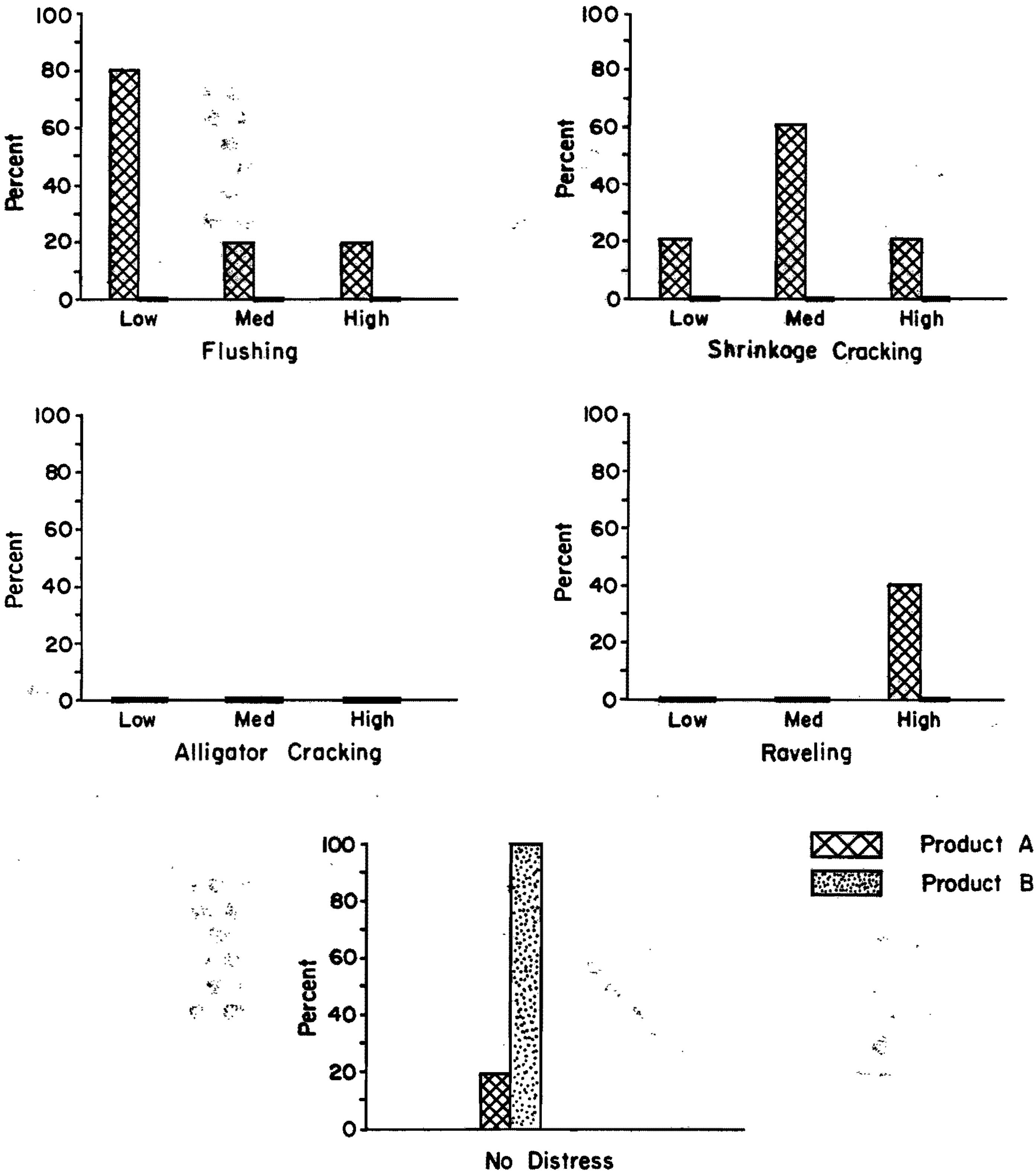


Figure A11. Between 500 and 1,000 ADT Per Lane.

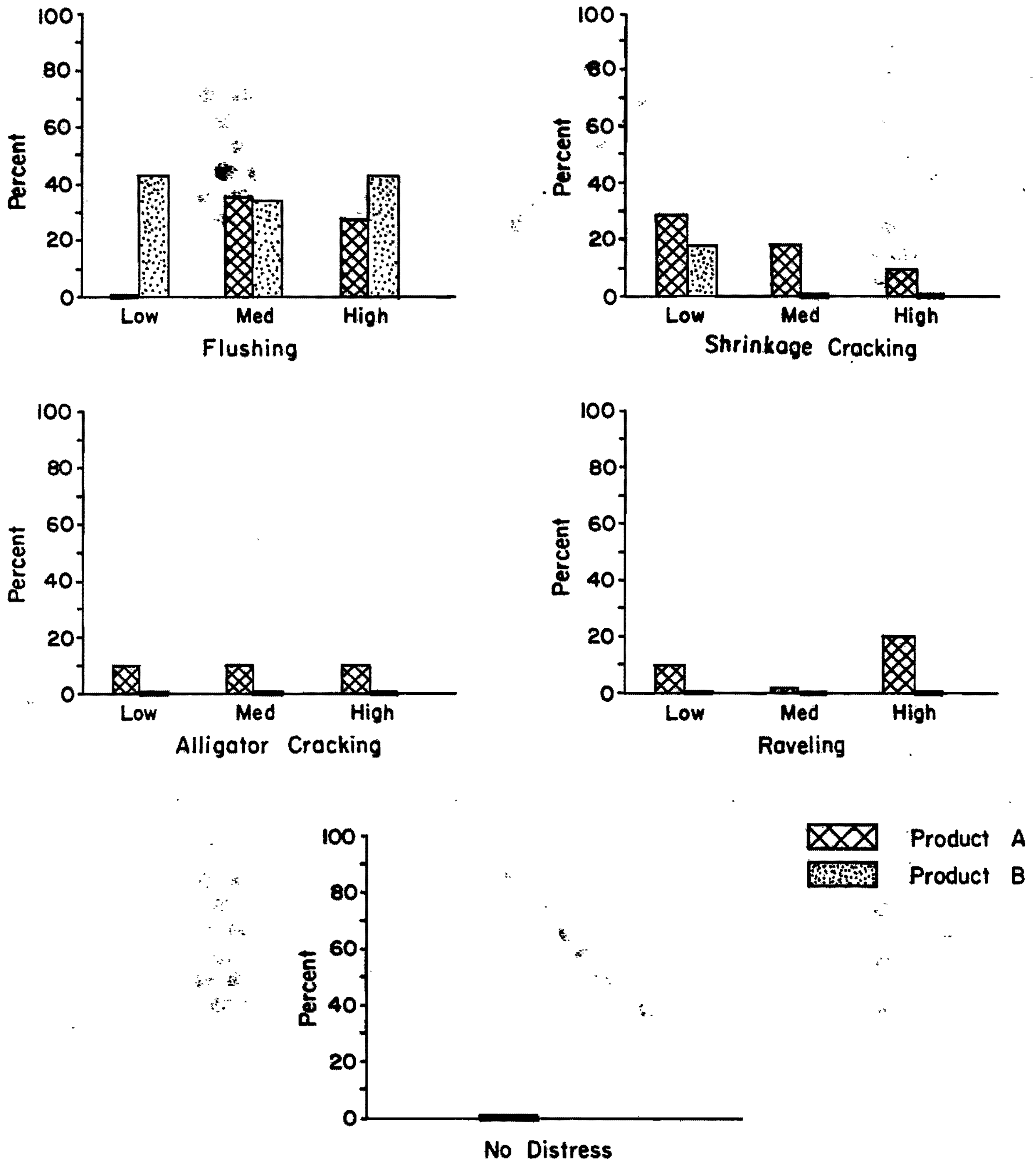


Figure A12. Over 1,000 ADT Per Lane.

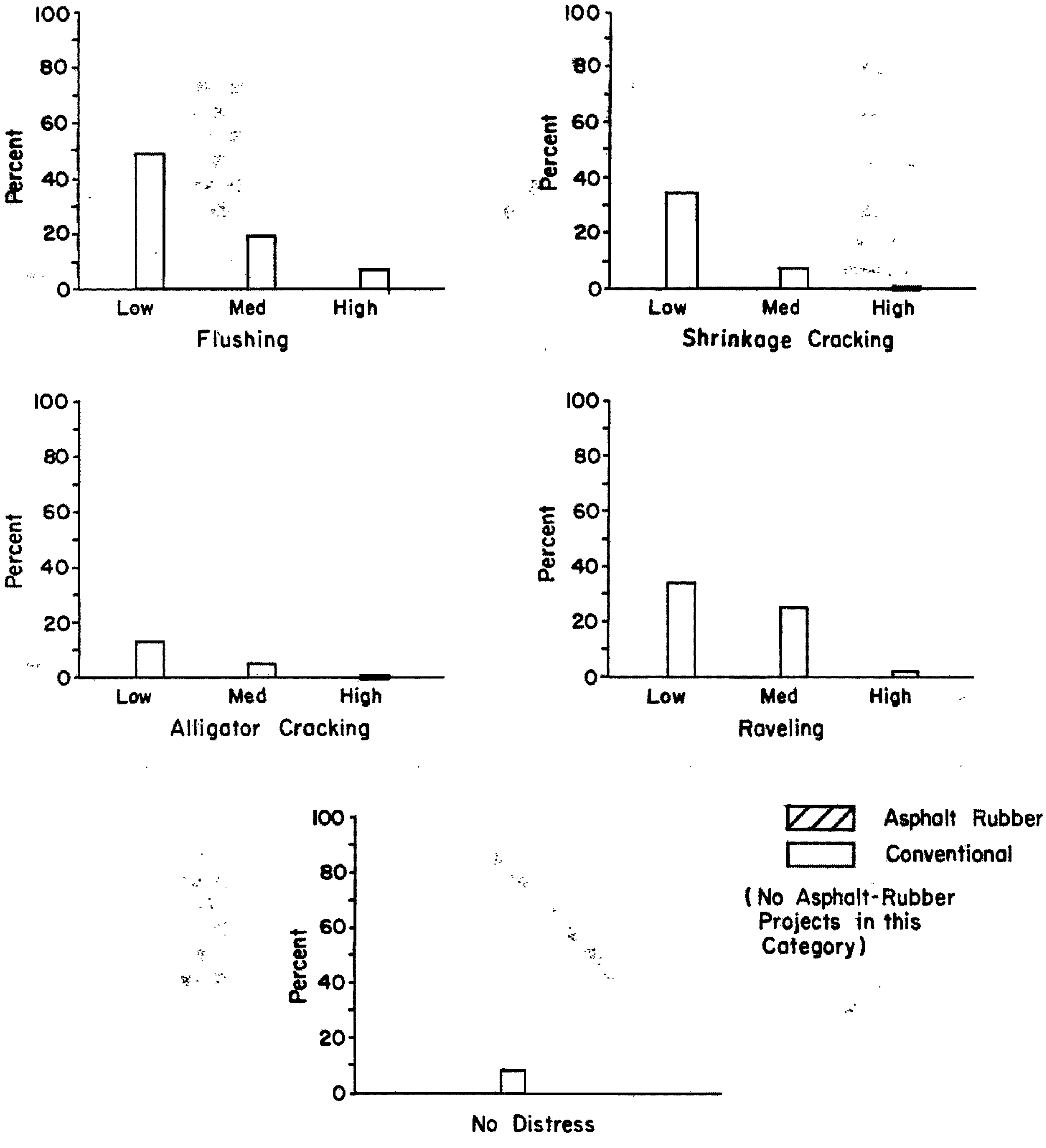


Figure A13. Up to 500 ADT Per Lane.

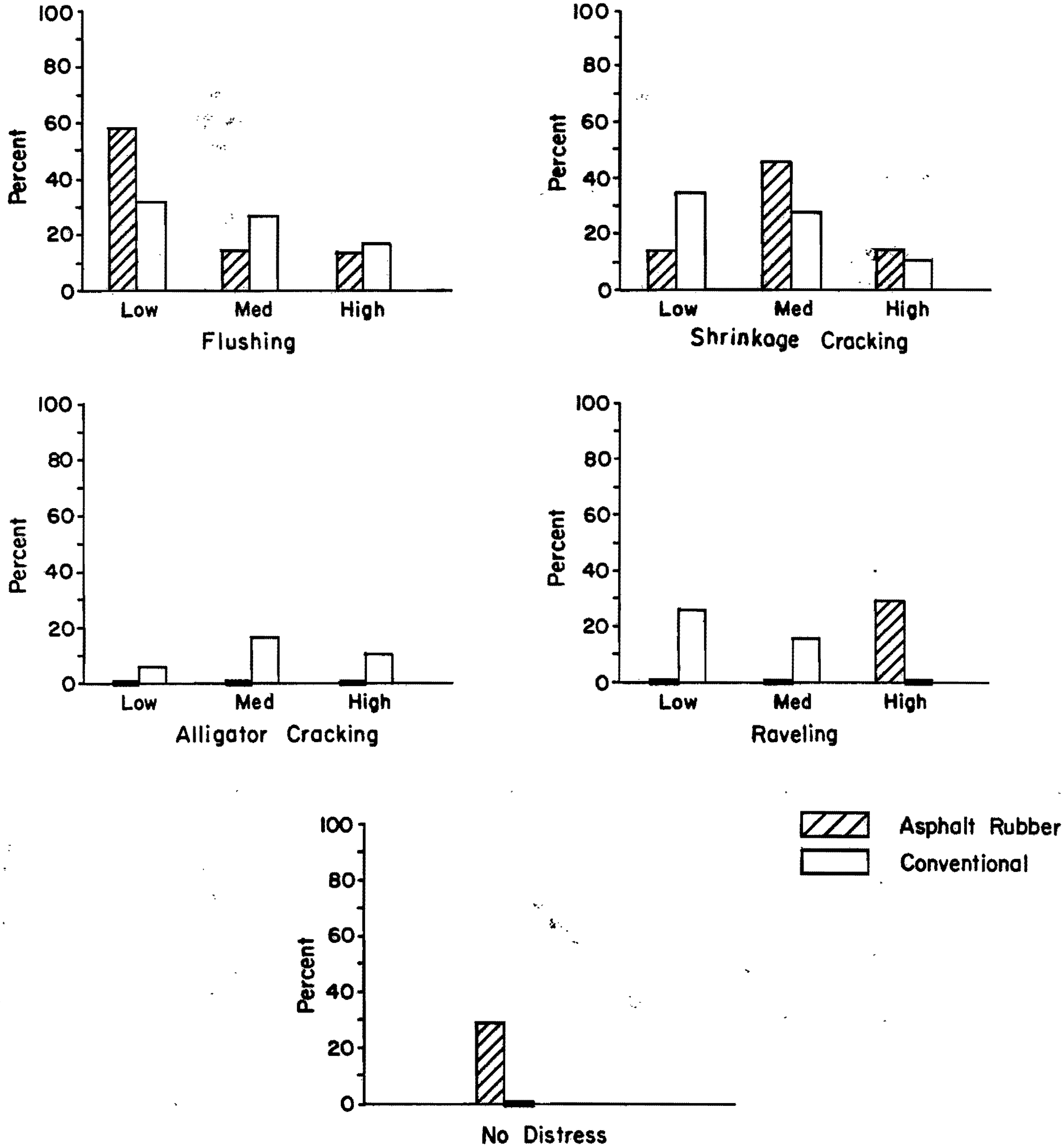


Figure A14. Between 500 and 1,000 ADT Per Lane.

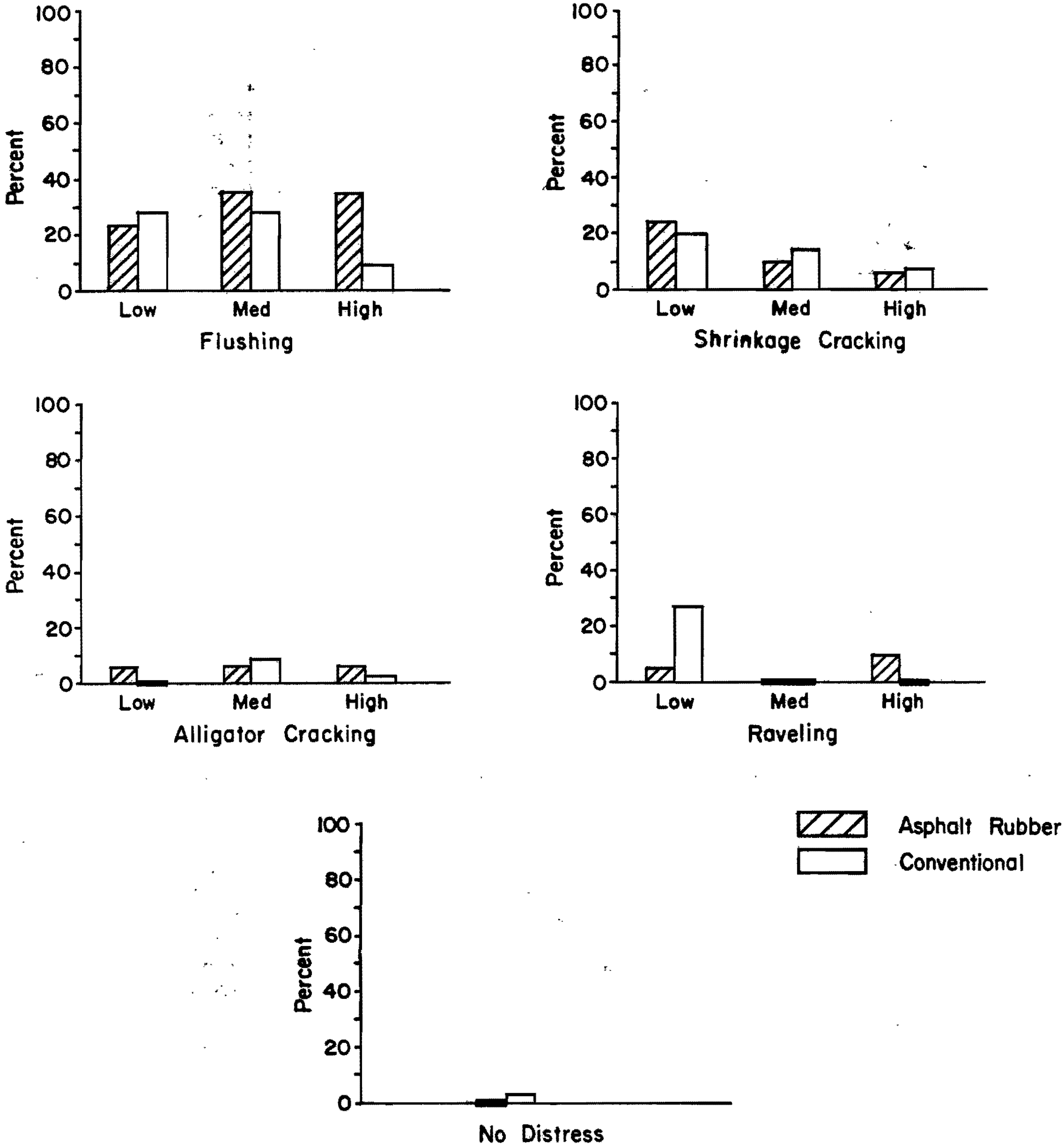


Figure A15. Over 1,000 ADT Per Lane.

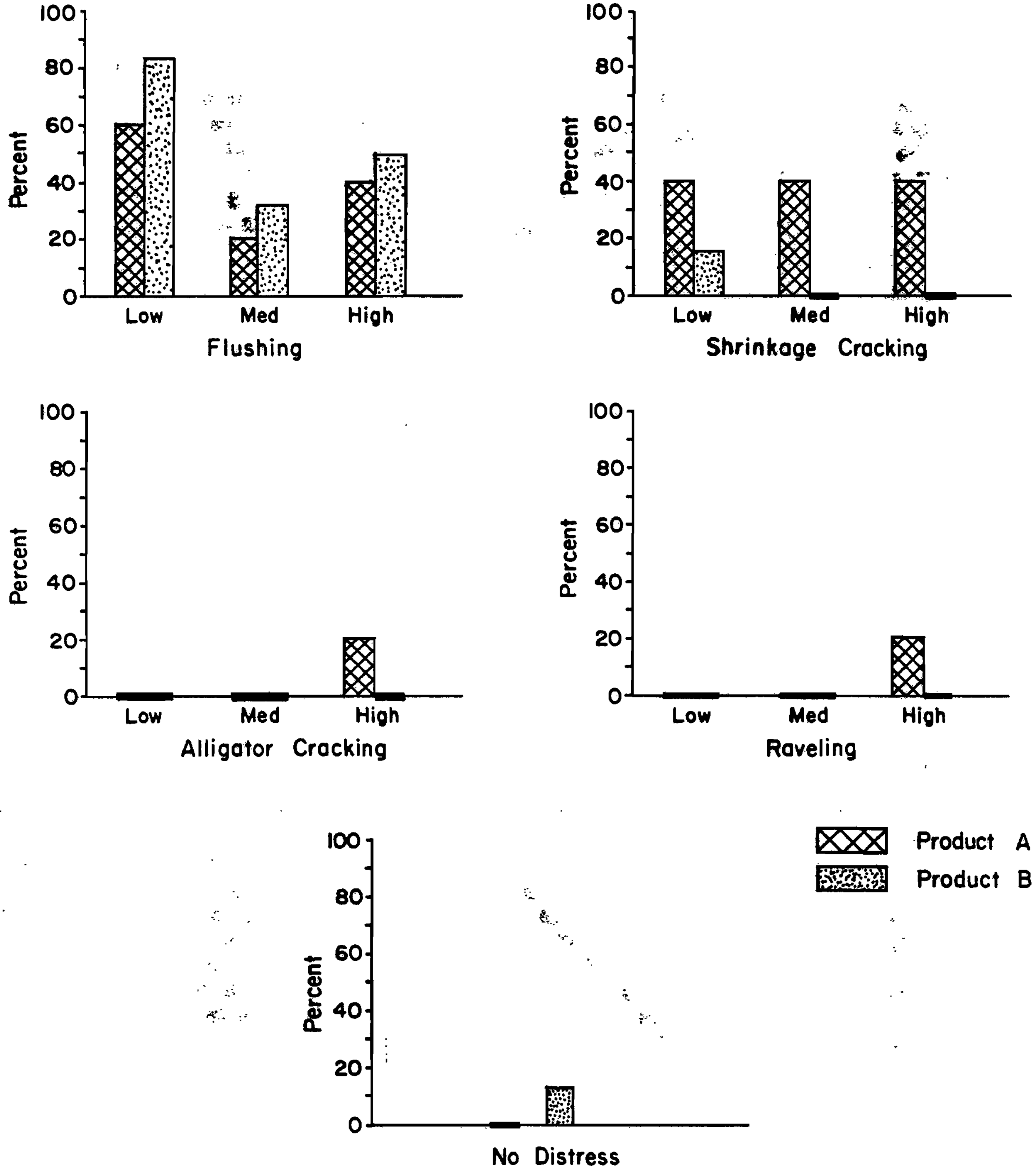


Figure A16. Up to 1 Million Accumulated Vehicles.

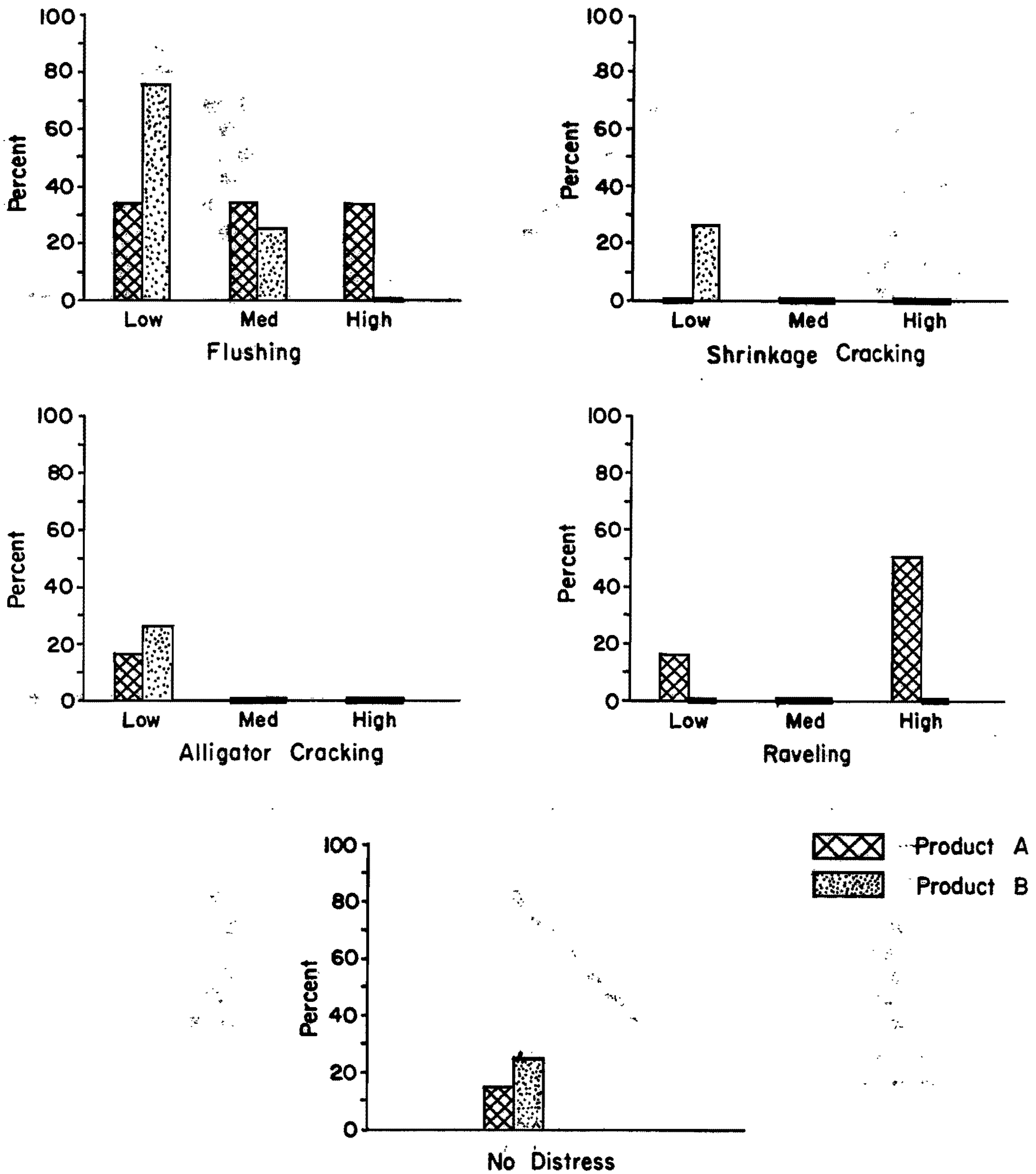


Figure A17. Between 1 and 2 Million Accumulated Vehicles.

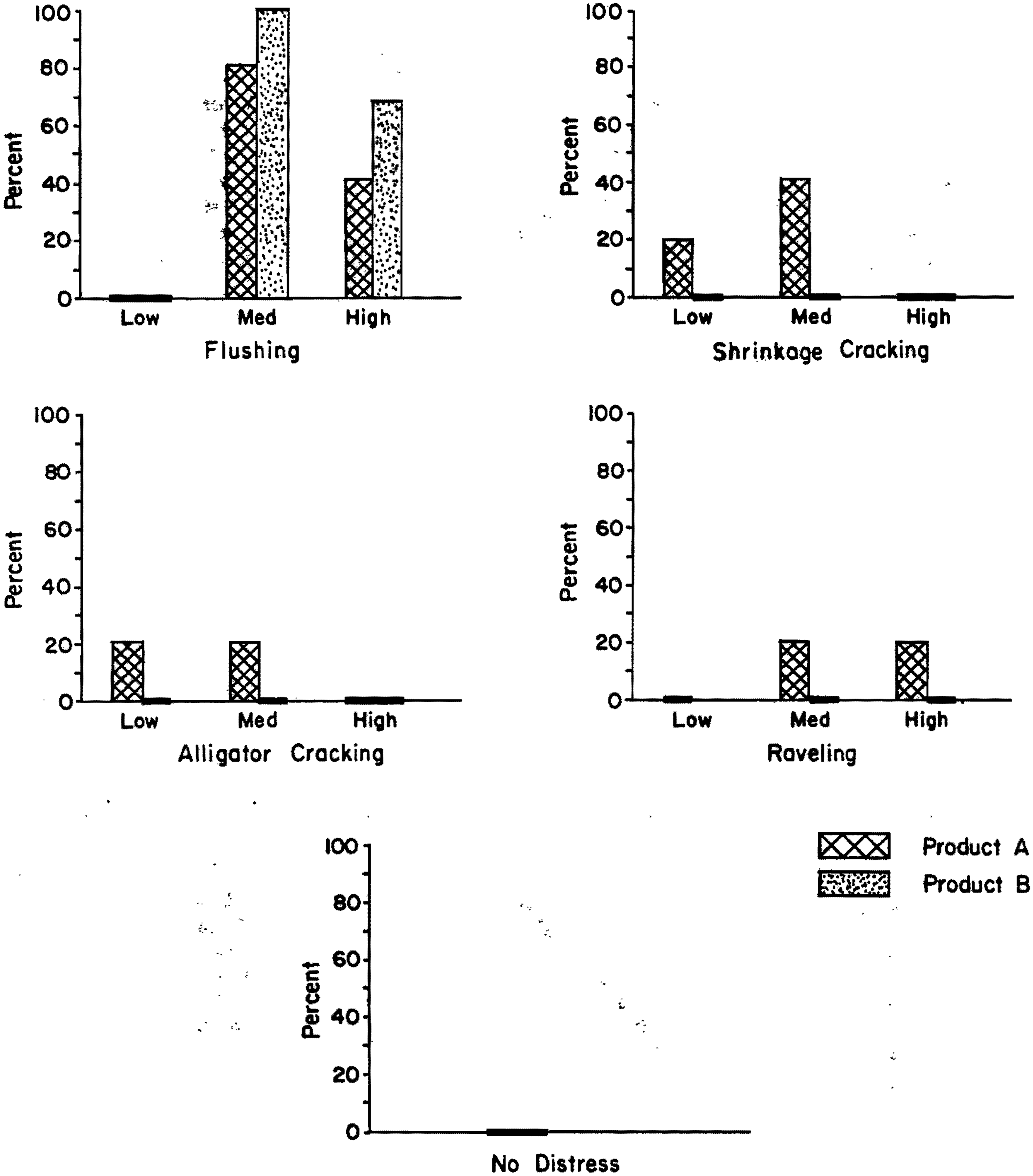


Figure A18. Over 2 Million Accumulated Vehicles.

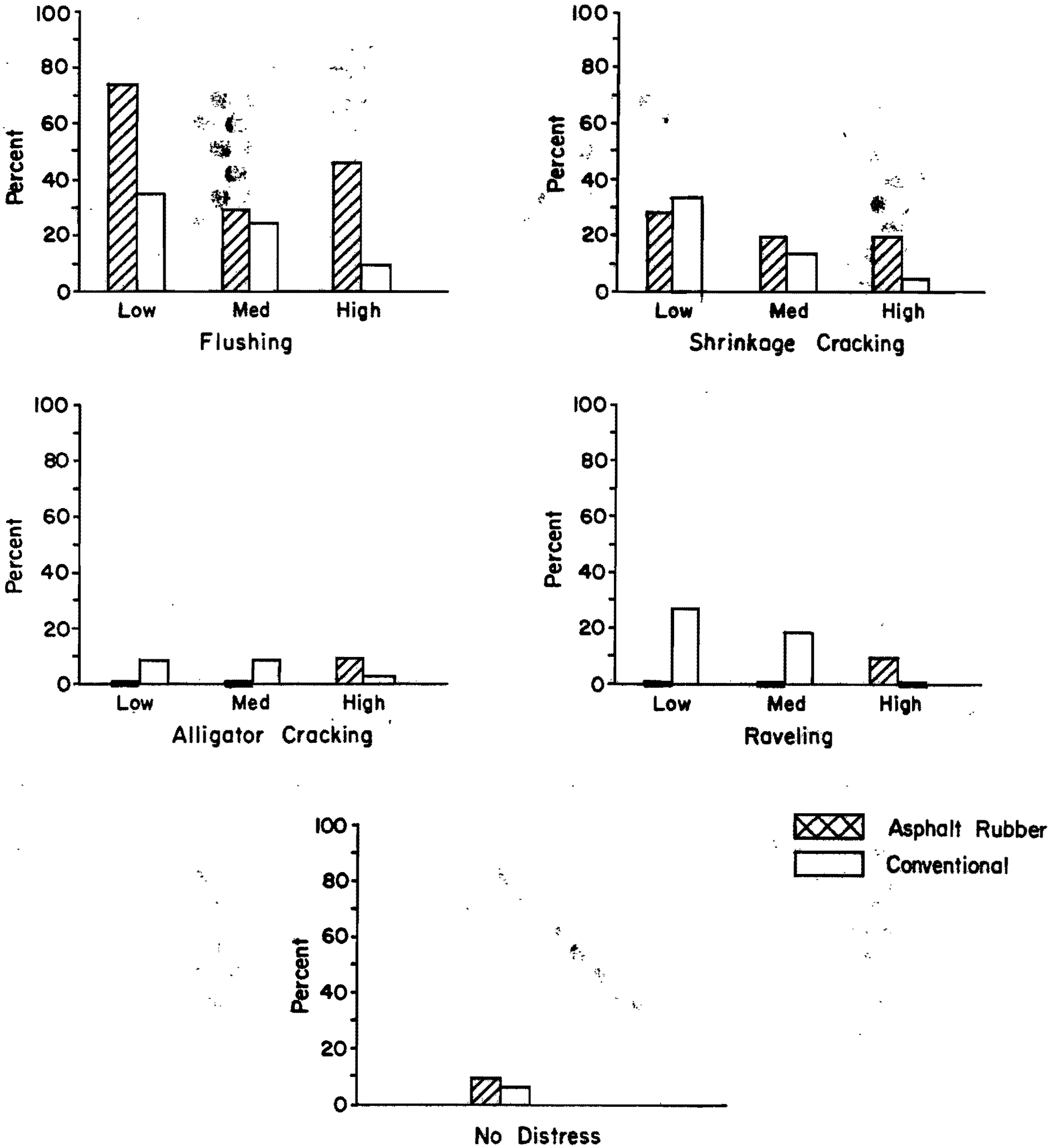


Figure A19. Under 1 million Accumulated Vehicles.

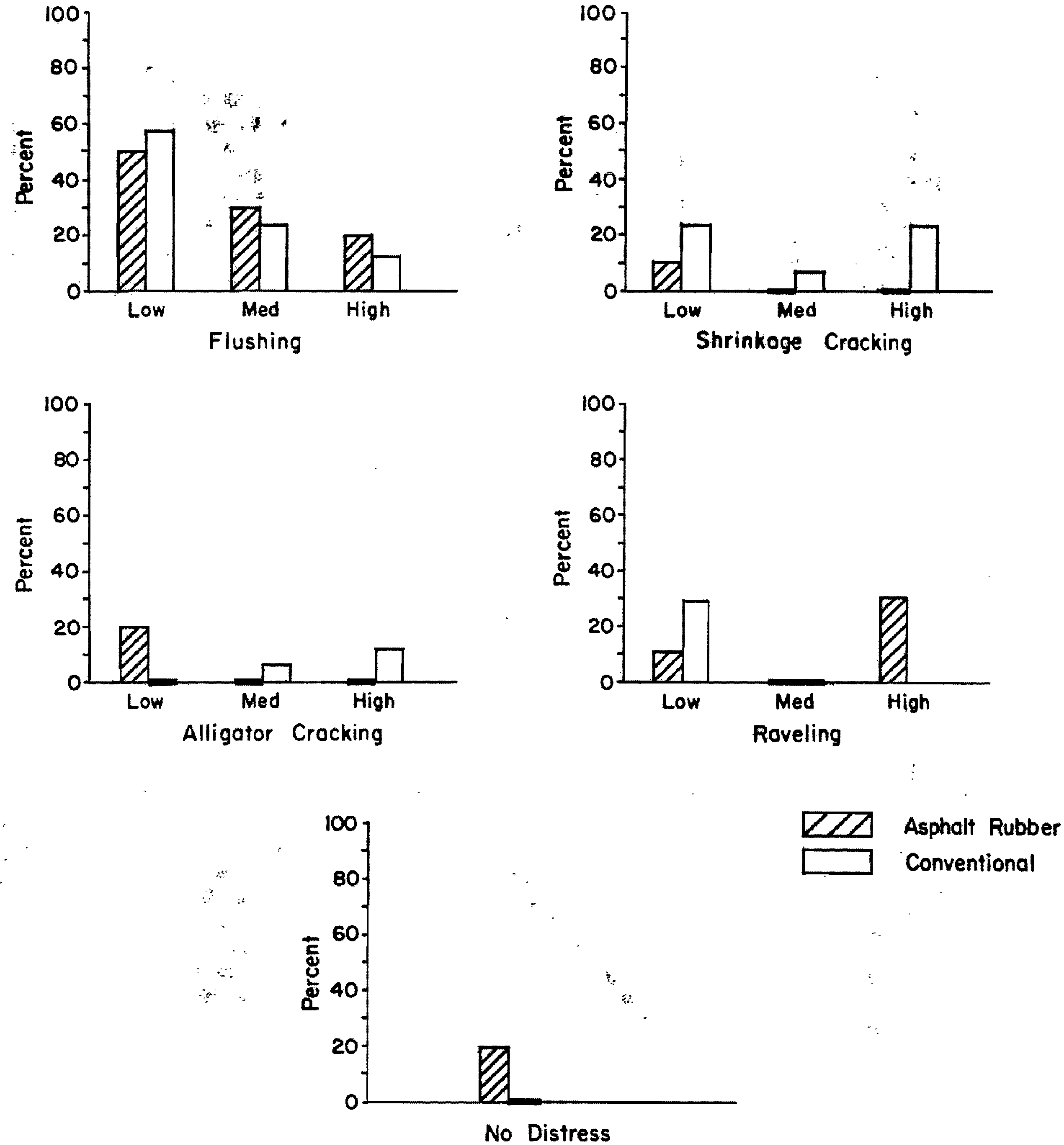


Figure A20. Between 1 and 2 Million Accumulated Vehicles.

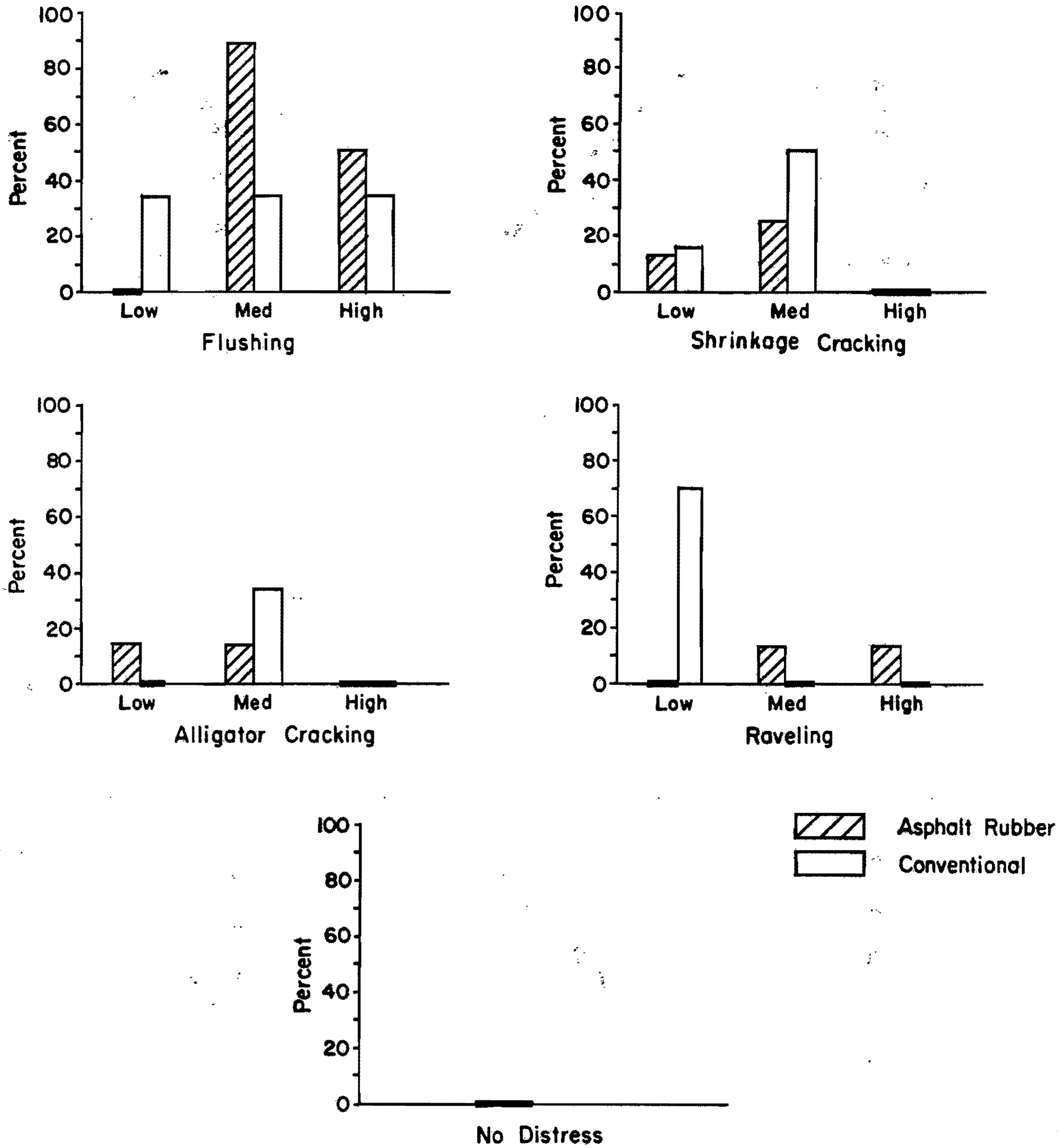


Figure A21. Over 2 Million Accumulated Vehicles.

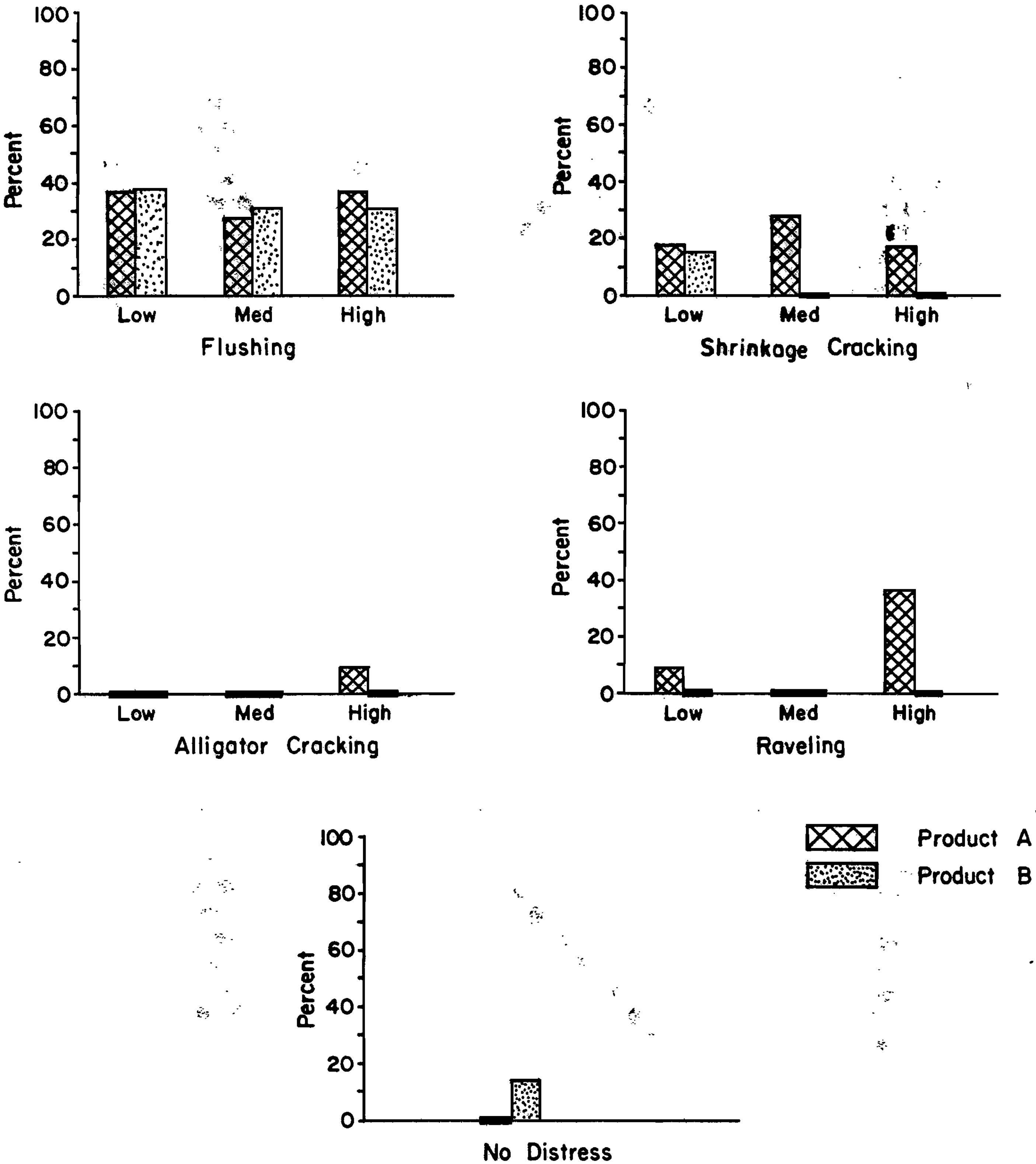


Figure A22. Pavements 0 to 2 Years Old - Effect of Age.

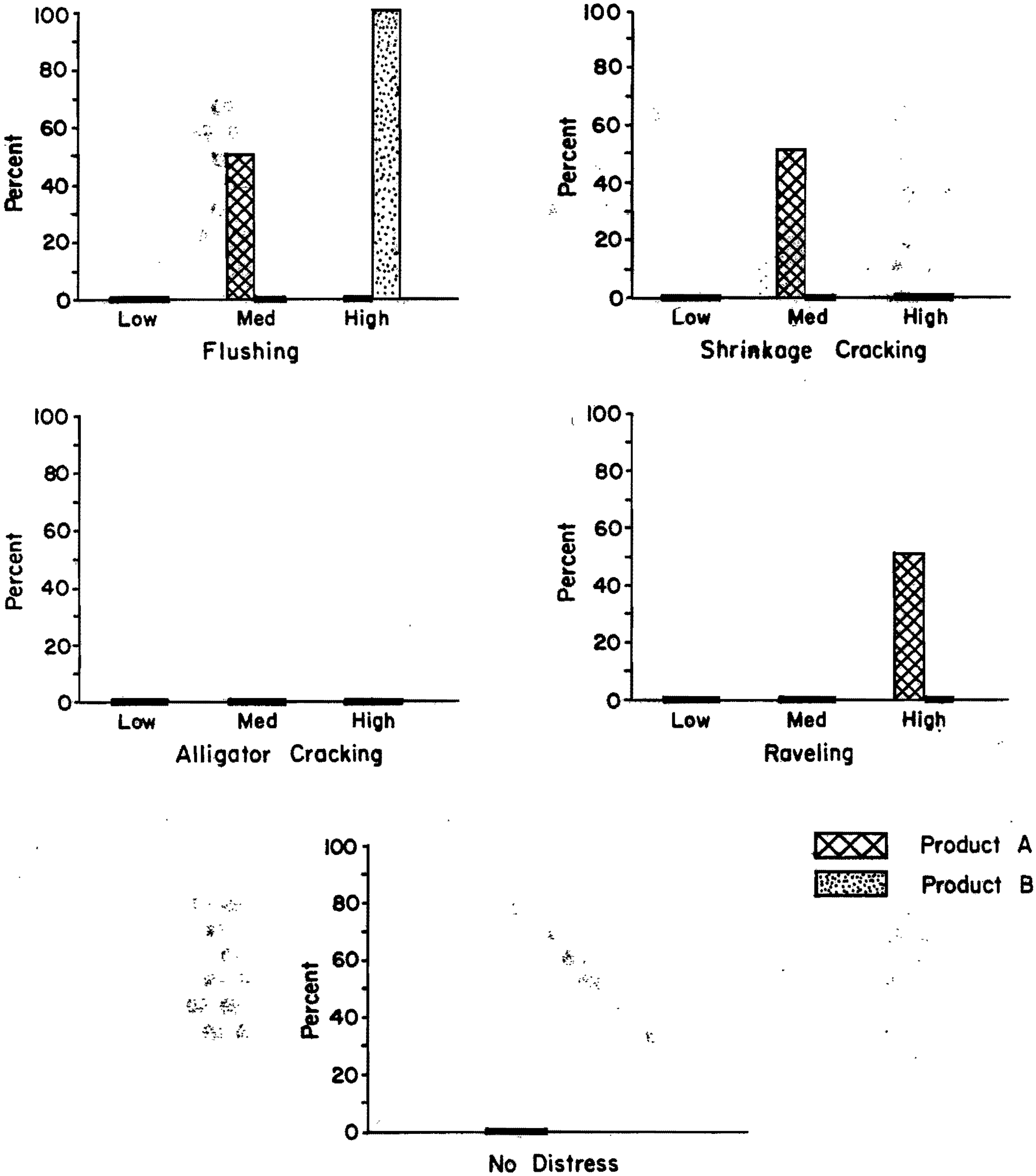


Figure A23. Pavements 3 to 4 Years Old - Effect of Age.

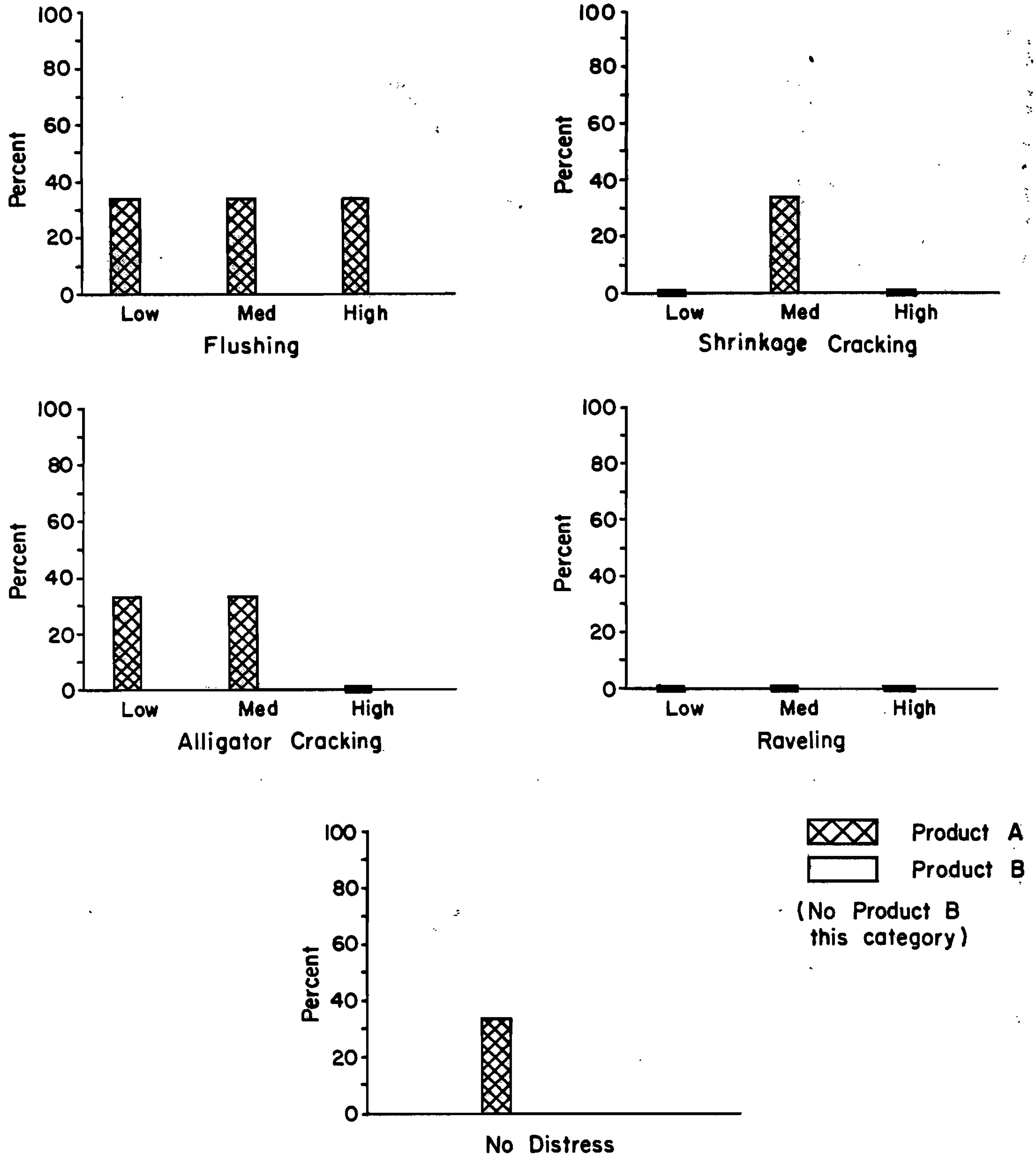


Figure A24. Pavements 5 to 6 Years Old - Effect of Age.

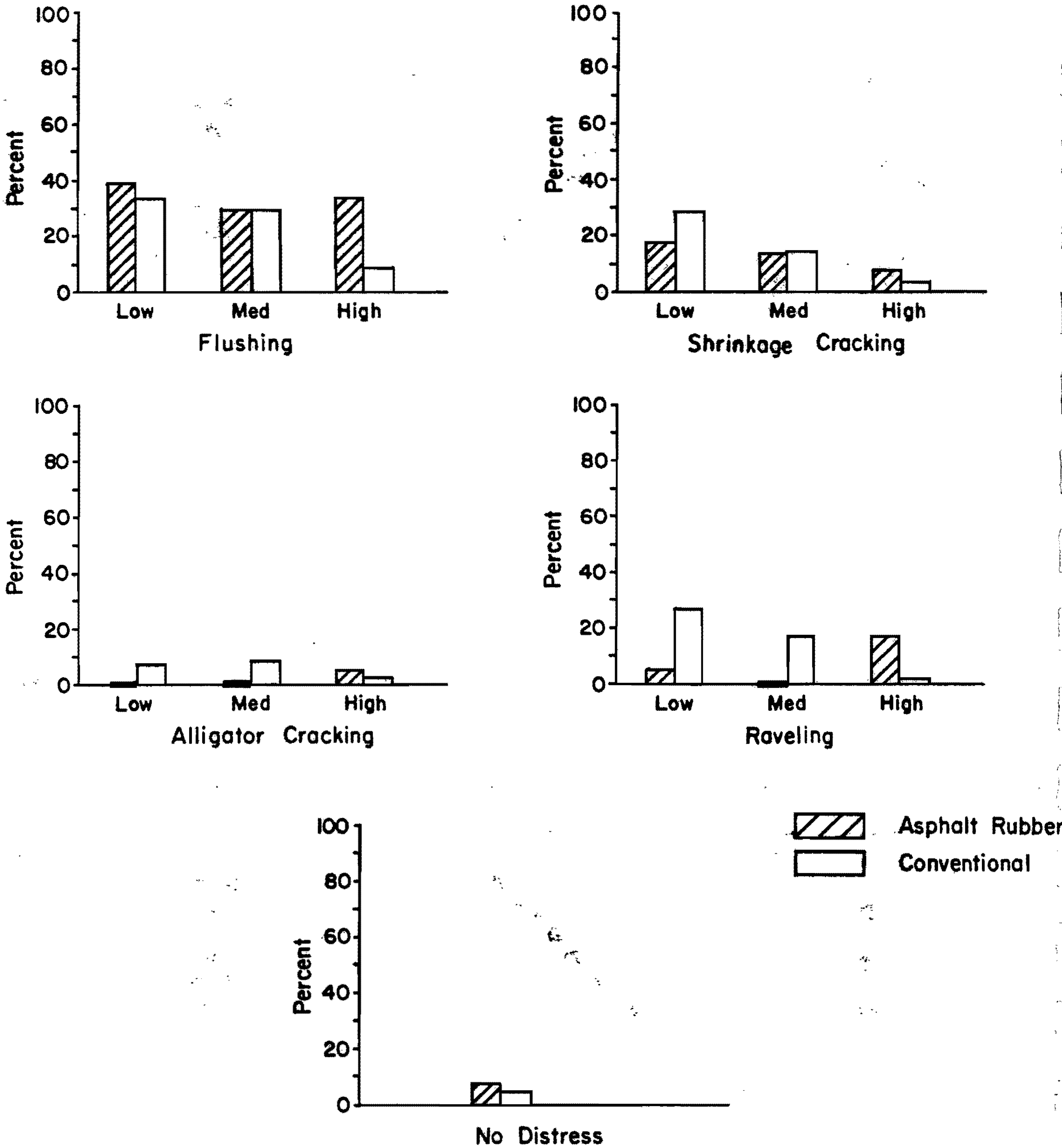


Figure A25. Pavements 0 to 2 Years Old - Effect of Age.

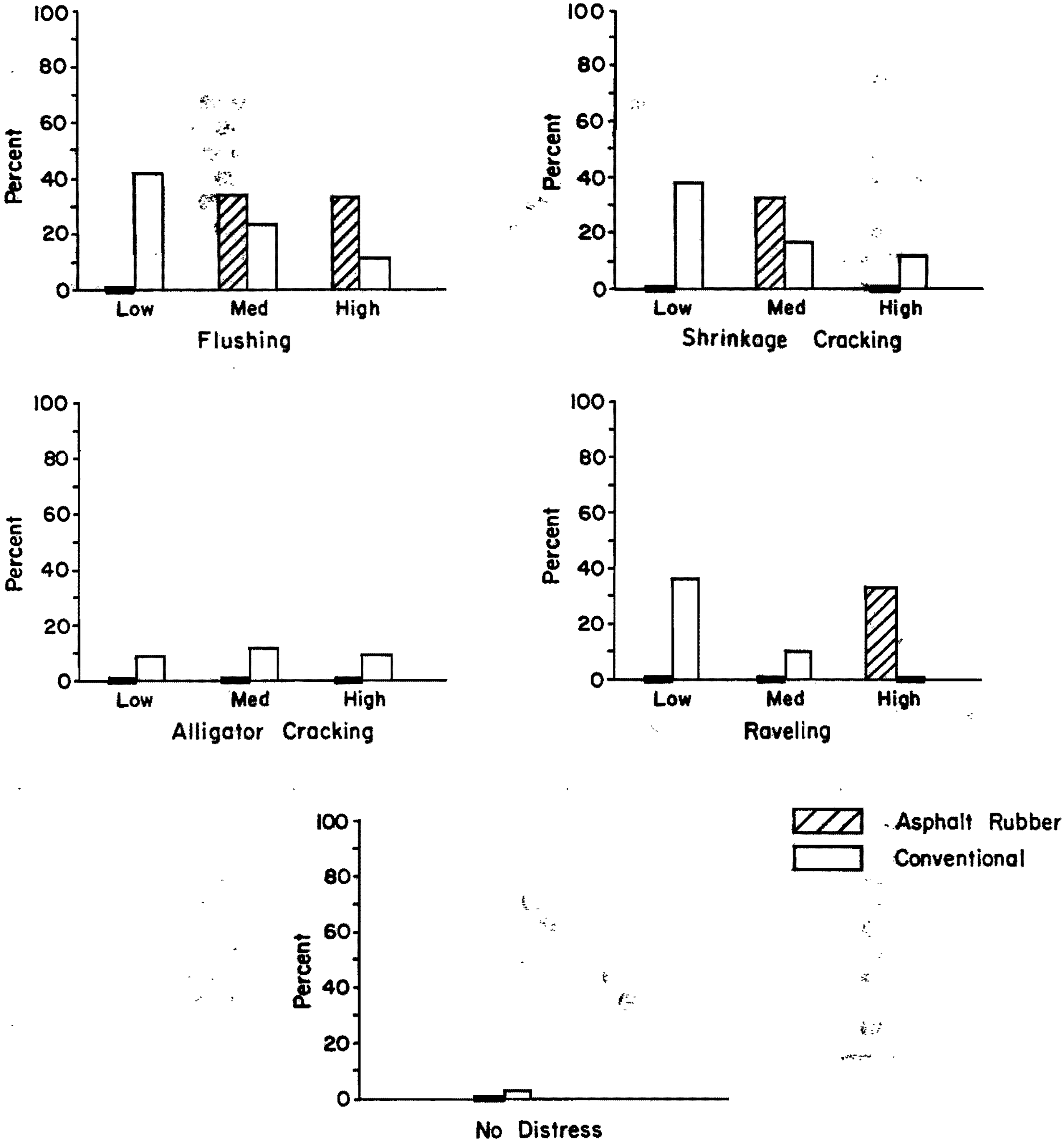


Figure A26. Pavements 3 to 4 Years Old - Effect of Age.

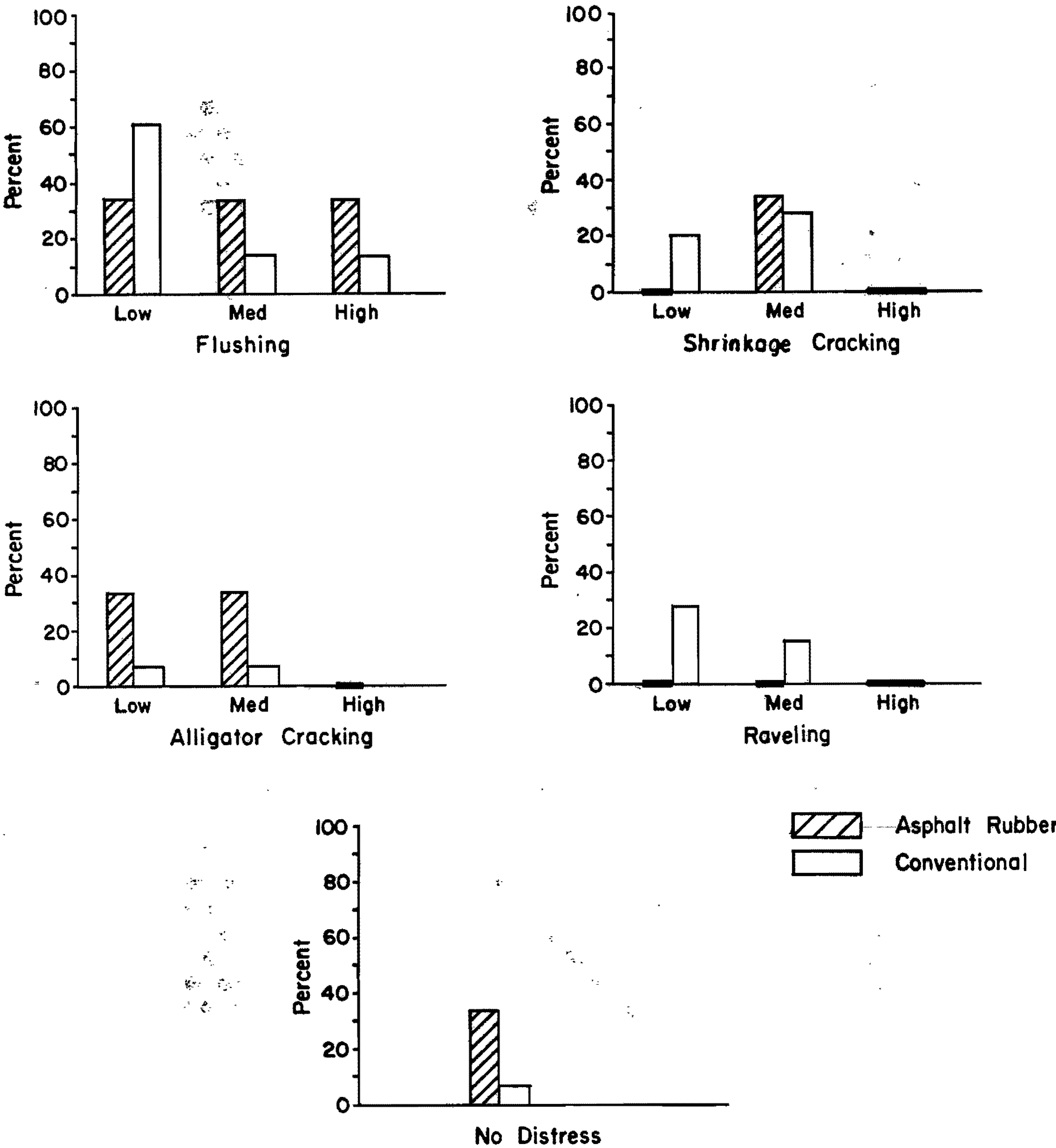


Figure A27. Pavements 5 to 6 Years Old - Effect of Age.

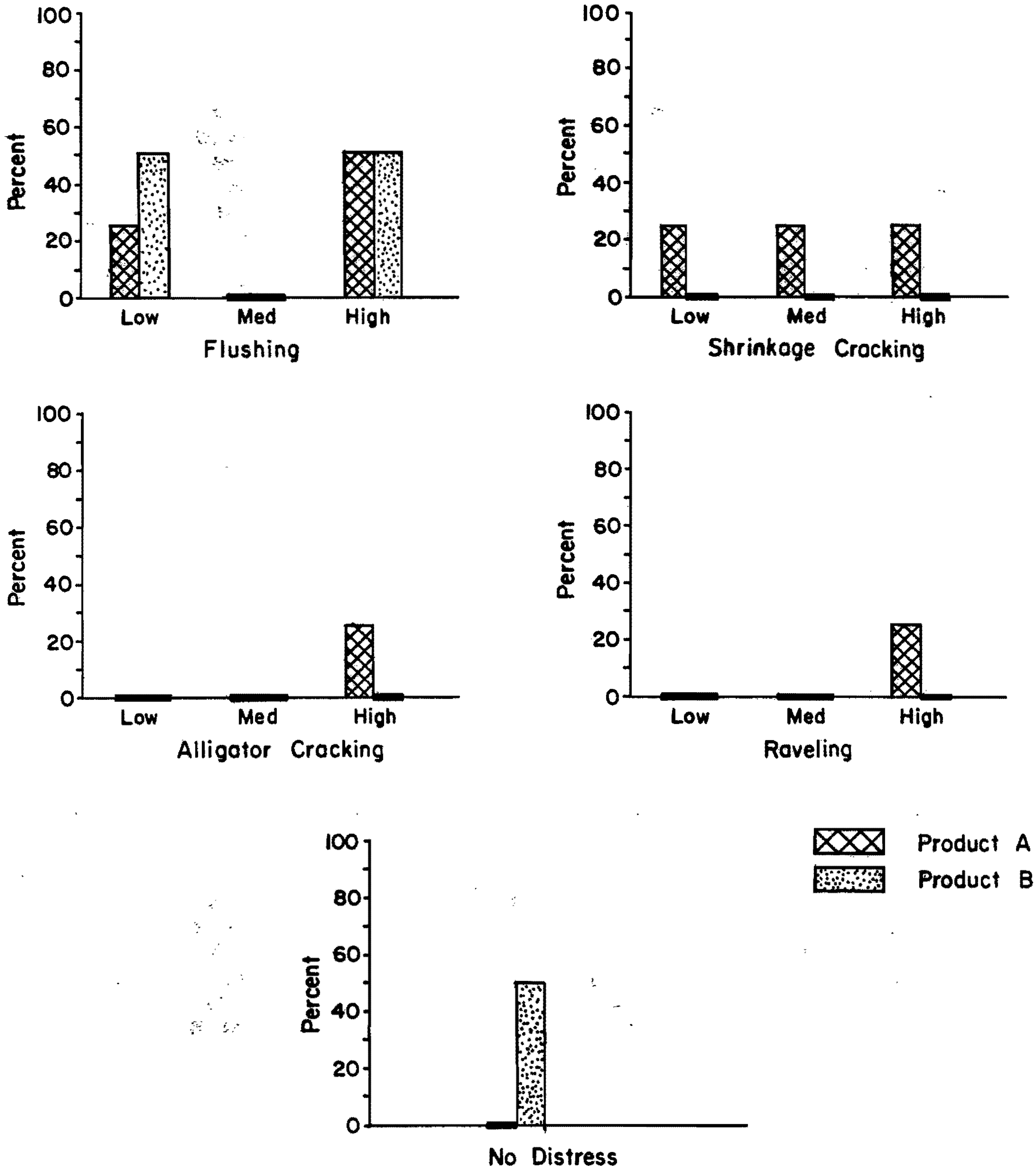


Figure A28. Performance Over Thin Flexible Substrates.

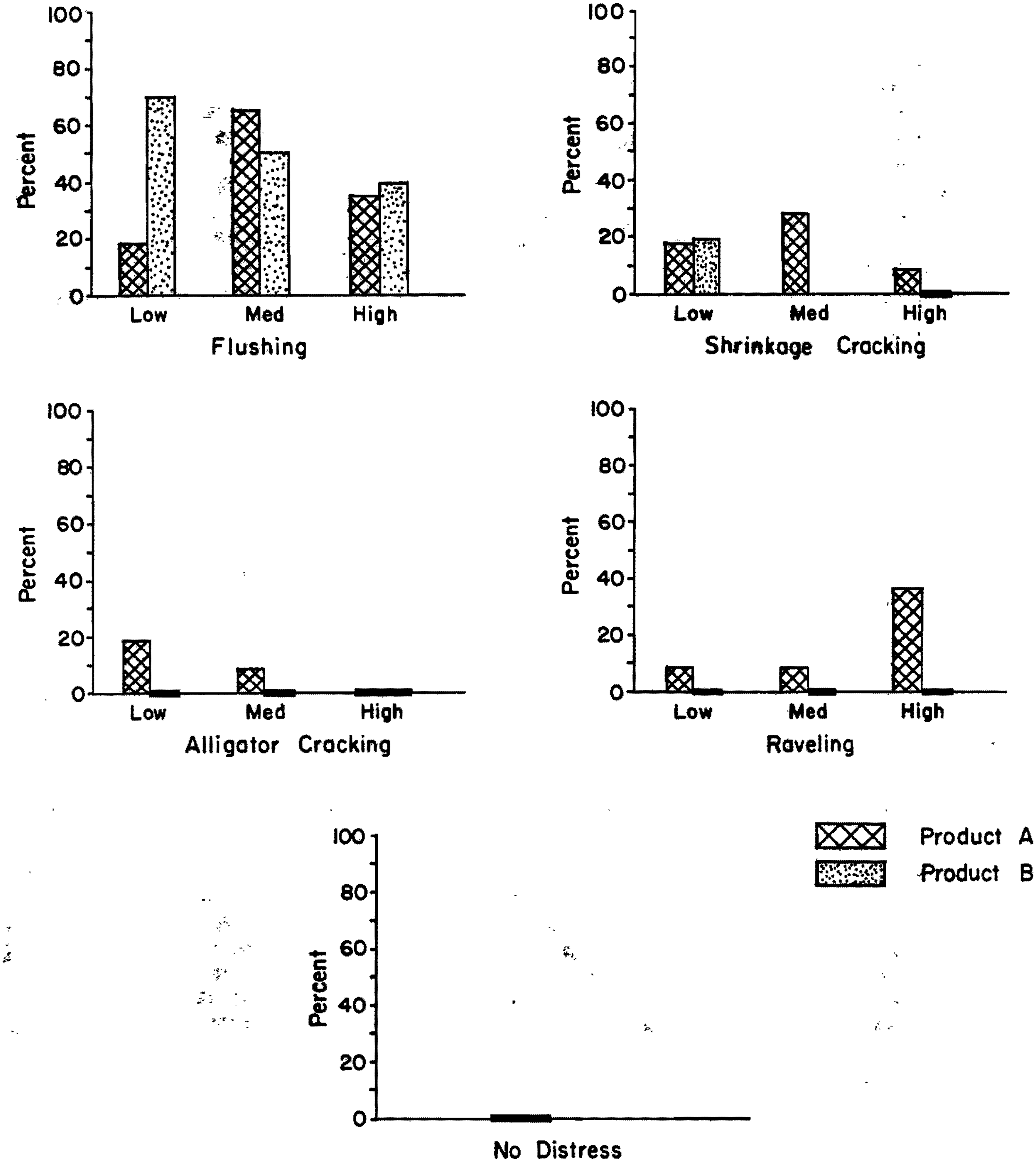


Figure A29. Performance Over Thick Flexible Substrates.

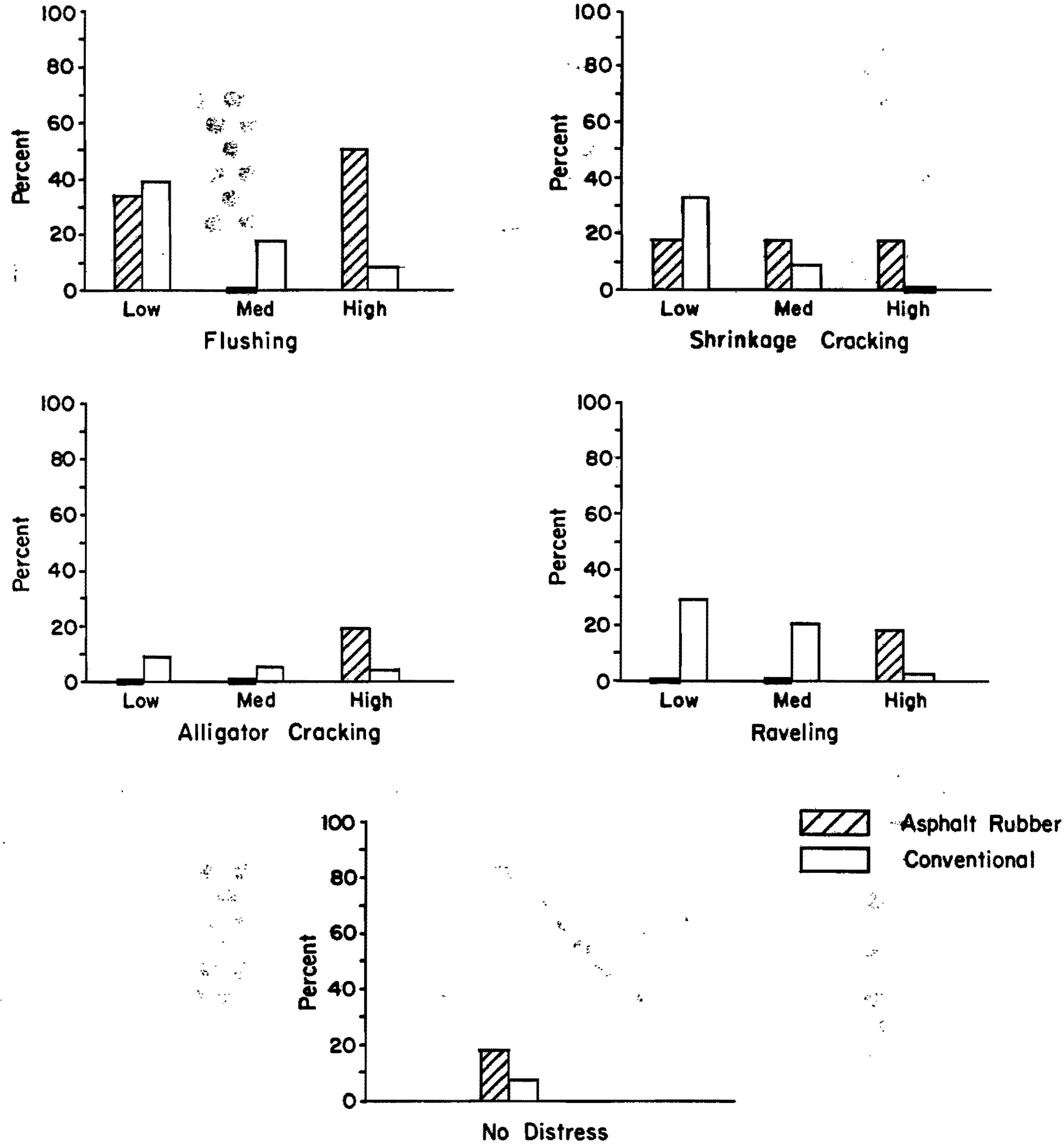


Figure A30. Performance Over Thin Flexible Substrates.

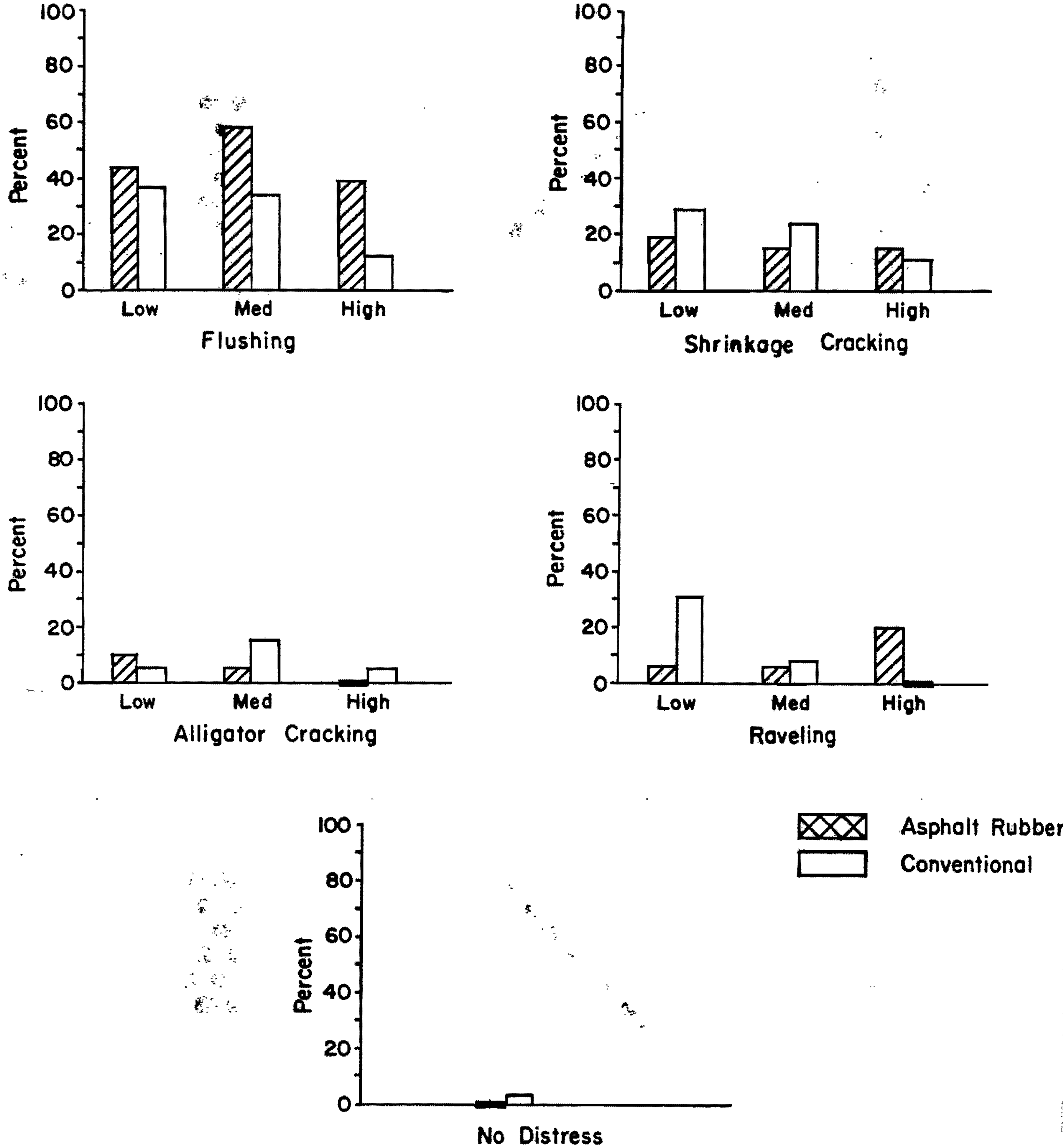


Figure A31. Performance Over Thick Flexible Substrates.

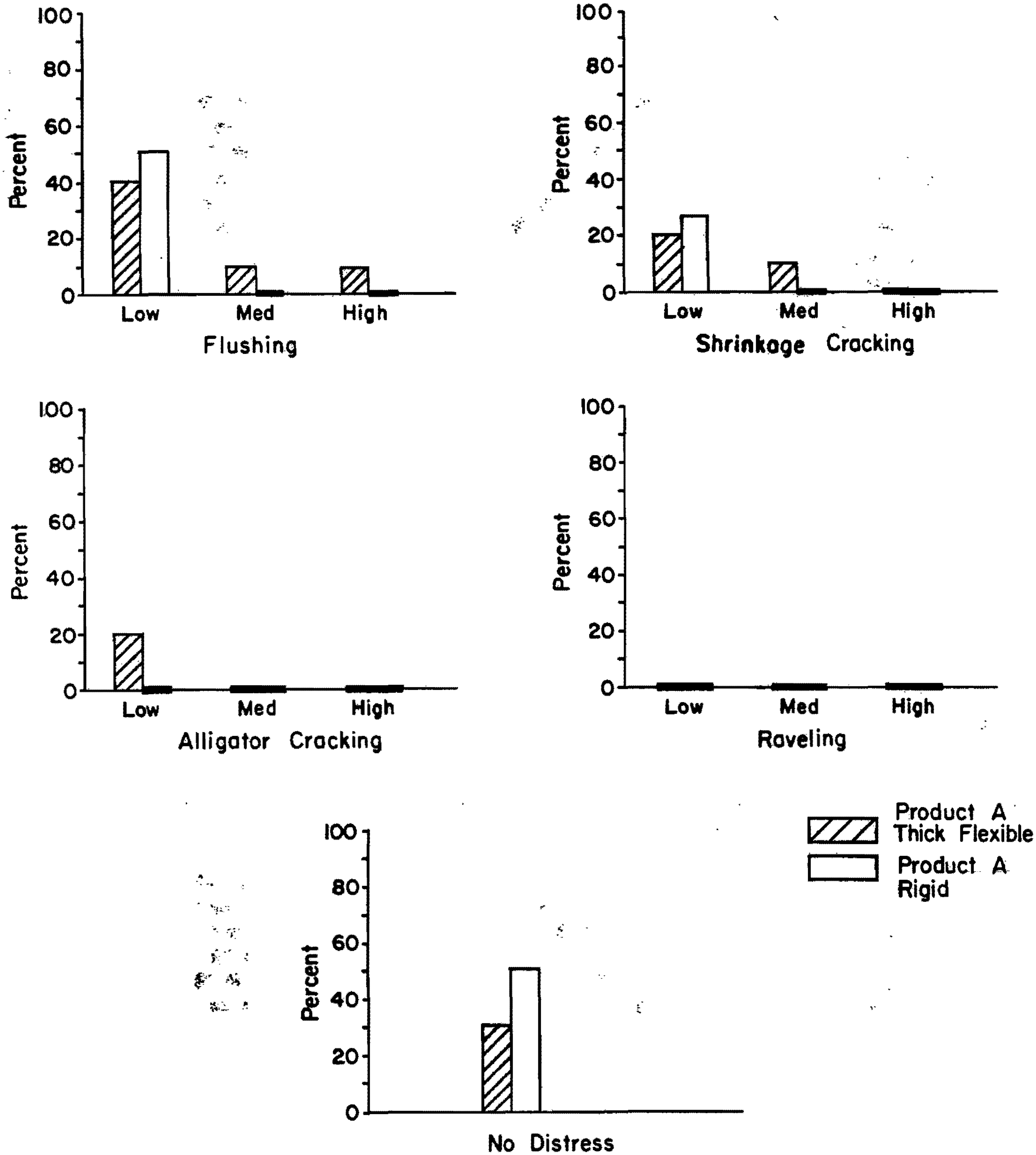
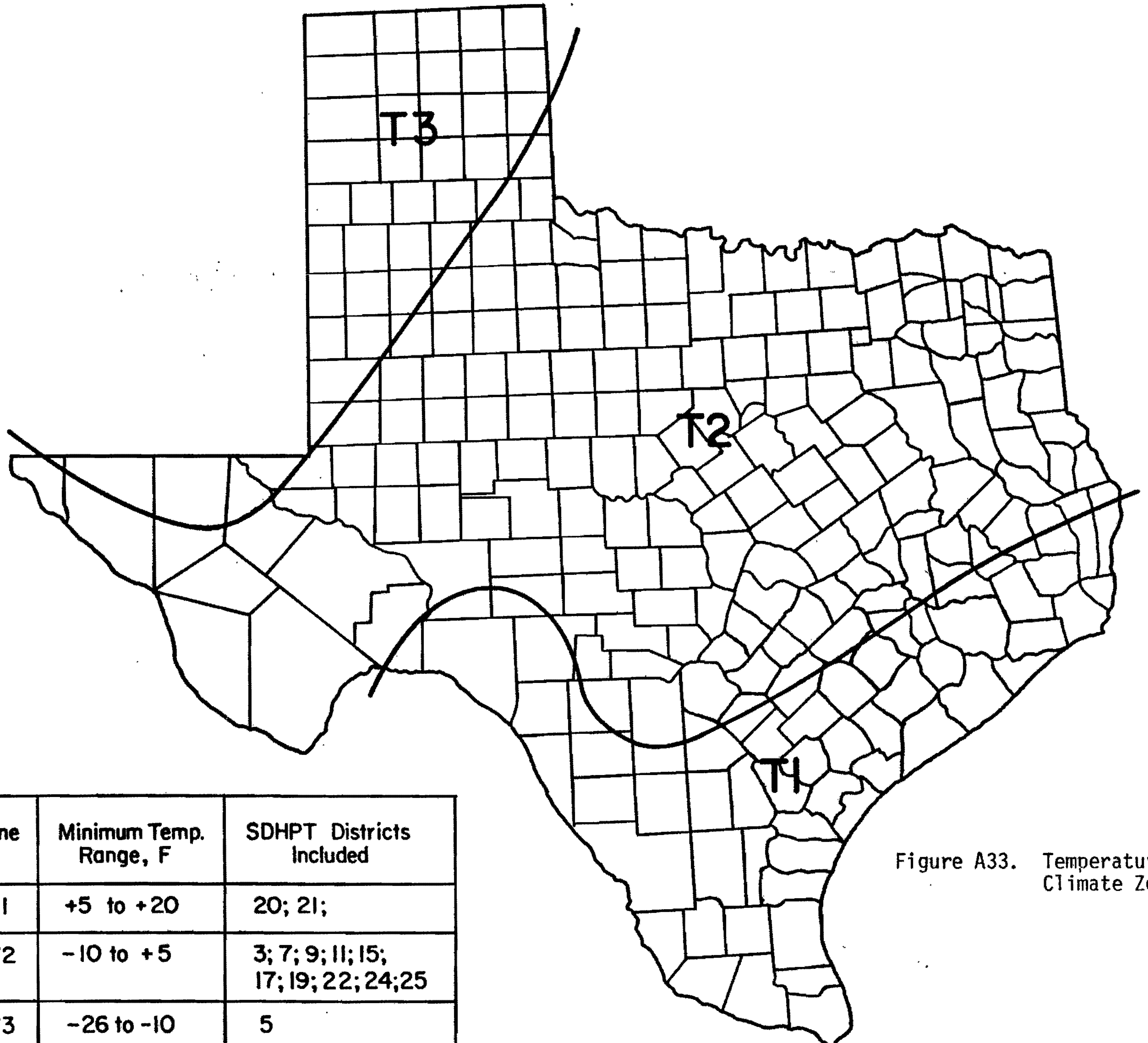
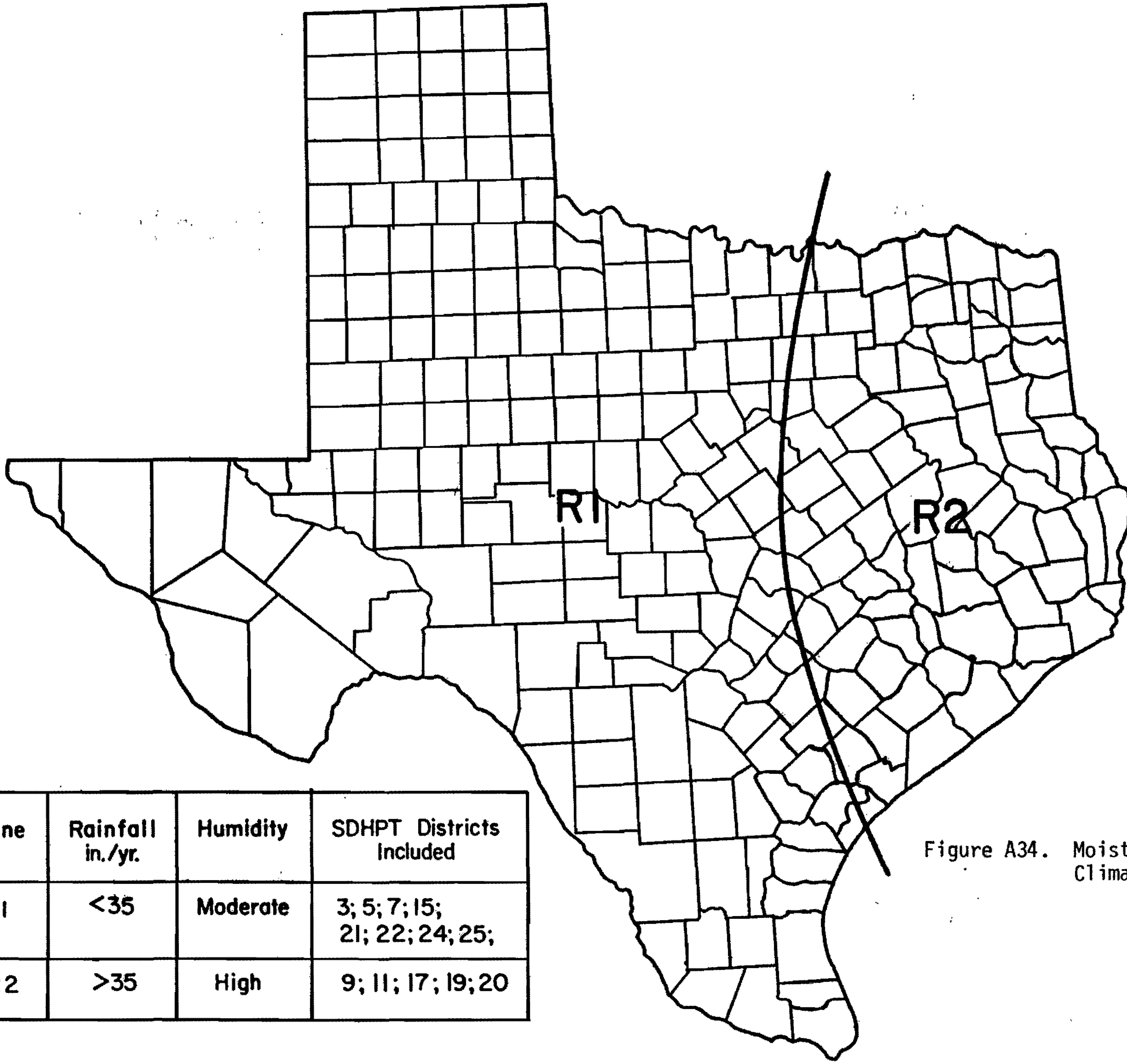


Figure A32. Product A SAMI Performance Related to Substrate.



Zone	Minimum Temp. Range, F	SDHPT Districts Included
T1	+5 to +20	20; 21;
T2	-10 to +5	3; 7; 9; 11; 15; 17; 19; 22; 24; 25
T3	-26 to -10	5

Figure A33. Temperature Related Climate Zones.



Zone	Rainfall in./yr.	Humidity	SDHPT Districts Included
R1	<35	Moderate	3; 5; 7; 15; 21; 22; 24; 25;
R2	>35	High	9; 11; 17; 19; 20

Figure A34. Moisture Related Climate Zones.

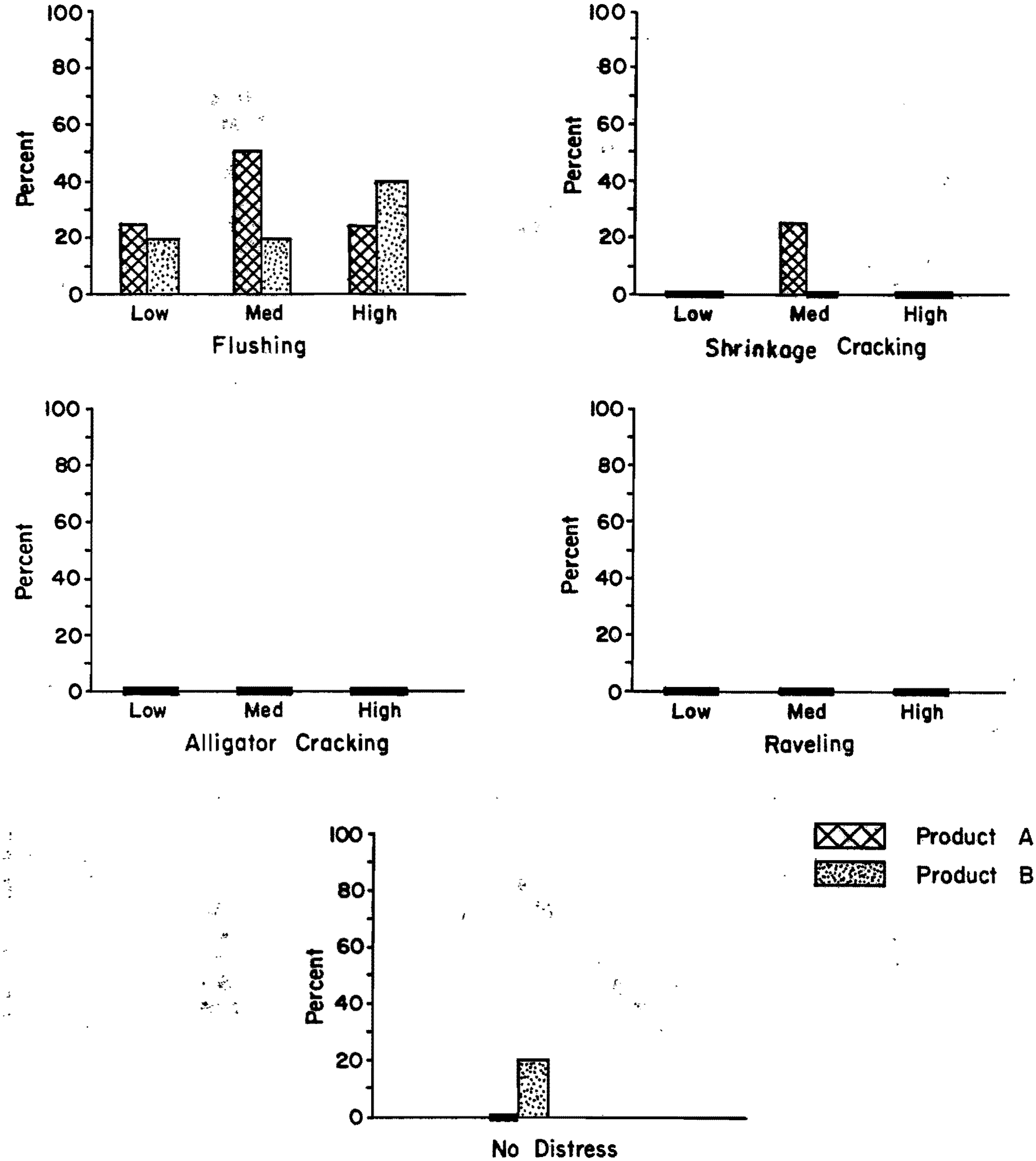


Figure A35. Hot Climate Performance, Zone T1.

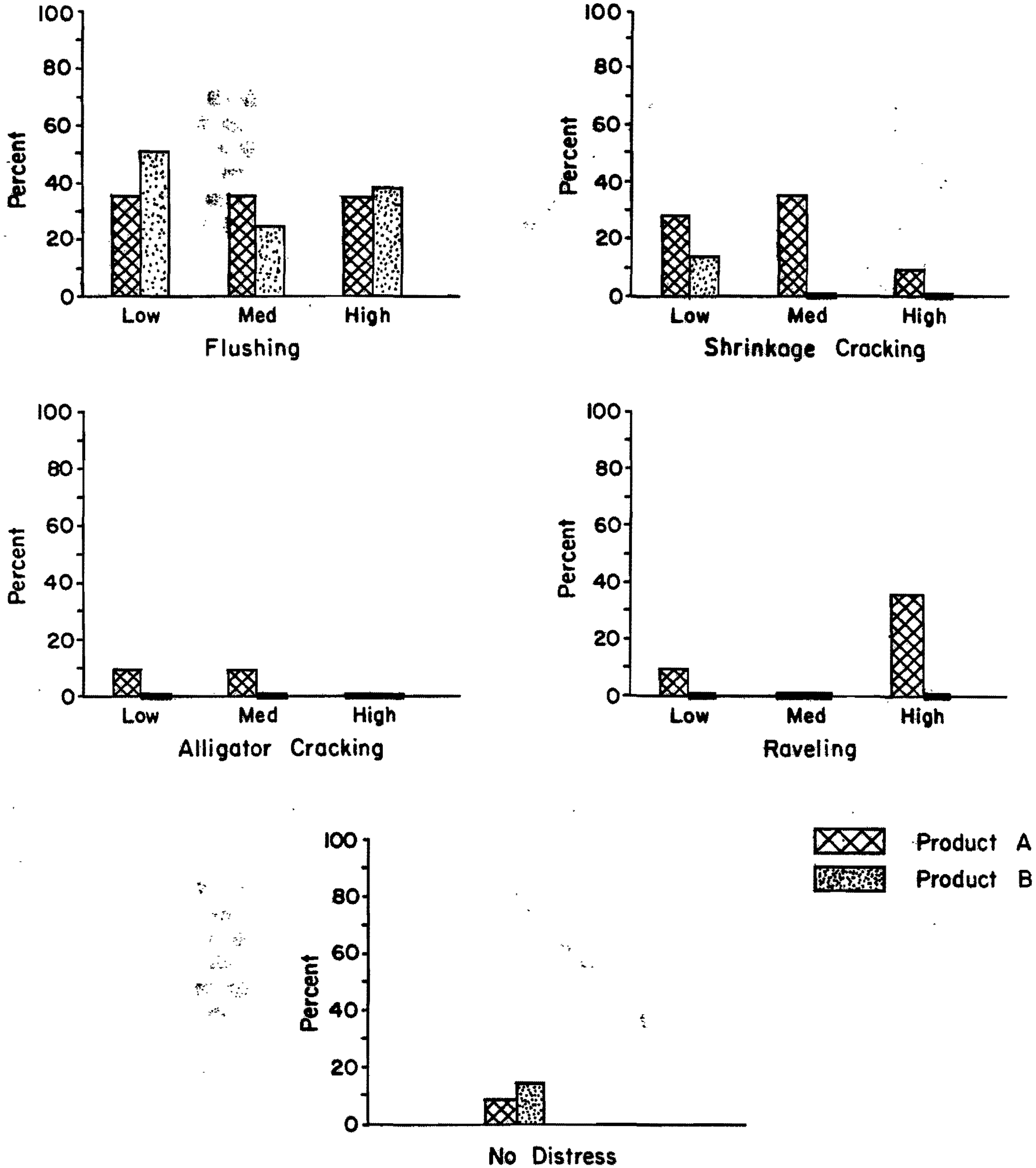


Figure A36. Moderate Climate Performance, Zone T2.

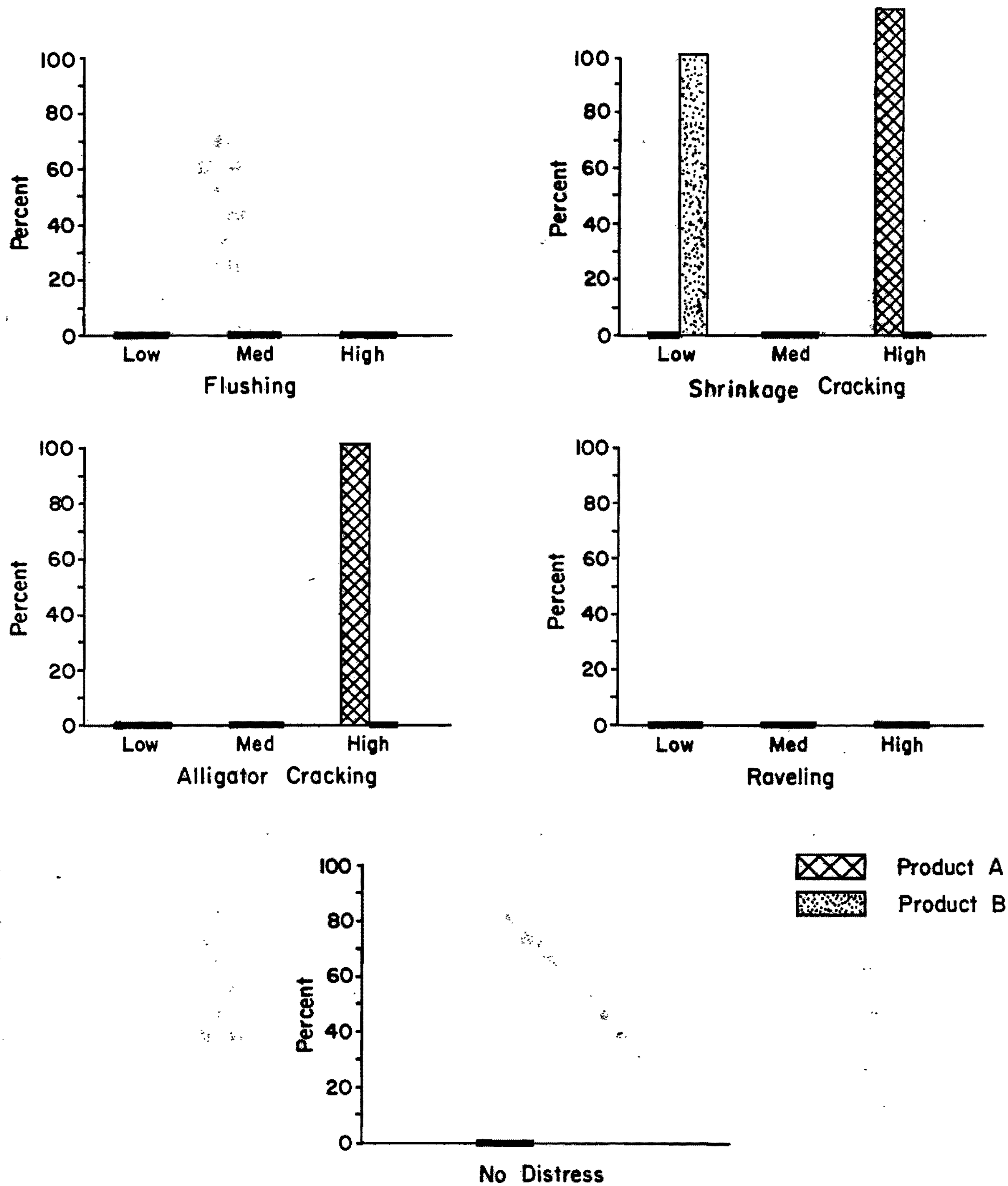


Figure A37. Cold Climate Performance, Zone T3.

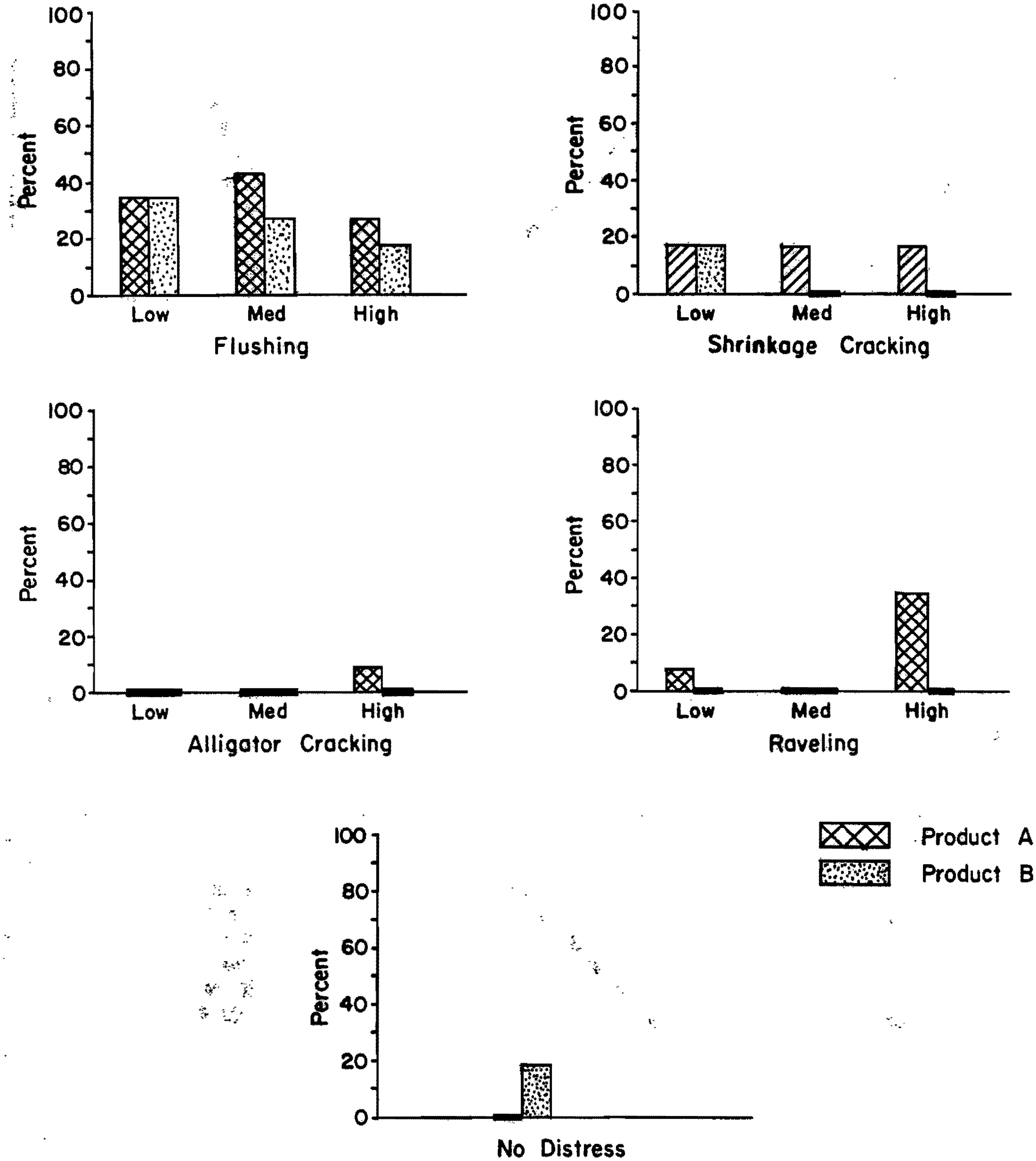


Figure A38. Dry Climate Performance, Zone R1.

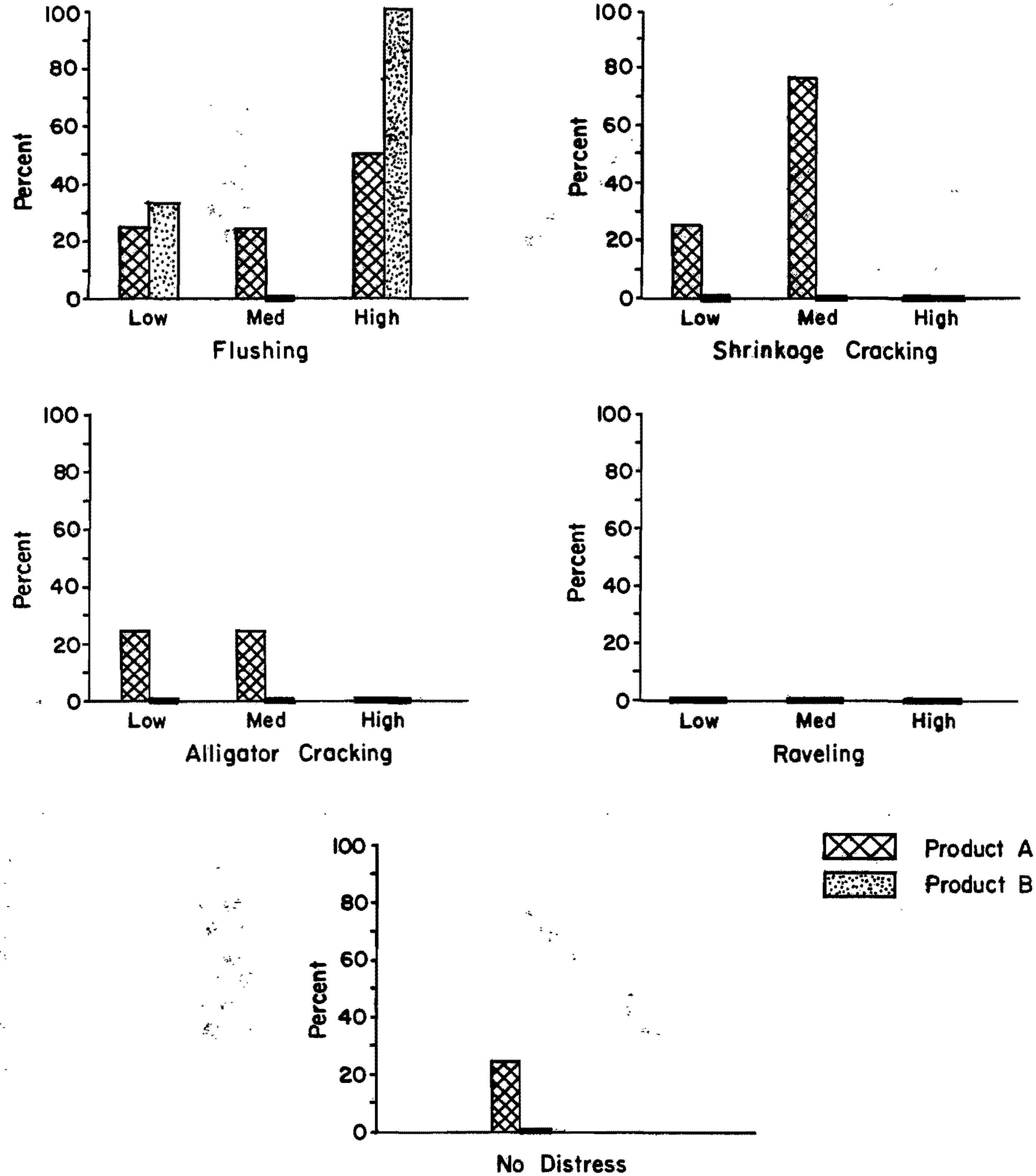


Figure A39. Wet Climate Performance, Zone R2.

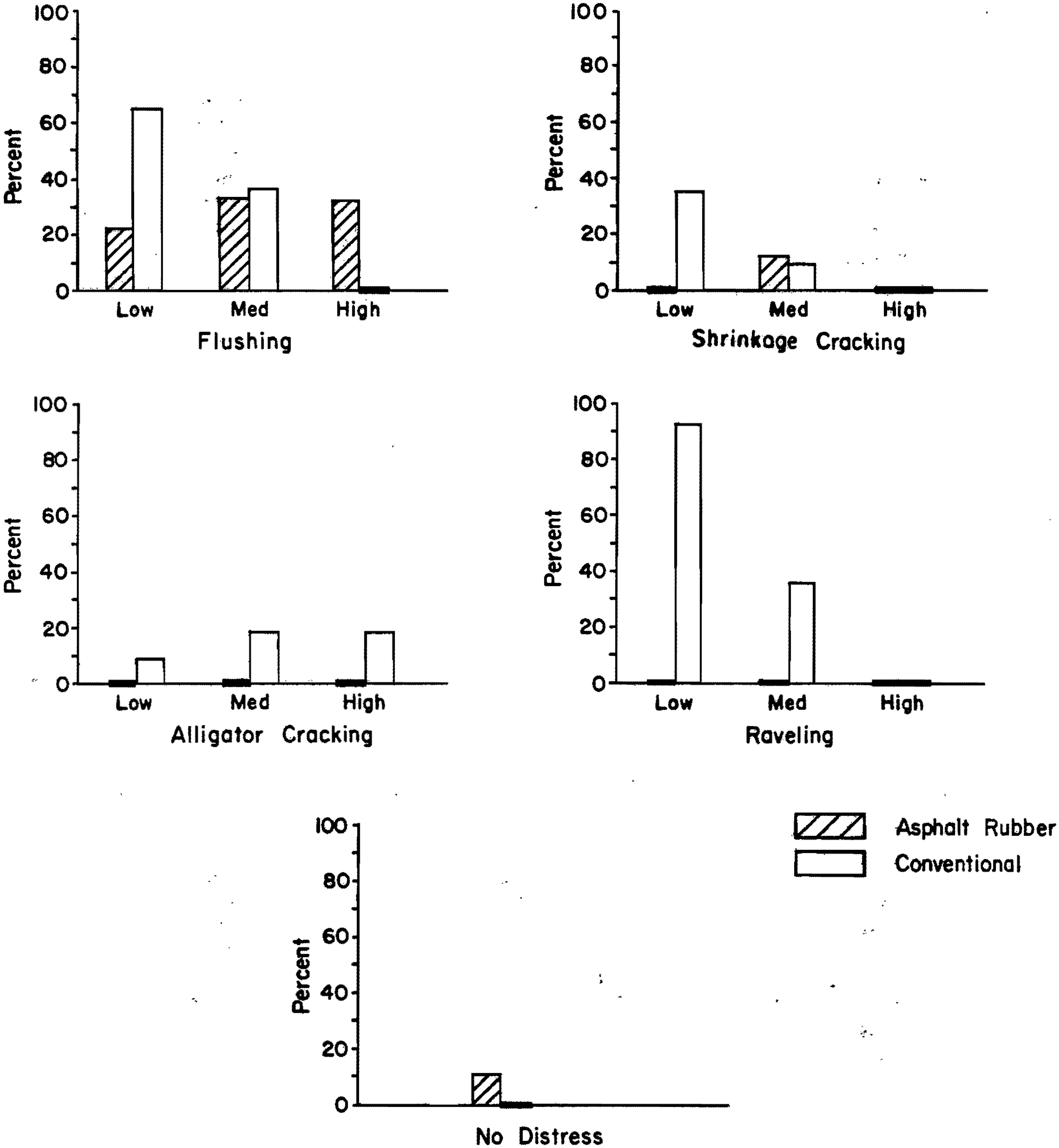


Figure A40. Hot Climate Performance.

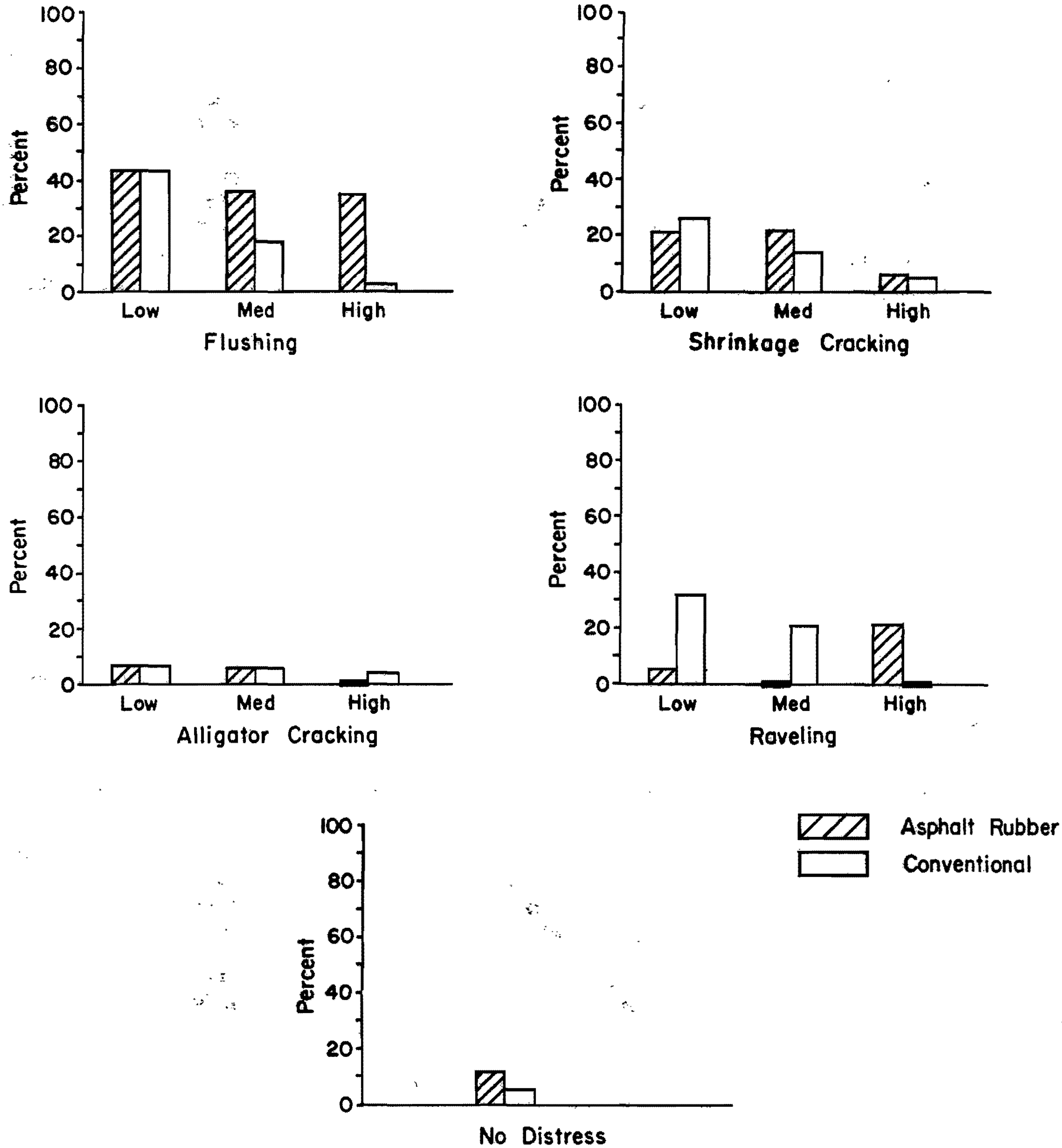


Figure A41. Moderate Climate Performance.

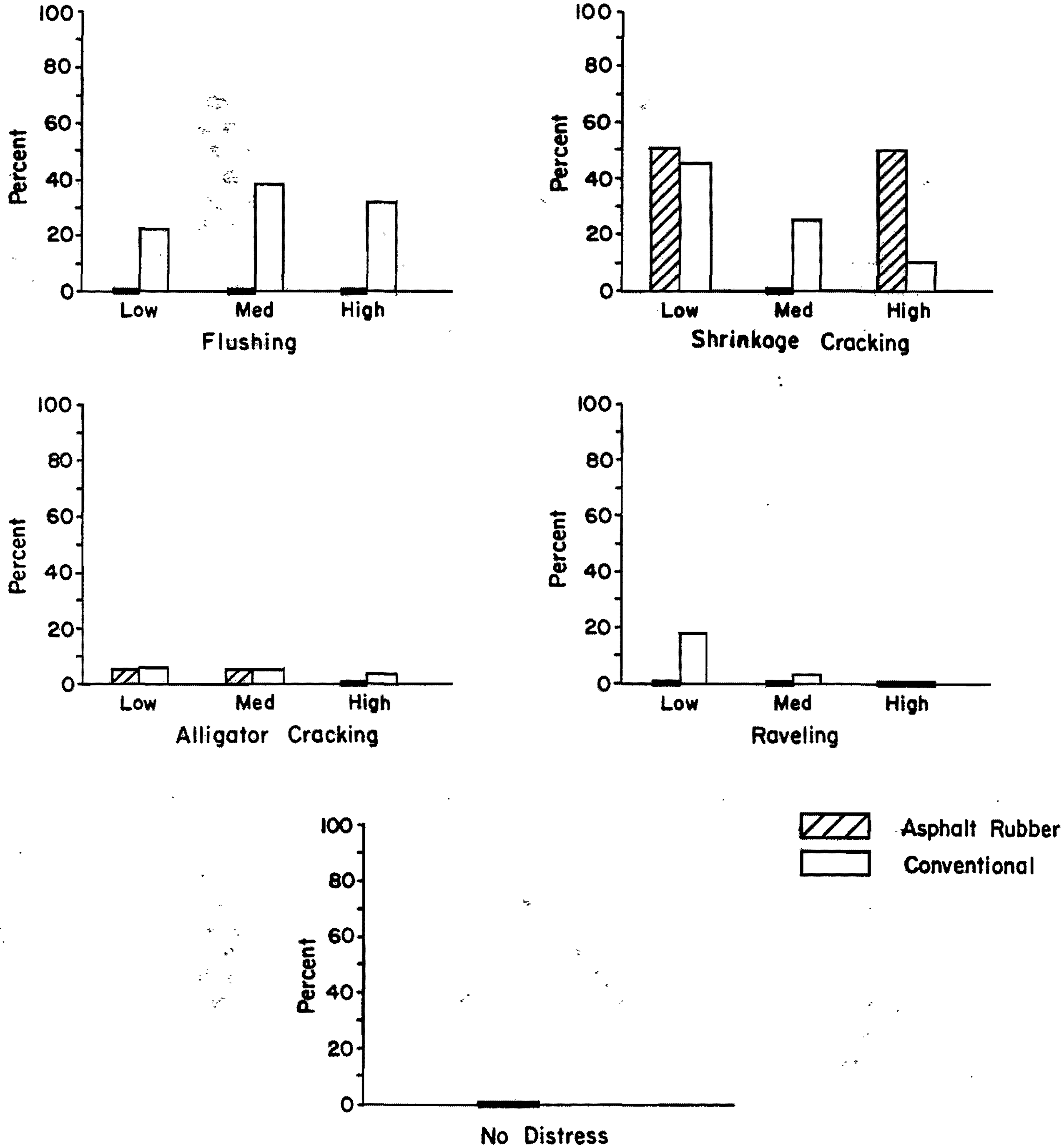


Figure A42. Cold Climate Performance.

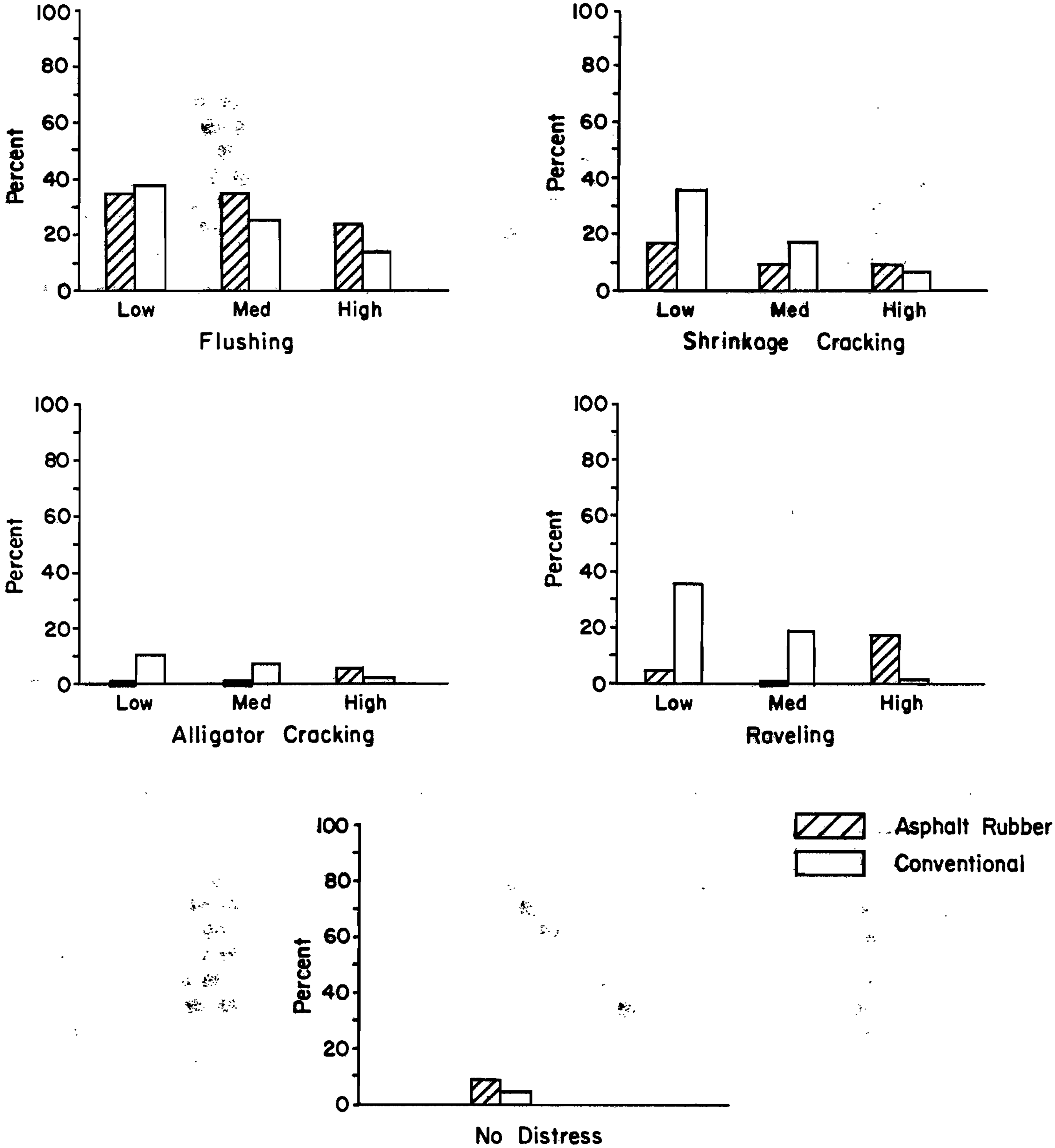


Figure A43. Dry Climate Performance.

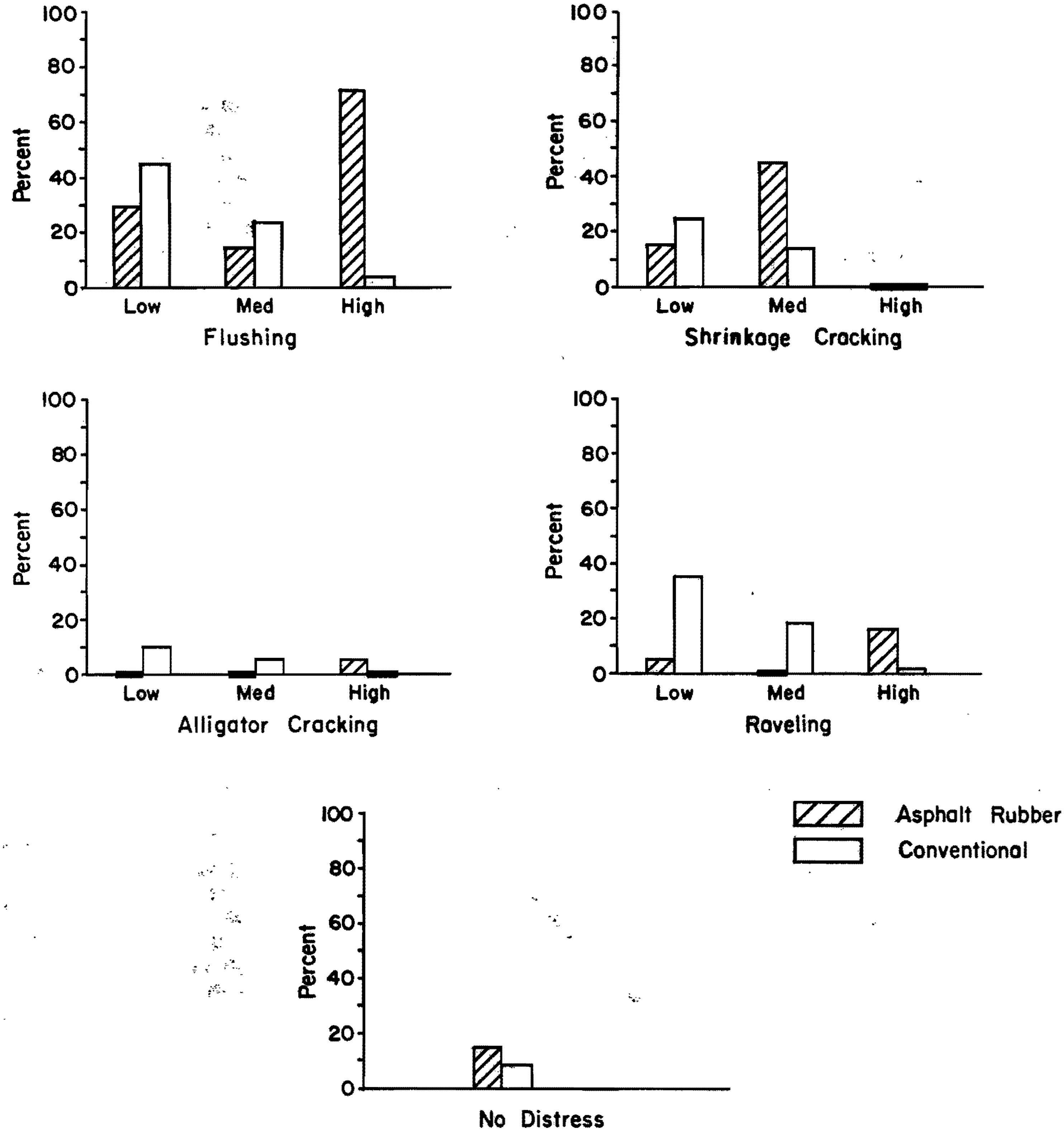


Figure A44. Wet Climate Performance.

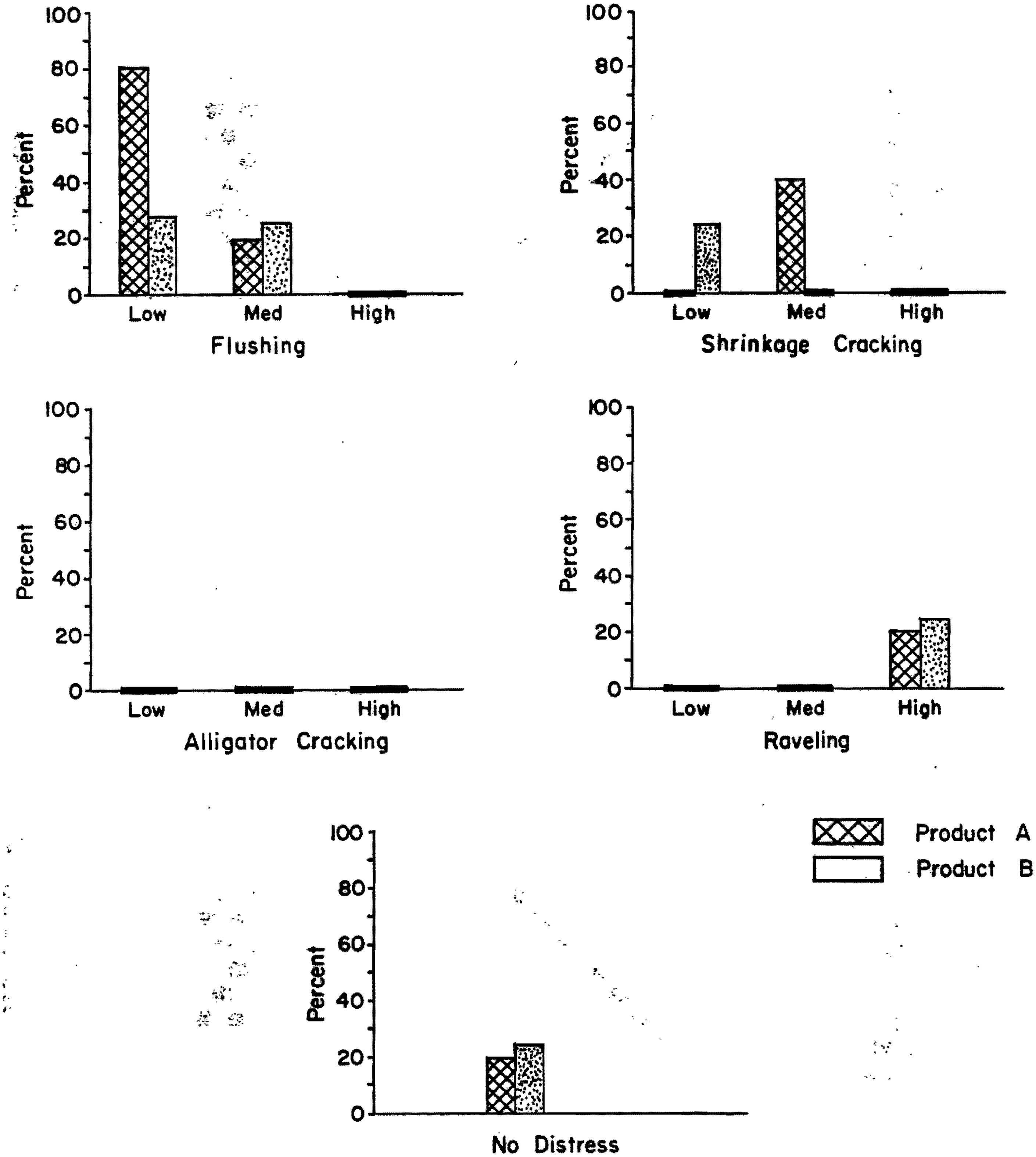


Figure A45. Asphalt-Rubber Seal Coats of 0 to 3 Miles.

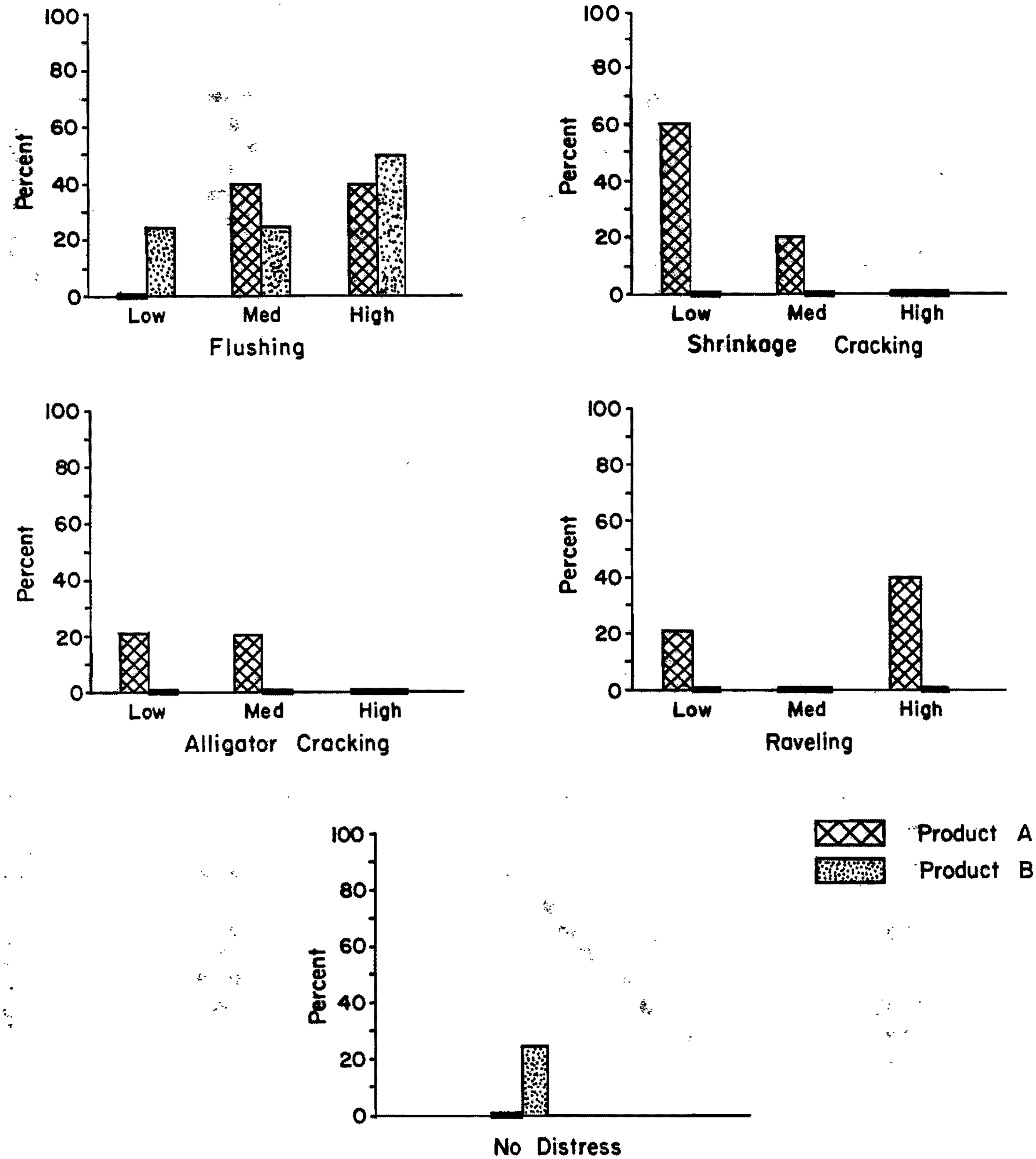


Figure A46. Asphalt-Rubber Seal Coats of 4 to 6 Miles.

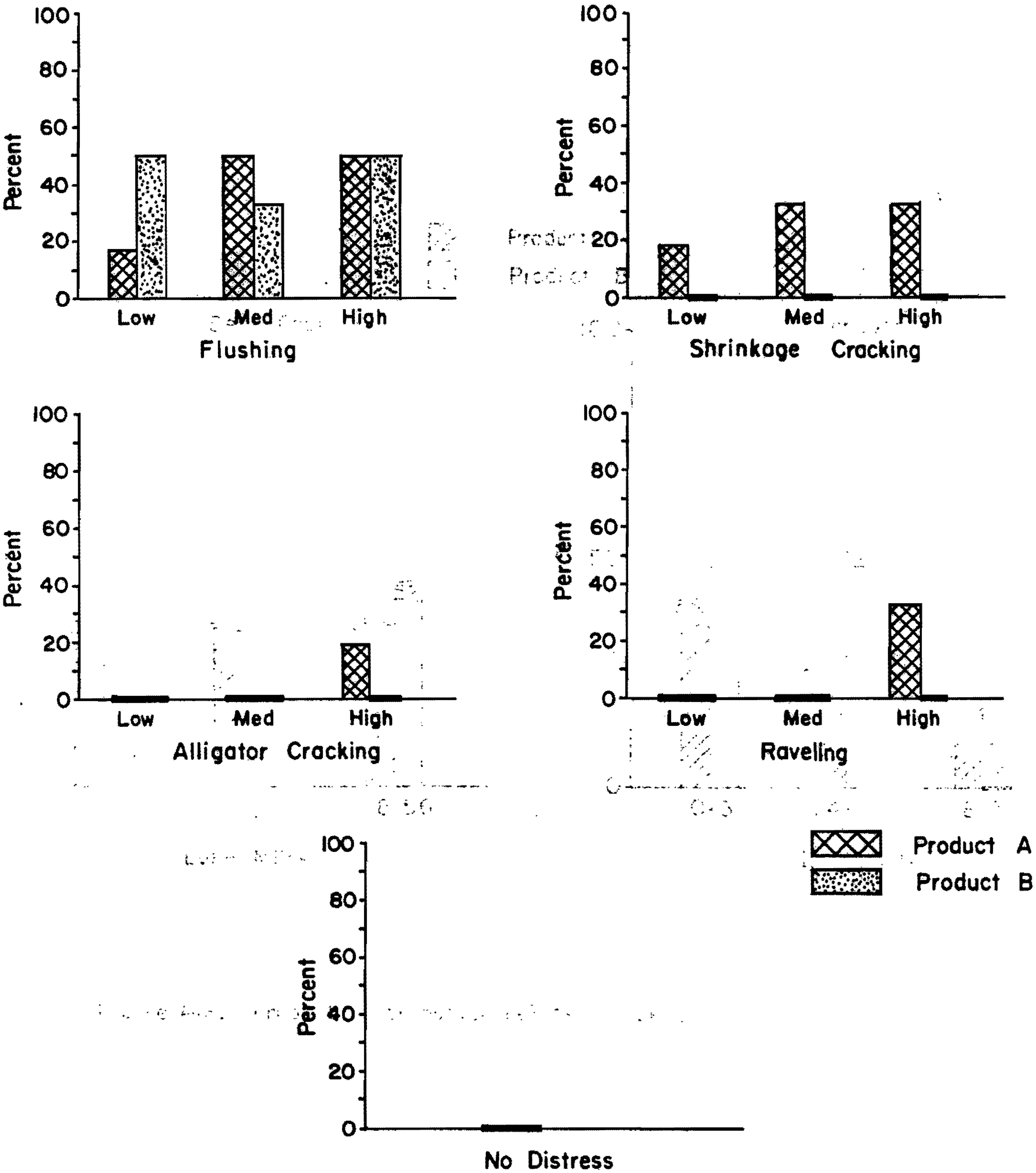


Figure A47. Asphalt-Rubber Seal Coats of 8 to 56 Miles.

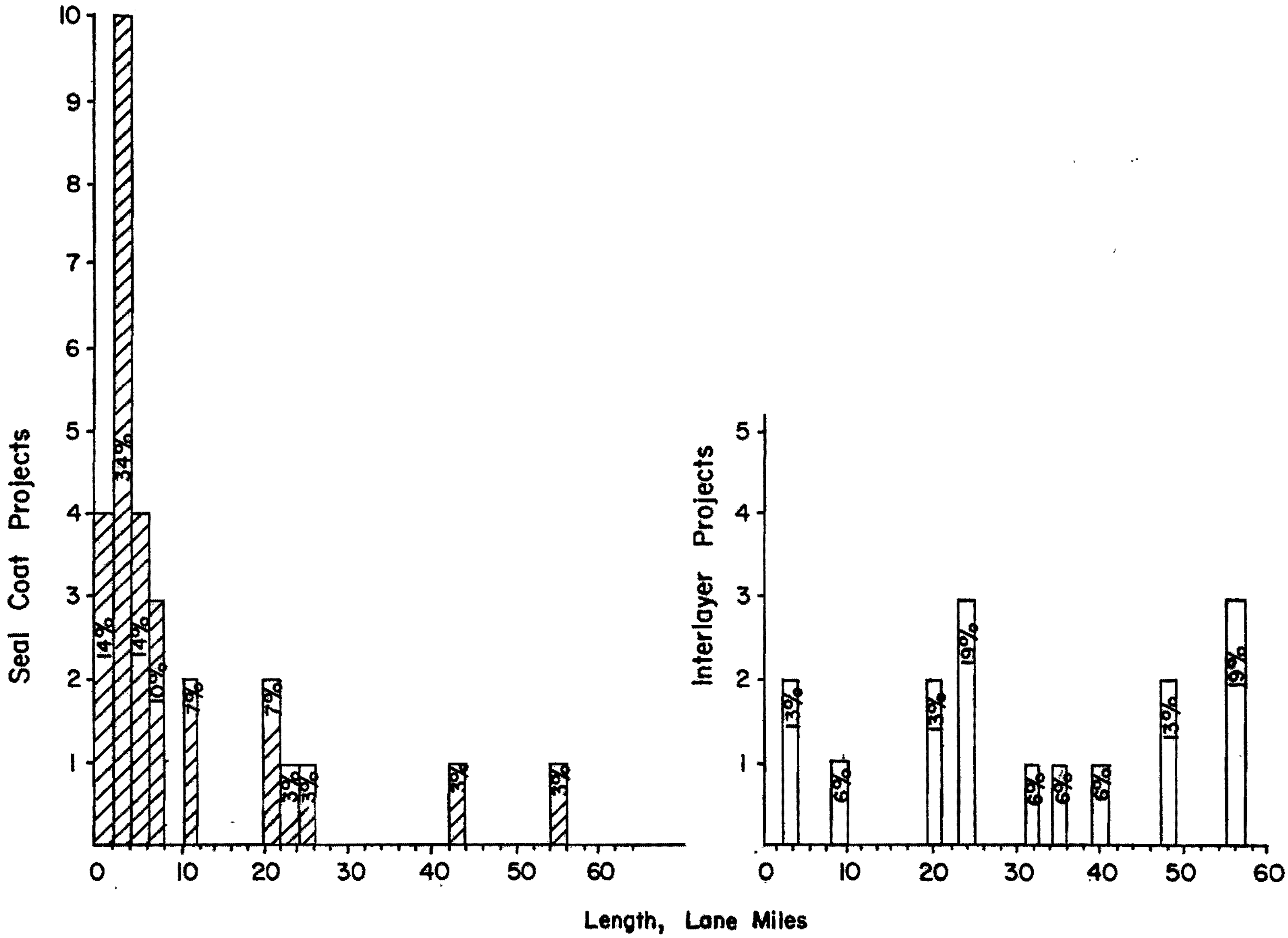


Figure A49. Asphalt-Rubber Distribution Related to Project Length.

Appendix - B

Table B-1. Mean Deduct Values for Flushing Related to Average Daily Traffic.

Supplier	Facility Type	ADT			
		L	M	H	0.05 α
A	SAM	-	9.0	13.6	NS
B	SAM	-	5.0	11.0	NS
C	-	8.3	11.3	10.9	L/M
	0.5 α	-	NS	NS	
A	SAMI	-	8.0	8.6	NS
B	SAMI	-	-	5.0	-
	0.5 α	-	-	NS	

Table B-2. Mean Deduct Values for Thermal Cracking Related to Average Daily Traffic.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	ADT			0.05 α
		L	M	H	
A	SAM	-	7.7	13.3	NS
B	SAM	-	3.0	3.0	-
C	-	6.0	7.6	7.7	NS
	0.5 α	-	NS	A/BC	
A	SAMI	-	-	5.0	-
B	SAMI	-	11.0	3.0	-
	0.5 α	-	-	NS	

Table B-3. Mean Deduct Values for Alligator Cracking Related to Average Daily Traffic.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	ADT			
		L	M	H	0.05 α
A	SAM	-	-	3.8	-
B	SAM	-	-	5.0	-
C	-	8.9	13.4	15.0	NS
	0.5 α	-	-	NS	
A	SAMI	-	-	10.0	-
B	SAMI	-	-	15.0	-
	0.5 α	-	-	NS	

Table B-4. Mean Deduct Values for Raveling Related to Average Daily Traffic.

Supplier	Facility Type	ADT (Level/Parameter): L	ADT: M	ADT: H	0.05 α
A	SAM	-	15.0	13.8	NS
B	SAM	-	-	-	-
C	-	8.6	7.7	6.0	L/H
	0.5 α	-	NS	A/C	
A	SAMI	-	-	-	-
B	SAMI	-	-	-	-
	0.5 α	-	-	-	

Table B-5. Mean Deduct Values for Flushing Related to Accumulated Traffic.

Supplier	Facility Type	Accumulated Traffic			
		L	M	H	0.05 α
A	SAM	10.3	11.8	14.0	NS
B	SAM	9.0	8.0	15.3	M/H
C	-	9.8	10.3	12.2	NS
	0.5 α	NS	NS	NS	
A	SAMI	8.0	5.0	20.0	L/M/H
B	SAMI	-	-	5.0	-
	0.5 α	-	-	S	

Table B-6. Mean Deduct Values for Thermal Cracking Related to Accumulated Traffic.

Supplier	Facility Type	Accumulated Traffic (Level / Parameter): L	M	H	0.05 α
A	SAM	7.7	20.0	11.0	L/M
B	SAM	3.0	-	-	-
C	-	6.6	9.6	9.0	NS
	0.5 α	NS	NS	NS	
A	SAMI	3.0	7.0	3.0	NS
B	SAMI	11.0	-	13.0	L/H
	0.5 α	A/B	-	NS	

Table B-7. Mean Deduct Values for Alligator Cracking Related to Accumulated Traffic.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	Accumulated Traffic			
		L	M	H	0.05 α
A	SAM	-	15.0	17.5	NS
B	SAM	-	5.0	-	-
C	-	11.3	20.0	12.5	L/M
	0.5 α	-	NS	NS	
A	SAMI	5.0	-	15.0	S
B	SAMI	-	-	15.0	-
	0.5 α	-	-	NS	

Table B-8. Mean Deduct Values for Raveling Related to Accumulated Traffic.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	Accumulated Traffic			
		L	M	H	0.05 α
A	SAM	15.0	14.0	13.0	NS
B	SAM	-	-	-	-
C	-	8.2	6.2	5.8	NS
	0.5 α	NS	S	S	
A	SAMI	-	-	-	-
B	SAMI	-	-	-	-
	0.5 α	-	-	-	

Table B-9. Mean Deduct Values for Flushing Related to Construction Year.

Supplier	Facility Type	Year: 76-77	78-79	80-81	0.05 α
A	SAM	10.3	13.3	12.0	NS
B	SAM	-	15.3	8.8	S
C	-	8.9	11.0	9.5	NS
	0.5 α	NS	NS	NS	
A	SAMI	-	14.0	6.2	NS
B	SAMI	-	5.0	-	-
	0.5 α	-	NS	-	

Level

Parameter

Table B-10. Mean Deduct Values for Thermal Cracking Related to Construction Year.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	Year 76-77 (1)	Year 78-79 (2)	Year 80-81 (3)	0.05 α
A	SAM	11.0	9.0	13.5	NS
B	SAM	-	-	3.0	-
C	-	8.2	7.7	5.2	1,2/3
	0.5 α	NS	NS	A/BC	
A	SAMI	-	-	5.0	-
B	SAMI	-	3.0	11.0	-
	0.5 α	-	-	NS	

Table B-11. Mean Deduct Values for Alligator Cracking Related to Construction Year.

Supplier	Facility Type	Year (Parameter)			
Level →		76-77 (1)	78-79 (2)	80-81 (3)	0.05 α
A	SAM	12.5	5.0	25.0	NS
B	SAM	-	-	5.0	-
C	-	13.1	12.3	11.5	NS
	0.5 α	NS	NS	A/B	
A	SAMI	-	-	10.0	-
B	SAMI	-	15.0	-	-
	0.5 α	-	-	-	

Table B-12. Mean Deduct Values for Raveling Related to Construction Year.

Supplier	Facility Type	Year: 76-77	Year: 78-79	Year: 80-81	0.05 α
A	SAM	-	12.8	16.5	NS
B	SAM	-	-	-	-
C	-	7.0	8.1	8.2	NS
	0.5 α	-	S	S	
A	SAMI	NO RAVELING			
B	SAMI	NO RAVELING			
	0.5 α				

Table B-13. Mean Deduct Values for Flushing Related to Substrate.

Supplier	Facility Type	Substrate: Thin(1)	Substrate: Thick(2)	Substrate: Rigid(3)	0.05 α
	Level / Parameter	Thin(1)	Thick(2)	Rigid(3)	0.05 α
A	SAM	12.3	13.0	-	NS
B	SAM	13.0	10.3	-	NS
C	-	8.9	11.0	5.0	2/1,3
	0.5 α	NS	NS	-	
A	SAMI	-	4.8	5.0	NS
B	SAMI	-	5.0	-	-
	0.5 α	-	NS	-	

Table B-14. Mean Deduct Values for Thermal Cracking Related to Substrate.

Supplier	Facility Type	Substrate (Level)			
		Thin	Thick	Rigid	0.05 α
A	SAM	12.0	10.0	-	NS
B	SAM	-	3.0	-	-
C	-	5.7	8.1	-	S
	0.5 α	S	NS	-	
A	SAMI	-	3.0	7.0	NS
B	SAMI	-	3.0	11.0	S
	0.5 α	-	NS	NS	

Supplier / Facility Type / Level / Parameter

Table B-15. Mean Deduct Values for Alligator Cracking Related to Substrate.

Supplier	Facility Type	Parameter: Substrate			
	Level	Thin	Thick	Rigid	0.05 α
A	SAM	25.0	10.0	-	-
B	SAM	-	5.0	-	-
C	-	10.9	13.1	-	NS
	0.5 α	S	NS		
A	SAMI	-	10.0	-	-
B	SAMI	-	15.0	-	-
	0.5 α	-	NS	-	

Table B-16. Mean Deduct Value for Raveling Related to Substrate.

Supplier	Facility Type	Level: Substrate / Parameter: Thin	Thick	Rigid	0.05 α
A	SAM	18.0	13.2	-	NS
B	SAM	-	-	-	-
C	-	8.5	6.9	10.0	NS
	0.5 α	S	S	-	
A	SAMI		NO RAVELING		
B	SAMI		NO RAVELING		
	0.5 α				

Table B-17. Mean Deduct Values for Flushing Measured by Thermal Climate.

Supplier / Facility Type / Level / Parameter

Supplier	Facility Type	Thermal Climate			
		H	M	C	0.05 α
A	SAM	13.0	12.0	-	NS
B	SAM	13.5	9.5	5.0	NS
C	-	8.4	8.2	13.3	HM/C
	0.5 α	NS	A/C	NS	
A	SAMI	5.0	9.8	-	NS
B	SAMI	5.0	-	-	-
	0.5 α	-	-	-	

Table B-18. Mean Deduct Values for Thermal Cracking Measured by Thermal Climate.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	Thermal Climate			
		H	M	C	0.05 α
A	SAM	11.0	9.0	20.0	M/C
B	SAM	-	3.0	3.0	-
C	-	3.0	7.9	6.4	NS
	0.5 α	-	NS	A/BC	
A	SAMI	7.0	3.0	-	-
B	SAMI	3.0	11.0	-	-
	0.5 α	NS	-		

Table B-19. Mean Deduct Values for Alligator Cracking Measured by Thermal Climate.

Supplier	Facility Type	Thermal Climate			
	Level / Parameter	H	M	C	0.05 α
A	SAM	-	10.0	25.0	NS
B	SAM	5.0	-	-	-
C	-	11.7	11.8	12.9	NS
	0.5 α	NS	NS	NS	
A	SAMI	15.0	5.0	-	-
B	SAMI	15.0	-	-	-
	0.5 α	-	-	-	

Table B-20. Mean Deduct Values for Raveling Measured by Thermal Climate.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	Thermal Climate: H	M	C	0.05 α
A	SAM	13.0	14.2	-	NS
B	SAM	-	-	-	-
C	-	6.6	8.4	6.0	NS
	0.5 α	S	S	-	
A	SAMI	-	-	-	-
B	SAMI	-	-	-	-
	0.5 α	-	-	-	

Table B-21. Mean Deduct Values for Flushing Related to Rain Climate.

Supplier	Facility Type	Rain Climate (Level)		
		<35"	>35"	0.05 α
A	SAM	12.3	12.3	NS
B	SAM	10.8	10.0	NS
C	-	10.2	9.2	NS
	0.5 α	NS	NS	
A	SAMI	8.0	8.6	NS
B	SAMI	5.0	-	-
	0.5 α	-	-	

Table B-22. Mean Deduct Values for Thermal Cracking Related to Rain Climate.

Supplier	Facility Type	Rain Climate		
		<35"	>35"	0.05 α
A	SAM	10.8	11.0	NS
B	SAM	3.0	-	-
C	-	7.2	6.6	NS
	0.5 α	NS	NS	
A	SAMI	3.0	5.7	NS
B	SAMI	7.0	-	-
	0.5 α	NS	-	

Table B-23. Mean Deduct Values for Alligator Cracking Related to Rain Climate.

Supplier	Facility Type	Level / Parameter: Rain Climate		
		<35"	>35"	0.05 α
A	SAM	15.0	12.5	NS
B	SAM	5.0	-	-
C	-	12.6	10.0	NS
	0.5 α	NS	NS	
A	SAMI	15.0	5.0	-
B	SAMI	15.0	-	-
	0.5 α	-	-	

Table B-24. Mean Deduct Values for Raveling Related to Rain Climate.

Supplier
Facility Type
Level
Parameter

Supplier	Facility Type	Rain Climate		
		<35"	>35"	0.05 α
A	SAM	13.2	18.0	NS
B	SAM	-	-	-
C	-	7.8	8.4	NS
	0.5 α	A/C	NS	
A	SAMI	-	-	-
B	SAMI	-	-	-
	0.5 α	-	-	

Table B-25. Mean Deduct Values for Flushing Related to Project Length.

Supplier	Facility Type	Length: 0-4 (1)	Length: 5-7 (2)	Length: 8-56 (3)	α 0.05
A	SAM	8.8	14.0	14.4	1/2, 3
B	SAM	8.3	13.0	10.8	NS
C	-	-	-	-	-
	α 0.5	NS	-	NS	
A	SAMI	-	-	8.4	-
B	SAMI	5.0	-	-	-
	α 0.5	-	-	-	

Table B-26. Mean Deduct Values for Thermal Cracking Related to Project Length.

Supplier	Facility Type	Length 0-4	Length 5-7	Length 8-56	0.05 α
A	SAM	8.0	11.0	12.7	NS
B	SAM	3.0	-	3.0	-
C	-	-	-	-	-
	0.5 α	NS	-	NS	
A	SAMI	3.0	-	5.7	NS
B	SAMI	3.0	-	11.0	-
	0.5 α	-	-	NS	

Level

Parameter

Table B-27. Mean Deduct Values for Alligator Cracking Related to Project Length.

Supplier	Facility Type	Length 0-4	Length 5-7	Length 8-56	0.05 α
A	SAM	-	10.0	25.0	NS
B	SAM	5.0	-	-	-
C	-	-	-	-	-
	0.5 α	NS	-	-	
A	SAMI	15.0	-	5.0	-
B	SAMI	15.0	-	-	-
	0.5 α	-	-	-	

Table B-28. Mean Deduct Values for Raveling Related to Project Length.

Supplier	Facility Type	Length 0-4	Length 5-7	Length 8-56	0.05 α
A	SAM	13.0	12.7	16.5	NS
B	SAM	-	-	-	-
C	-	-	-	-	-
	0.5 α	-	-	-	
A	SAMI		NO RAVELING		
B	SAMI		NO RAVELING		
	0.5 α				

Appendix C

Table C1. Texas Asphalt-Rubber Membrane Performance Evaluation For District 3.

Proj No.	Hwy. No.	Length Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
1	US 287	56	X			X	11-80	AC AC	CT PC	- -	9300	4	2300	NO DISTRESS			

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continuously Reinforced Concrete

Table C2. Texas Asphalt-Rubber Membrane Performance Evaluation For District 5.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
2	SH 114	56	X		X		1980	3SC	11FB	-	4500	4	1125		3SE(20)	3SE(25)	
3	Loop 289	0.6		X	X		1980	1 1/2AC	10FB	-	15,000	4	3750	1SL(5)	1SL(5)		
4	US 60	56	X			X	1980	1AC	-	-	2900	2	1450	NO DISTRESS			

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C3. Texas Asphalt-Rubber Membrane Performance Evaluation For District 7.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier A	Supplier B	A-R Type SAM	A-R Type SAMI	Construction Date	Substrate, in. Surf.	Substrate, in. Base	Substrate, in. Subgr.	ADT	No. Lanes	Lane ADT	Condition Flush	Condition Therm Crack	Condition Allig. Crack	Condition Raveling
5	US 87	4	X		X		8-78	1AC	16FB	-	4100	4	1025	2MO(12)			1SE(15)
6	SH 208	2.5	X		X		9-79	2SC	8FB	-	1600	2	800	2SL(8)	1SL(3) 2MO(11)		
7	SH 208	2.5	X		X		9-79	2SC	8FB	-	1600	2	800	2SL(8) 1SE(15)	1MO(7) 2MO(11)		
8	Loop 306	6		X	X		7-80	2SC	101/2 FB	-	10,000	4	2500	N O D I S T R E S S			
9	Loop 306	4	X		X		7-80	2SC	101/2 FB	-	10,000	4	2500	2SE(18)			2SE(18)
10	US 87E	4.5		X	X		6-81	AC 2SC	181/2	-	5,000	4	1250	2SL(8) 3MO(15) 3SE(20)			
11	US 87	4	X		X		8-79	1AC 3SC	12FB	-	4700	2	2350			1SL(5)	1SL(5)
12	IH 10	35	X			X	12-79	3AC 2SC	9FB	-	3800	4	950	2SL(8)			
13	IH 10	40	X			X	01-80	3AC 2SC	9FB	-	3800	4	950	2SL(8)			

Legend for Substrate Code:
FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C4. Texas Asphalt-Rubber Membrane Performance Evaluation for District 9.

Proj No.	Hwy. No.	Length Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig Crack	Raveling
14	SH22	4	S		S		6-76	1½ AC	9 FB	-	3100	2	1500	2MO(12) 1SE(15)	2SL(7)	1SL(5)	

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continuously Reinforced Concrete

Table C5. Texas Asphalt-Rubber Membrane Performance Evaluation For District 11.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
15	US 259	24	X		X		10-79	5AC	5AT	7LT	7000	4	1750	2SE(18)			2SE(18)

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C6. Texas Asphalt-Rubber Membrane Performance Evaluation For District 15.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Subgrade, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgrade				Flush	Therm Crack	Allig. Crack	Raveling
16	IH 35	20	X		X		10-80	3AC	20FB	6LT	18,000	4	4500	1MO(10)			
17	IH 10	56		X	X		10-80	3AC	16FB	-	11,800	4	2950	1SL(5) 1MO(10)			
18	IH 37	48	X			X	10-80	CRCP	-	-	17,000- 53,000	4	4250- 13250	N O D I S T R E S S			

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C7. Texas Asphalt-Rubber Membrane Performance Evaluation For District 17.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Subgrade, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
19	SH 21	8		X	X		9-81				10,700	4	2675	1SL(5)			
20	US 79	6		X	X		9-81				8,000	2	4000	1SL(5) 2MO(12) 3SE(20)			
21	US 79	20		X	X		9-81				2,800	2	1400	1SL(5) 3SE(20)			
22	SH 6		X			X	6-80	3AC	13FB	-	6,000	4	1500	1SL(5) 1MO(10)	1SL(3)	1SL(5)	
23	SH 36	24	X			X	5-78	5AC	21FB	-	5,200	2	2600	3SE(20)			
24	IH 45	56	X			X	4-80	CRC	-	-	11,200	4	2800	1SL(5)	1SL(3)		

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C8. Texas Asphalt-Rubber Membrane Performance Evaluation For District 19.

Proj No.	Hwy. No.	Length Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
25	US 80	4	X		X		6-76	AC	-	-	11,000	4	2750	2MO(12)	3MO(15)	3MO(20)	
26	SH 43	3	X		X		6-76	N/A	N/A	N/A	11,000	2	550	NB 1SL-SB (5)	NO DISTRESS		

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C9. Texas Asphalt-Rubber Membrane Performance Evaluation For District 20.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
27	US 59	9	X			X	1981	2AC	PC	-	20,000	4	5000		2MO(11)		
28	IH 10	32	X			X	1981	1FC 6 ½ AC	14SB	12RT	20,000	4	5000	1SL(5)			
29	IH 10	24	X			X	1981	CRC	6CT	6LT	17,400	4	4350	1SL(5)			

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C10. Texas Asphalt Rubber Membrane Performance Evaluation For District 21.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier A	Supplier B	A-R Type SAM	A-R Type SAMI	Construction Date	Substrate, in. Surf.	Substrate, in. Base	Substrate, in. Subgr.	ADT	No. Lanes	Lane ADT	Condition Flush	Condition Therm Crack	Condition Allig. Crack	Condition Raveling
30	US 83	11	X		X		1979	4AC	16FB	14LT	22,000	4	5,500	3SE(20)			
31	US 83	11		X	X		1979	4AC	16FB	14LT	22,000	4	5,500	3MO(15) 3SE(20)			
32	US 83	2	X		X		1981	2AC	16FB	14LT	16,000	4	4,000	2SL(8)			
33	US 83	2		X	X		1981	2AC	16FB	14LT	16,000	4	4,000	2SL(8)		1SL(5)	
34	SH 48	3		X	X		1979	21/2 AC	8FB	3LT	21,000	4	5,250	2MO(12)			
35	SH 48	3	X		X		1979	21/2 AC	8FB	3LT	21,000	4	5,250	2MO912)			1MO(10) 1SE(15)
36	US 83	8	X		X		1978	4AC	16FB	14LT	22,000	4	5,500	2MO(C2)	2MO(11)		
37	US 83	8		X	X		1978	4AC	16FB	14LT	22,000	4	5,500	3SE(20) 2MO(12)			
38	SPUR 115	3		X		X	1978	3AC	14FB	10LT	20,000	2	10,000	1SL(5)	1SL(3)	3SL(15)	
39	SPUR 115	3	X			X	1981	3AC	14FB	10LT	20,000	2	10,000		1SL(3)	3SL(15)	

Table C10. Continued

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
40	FM 491	2		X	X		8-81	N/A	N/A	N/A	1550	2	775	NO DISTRESS			

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C11. Texas Asphalt-Rubber Membrane Performance Evaluation For District 22.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
41	US 90	44	X		X		5-80	2AC	16FB	-	1700	2	850	3SL(10) 2MO(12) 1SE(15)	1SL(3) 1MO(7) 1SE(11)		1SE(15)

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table C12. Texas Asphalt-Rubber Membrane Performance Evaluation For District 24.

Proj No.	Hwy. No.	Length, Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig. Crack	Raveling
42	IH 10	20	X			X	6-76	4AC	9FB	-	5,000	4	1250	NO DISTRESS			
43	IH 10	20	X			X	1977	4AC	9FB	-	5,000	4	1250	NO DISTRESS			

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continously Reinforced Concrete

Table A13. Texas Asphalt-Rubber Membrane Performance Evaluation For District 25.

Proj No.	Hwy. No.	Length Lane Miles	Supplier		A-R Type		Construction Date	Substrate, in.			ADT	No. Lanes	Lane ADT	Condition			
			A	B	SAM	SAMI		Surf.	Base	Subgr.				Flush	Therm Crack	Allig Crack	Raveling
44	US62/70	26		X	X		1980	1½ AC	15FB	-	1100	2	550	1SL(5)	1SL(3)		
45	US 82	24		X		X	1980	4½ AC	6PC	-	1500	2	750		3MO(15) 1MO(7)		

Legend for Substrate Code:

FC - Friction Course
SC - Seal Coat
AC - Asphalt Concrete
AT - Asphalt Treated (Base)
FB - Flexible Base (Water Bound)
SB - Shell Base
LT - Lime Treated (Subgrade or Base)
CT - Cement Treated (Subgrade or Base)
PC - Portland Concrete
RT - Roadbed Treatment
CRC - Continuously Reinforced Concrete

Appendix D

Table D1. Projects with Low Severity Flushing on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.	Use: SAM					
		Producer	A			B		
		Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2		2				
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						2
		3-4						
		5-6		1				
	21-40	0-2						1
		3-4						
		5-6						
	41-60	0-2		1				1
		3-4						
		5-6						
Rigid	0-20	0-2			1			1
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D2. Projects with Low Severity Flushing on SAMI Construction.

Use			SAMI					
Producer			A			B		
Substrate	Length, Lane Miles	Age, Yrs. \ Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2		2	1			
		3-4						
		5-6						
	41-60	0-2			2			
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2			1			
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D3. Projects with Moderate Flushing on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.	Use: SAM Producer: A Lane Traffic, VPD: 0-500	SAM A 501-1000	SAM A 1001 +	SAM B 0-500	SAM B 501-1000	SAM B 1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2			1			1
		3-4						
		5-6			1			
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2		1				1
		3-4						
		5-6						
Rigid	0-20	0-2			1			2
		3-4			1			
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D4. Projects with Moderate Flushing on SAMI Construction.

Substrate	Length, Lane Miles	Age, Yrs.	Use / Producer / Lane Traffic, VPD: A 0-500	A 501-1000	A 1001 +	B 0-500	B 501-1000	B 1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2			1			
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D5. Projects with Severe Flushing on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.	SAM A: 0-500	SAM A: 501-1000	SAM A: 1001 +	SAM B: 0-500	SAM B: 501-1000	SAM B: 1001 +
Thin Flex	0-20	0-2			1			
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						3
		3-4						
		5-6			1			
Thick Flex	0-20	0-2		1				
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2		1				
		3-4						
		5-6						
Rigid	0-20	0-2			1			1
		3-4						1
		5-6						
	21-40	0-2			1			
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D6. Projects with Severe Flushing on SAMI Construction.

Use			(NONE)					
Producer			SAMI					
			A			B		
Substrate	Length, Lane Miles	Age, Yrs. / Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D7. Projects with Low Severity Alligator Cracking on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.	SAM					
Use			SAM					
Producer			A			B		
Lane Traffic, VPD			0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6			1			
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D8. Projects with Low Severity Alligator Cracking on SAMI Construction.

Use			SAMI					
Producer			A			B		
Substrate	Length, Lane Miles	Age, Yrs. / Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4			1			1
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D9. Projects with Moderate Severity Alligator Cracking on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.	SAM A 0-500	SAM A 501-1000	SAM A 1001 +	SAM B 0-500	SAM B 501-1000	SAM B 1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6			1			
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D10. Projects with High Severity Alligator Cracking on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.						
		Use	SAM					
		Producer	A			B		
		Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2			1			
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D11. Projects with Low Severity Thermal Cracking on SAM Construction.

Use			SAM					
Producer			A			B		
Substrate	Length, Lane Miles	Age, Yrs. / Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2			1			1
		3-4			1			
		5-6			1			
	21-40	0-2						1
		3-4						
		5-6						
	41-60	0-2		1				
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D12. Projects with Low Severity Thermal Cracking on SAMI Construction.

Use			SAMI					
Producer			A			B		
Substrate	Length, Lane Miles	Age, Yrs. \ Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4			1			1
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D13. Projects with Moderate Severity Thermal Cracking on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.	SAM					
			A			B		
		Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2		2				
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6			1			
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2		1				
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4			1			
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D14. Projects with Moderate Severity Thermal Cracking on SAMI Construction.

Substrate	Length, Lane Miles	Age, Yrs.	SAMI					
		Producer	A			B		
		Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2			1			
		3-4						
		5-6						
	21-40	0-2						1
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D15. Projects with High Severity Thermal Cracking on SAM Construction.

Use			SAM					
Producer			A			B		
Substrate	Length, Lane Miles	Age, Yrs. \ Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2			1			
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D16. Projects with Low Severity Raveling on SAM Construction.

Use			SAM					
Producer			A			B		
Substrate	Length, Lane Miles	Age, Yrs. \ Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2			1			
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D17. Projects with High Severity Raveling on SAM Construction.

Substrate	Length, Lane Miles	Age, Yrs.	Use: SAM					
		Producer	A			B		
		Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4		1				
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2		1				
		3-4						
		5-6						
Rigid	0-20	0-2			1			
		3-4						
		5-6						
	21-40	0-2			1			
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D18. SAM Projects with No Visible Distress.

Substrate	Length, Lane Miles	Age, Yrs.	SAM A 0-500	SAM A 501-1000	SAM A 1001 +	SAM B 0-500	SAM B 501-1000	SAM B 1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2					1	
		3-4						
		5-6		1				
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Table D19. SAMI Projects with No Visible Distress.

Use			SAMI					
Producer			A			B		
Substrate	Length, Lane Miles	Age, Yrs. / Lane Traffic, VPD	0-500	501-1000	1001 +	0-500	501-1000	1001 +
Thin Flex	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						
Thick Flex	0-20	0-2						
		3-4			1			
		5-6			1			
	21-40	0-2						
		3-4						
		5-6						
	41-60	0-2			2			
		3-4						
		5-6						
Rigid	0-20	0-2						
		3-4						
		5-6						
	21-40	0-2			1			
		3-4						
		5-6						
	41-60	0-2						
		3-4						
		5-6						

Appendix E

Table E1. - Texas Seal Coat Performance Evaluation For District 3.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
220	SH 79	5		X		1223	2	611	1SL			
233	FM 1197	5		X		260	2	130	2SL		1SL	1SL
262	US 183	4	X			640	2	320	1SL	3SL		1SL
		5							1SL	2MO		
275	FM 2651	5	X			120	2	60	1SL			1SL
288	US 70 & 183	1		X		1130	2	560				1SL
		2								2 MO/SE		3MO

Table E2. - Texas Seal Coat Performance Evaluation For District 5.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
555	US 87	4		X		5270	4	1317	2MO	2.5SE	2SE	0
2706	US 84	1	X			2760	4	690	1SE			
2719	US 84	1		X		2760	4	690	3SE	2MO		
2722	US 70 & 84	1		X		3705	4	926	2MO	1SL		
		2							2SE	1.5MO		
2735	US 70 & 84	1		X		3705	4	926	2MO	1SL		
		2							2SE	1.5SL		
		3							2SE	1.5SL/MO	2MO	
2531	US 385	1		X		2690	2	1345	1MO	1SL		

Table E2. Continued

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
		2							2MO	1SL		
2688	US 82	4	X			2310	4	562		1SL		
		5							2SE	2SL		
2515	US 62 & 70	1		X		1625	2	814		1SL		
		2							2MO	1MO	1MO	
2659	US 84	1		X		3740	4	935	2SL	1SL	1SL	
		2							3MO	1SE		1SL
2646	US 84	1		X		3810	4	952	1SL	1SL		
		2							3SE			1SL

Table E2. Continued.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
437	US 87	5		X		5670	4	1417	2MO	2.5MO		
440	SH 194	4	X			1640	2	820	3SL	1SL		
453	FM 400	3	X			945	2	473	2SL	2.5MO		
		4							3SL	1.5SL	1SL	
466	FM 1612	2	X			160	2	80				1MO
		3							1SL			1SL
2675	US 87	2		X		5100	4	1275		2MO		
		3							2SE	1SL		

Table E2. Continued.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
479	US 385	3		X		1400	2	700		2.5SE		1SL
495	FM 1585	1	X			475	2	238		2SL		
2599	US 87	2		X								2SL
2793	US 84	4	X			5030	4	1257	2SL		2MO	
		5							3SE	1MO	1MO	1SL
2777	US 84	1		X		5240	4	1310	2MO	1SL		
		2							2MO	1SL		
		3							2SE			
2748	US 84	1		X		2845	4	711	2SL	1.5MO	3MO	

Table E2. Continued.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
2751	US 84	1		X		3140	4	785	3SE	1MO	2MO	
2764	US 84	1		X		3140	4	785	3MO	1MO	1MO	
2662	US 87	1		X		4100	4	1025	2MO			
		3								3MO	1SL	
		4							3MO	1SE		1SL
568	SH 86	3	X			1340	2	675	1SL	2.5MO	2SE	
571	FM 1424	3	X			210	2	105	1MO			
584	SH 214	4	X			360	2	180	3SE	1SL	2SL	
597	FM 1780	1	X			310	2	155	2MO			
		2							3SE			

Table E3. Texas Seal Coat Performance Evaluation For District 7.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate SC	Substrate AC	Substrate Rigid	ADT	No. Lanes	Lane ADT	Condition Flush	Condition Therm Crack	Condition Allig. Crack	Condition Ravelling
759	US 67	2	X			1330	2	665	1MO			
775	US 83	2		X		1010	2	505	2MO			
733	US 83	1	X			690	2	345	1MO	1SL	1SL	
746	FM 2402	5	X			100	2	50		NO DISTRESS		
762	SH 163	1	X			130	2	65	2MO			
									2SE			
788	FM 2092	5	X			240	2	120	1SL			
791	US 67	1		X		2780	4	695	2MO			
819	FM 2111	1	X			225	2	112	1MO	1SL	2SL	

Table E4. Texas Seal Coat Performance Evaluation For District 9.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
924	IH 35	2		X		14480	4	3620	1MO			
966	SH 6	1		X		2715	2	1357	1SL			
940	FM 935	1	X			555	2	278	NO DISTRESS			
		2							NO DISTRESS			
		3										1SL
982	FM 434	1	X			310	2	155				3MO
1001	SH 31	1		X		2820	2	1410	2SL			
		2							2SL	2.5SL		1SL
		3							2SE	2MO	2MO	1SL
1014	FM 309	1	X			375	2	188	1SL			

Table E4. Continued

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate SC	Substrate AC	Substrate Rigid	ADT	No. Lanes	Lane ADT	Condition Flush	Condition Therm Crack	Condition Allig. Crack	Condition Ravelling
1027	FM 1243	4	X			140	2	70	NO DISTRESS			
1043	US 80	1		X		11635	4	2908	28L			2SL

Table E5. Texas Seal Coat Performance Evaluation For District 11.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
1218	SH 94	1		X		1380	2	690				
1218	SH 94	2		X		1380			2MO			1SL
1218	SH 94	3		X		1380			2SL	2SL	1SL	1MO
1145	US 287	1		X		3780	2	1890	1SL			
		2								3MO		2SL
1158	FM 1733	5	X			100	2	50				3MO
1161	FM 1280	1	X			400	2	200	1SL			3MO
1190	US 96	1	X			2310	2	1155		1SL		
		2							3SL	2SL		

Table E6. Texas Seal Coat Performance Evaluation For District 15.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
1527	SH 16	1	X			780	2	390	NO DISTRESS			
		2							1SL			
		3							1MO	1SL		2SL
		4							2MO			2SL
1530	FM 2146	3	X			360	2	180	1SL			
		4							2MO			1SL
1598	FM 1044	1	X			450	2	225				2MO
		2										1SE
3341	IH 35	1		X		4065	4	1016	2SL	1MO		1SL
1603	IH 35	1		X		3810	4	953	2SL	1SE		1MO

Table E6. Continued.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
1616	SH 97	4	X			445	2	222				1SL
1629	FM 468	2	X			180	2	90	1MO			1MO

Table E7. Texas Seal Coat Performance Evaluation For District 17.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
1747	FM 60	1		X		1350	2	675	2MO	1SL	1SL	
	FM 60	2		X		1350	2	675	2SL	1SL		1SL
	FM 60	3		X		1350	2	675	2MO	1.5MO	2MO	
1750	US 190+	2		X		1750	2	875		3MO	1SL	
1807	FM 1374	5				300	2	150		1SL	1MO	

Table E8. Texas Seal Coat Performance Evaluation For District 19.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
1996	FM 2088	1	X			765	2	383	1SL			
		2							2SL			

Table E9. Texas Seal Coat Performance Evaluation For District 20.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
2044	SH 73	1		X		2705	2	1352	2MO			
		2							3MO			1SL
		2							1SL			2SL

Table E10. Texas Seal Coat Performance Evaluation For District 21.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
2086	US 77	1		X		3810	2	1905	1SL			1SL
	US 77	3				3810			1SL			2SL
2117	US 281	1		X		4830	4	1207	2SL			1SL
	US 281	3							2SL			
	US 281	4							2MO			
2120	FM 493	1		X		1115	2	558	1SL		2MO	2SL
		2							2MO		1SE	1SL
2104	FM 716	2	X			180	2	90	1SL	1SL	1SL	
2146	FM 2687	2			X	280	2	140	1SL			1MO

Table E11. Texas Seal Coat Performance Evaluation For District 22.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate SC	Substrate AC	Substrate Rigid	ADT	No. Lanes	Lane ADT	Condition Flush	Condition Therm Crack	Condition Allig. Crack	Condition Ravelling
2162	FM 186	1	X			285	2	143		1SL		2MO
2188	FM 674	5	X			100	2	50	2SL			
2191	US 277	4	X			1640	2	820	1SL			1SL
		5							1SL	1SL		1SL
2206	FM 1021	1	X			700	2	350				1SL
		2							1SL			1SL
		3							2SF	1SL		2SL
2219	US 57	1	X			1160	2	580				1SL
		2										2MO
		3								1MO	1SE	1MO

Table E11. Continued.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
2222	FM 1025	1	X			260	2	130			3MO	1SL

Table E12. Texas Seal Coat Performance Evaluation For District 24.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
2353	US 180	1		X		2010	4	502		3MO	1MO	
		2							1SL	3SE	1SE	2MO
2395	US 90	1		X		1560	2	780		1SL		
		2							2SL			2MO
2340	FM 2185	3	X			160	2	80	1SL	3SL	1SL	
2379	SH 17	1	X			350	2	175	1SL	1SL		1MO
		2							1SL	2SL		2SL
		3							2MO	1SL		1SL
2382	FM 505	1	X			60	2	30	1SL			2SL
2400	FM 2810	1	X			100	2	50				1MO

Table E13. Texas Seal Coat Performance Evaluation For District 25.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate SC	Substrate AC	Substrate Rigid	ADT	No. Lanes	Lane ADT	Condition Flush	Condition Therm Crack	Condition Allig. Crack	Condition Ravelling
2413	SH 256	4	X			285	2	142		2.5SL		2SL
2426	FM 1065	2	X			75	2	38				1MO
		3										2MO
		4							1SL	1SL		2MO
		5							1MO			2MO
3134	SH 86	4	X			700	2	350	1SL			
2840	US 82	4		X		1460	4	365	1SL	2.5MO		1SL
3029	US 82	4		X		1830			2SL	2SL	2MO	
2471	FM 2362	1	X			70	2	35				1SL
2913	US 287	1		X		4795	4	1198	NO DISTRESS			

Table E13. Continued.

Sect. ID No.	Hwy. No.	Age Yrs.	Substrate			ADT	No. Lanes	Lane ADT	Condition			
			SC	AC	Rigid				Flush	Therm Crack	Allig. Crack	Ravelling
3118	SH 70	4	X			360	2	180		2SL		
		5							1SL	2SL		
2879	US 287	4		X		4735	4	1184	2SL	2SE		
2997	US 82	3		X		1460	2	730		3MO		
		4							1SL	3SE	3SE	
2971	US 82	3		X		1630	2	815		2.5MO		

Appendix F

Table F-1. Conventional Seal Coat Performance.

District	Total Projects	Number Of Projects With Indicated Condition												No Distress
		Flushing			Thermal Cracking			Alligator Cracking			Raveling			
		L	M	H	L	M	H	L	M	H	L	M	H	
3	7	5	0	0	1	1	0	1	0	0	4	1	0	0
5	45	8	16	13	18	11	3	3	7	2	7	1	0	0
7	9	1	6	1	2	0	0	2	0	0	0	0	0	1
9	12	5	1	1	1	1	0	0	1	0	4	1	0	3
11	9	4	1	0	3	1	0	1	0	0	2	3	0	0
15	12	4	4	0	1	1	1	0	0	0	5	3	1	1
17	5	2	3	0	3	2	0	1	1	0	1	0	0	0
19	2	2	0	0	0	0	0	0	0	0	0	0	0	0
20	4	2	2	0	0	0	0	0	0	0	3	0	0	0
21	9	7	2	0	1	0	0	1	1	1	5	1	0	0
22	11	4	0	1	3	1	0	0	1	1	7	3	0	0
24	10	6	1	0	5	1	1	1	1	1	3	4	0	0
25	16	7	1	0	5	3	2	0	1	1	3	4	0	1
Total	151	57	37	15	43	22	7	10	13	6	44	21	1	5
Percent, %		38	25	11	29	15	5	7	9	4	29	14	1	3

Table F2. Asphalt-Rubber and Conventional Seal Coat Deduct Statistics.

			Flushing			Thermal Cracking			Alligator Cracking			Raveling		
			L	M	H	L	M	H	L	M	H	L	M	H
Seal Coat Type	A	n	5	7	6	3	5	2	2	1	1	1	1	5
		$\bar{x}$	7.8	11.71	16.83	4.33	10.20	15.50	5.00	20.00	25.00	5.00	10.00	16.20
		S	1.7	0.76	2.14	2.31	3.35	6.36	0.00	0.00	0.00	0.00	0.00	1.64
	B	n	8	6	5	2	0	0	1	0	0	0	0	0
		$\bar{x}$	5.75	12.67	20.00	3.00	0	0	5.00	0	0	0	0	0
		S	1.39	1.97	0.00	0.00	0	0	0.00	0	0	0	0	0
	C	n	57	37	16	43	22	7	10	13	6	44	21	1
		$\bar{x}$	6.25	12.00	18.38	4.27	9.87	14.88	6.00	14.23	18.33	5.79	11.70	15.00
		S	1.67	1.58	1.63	2.25	2.87	3.60	2.11	3.44	4.08	1.34	1.92	0.00

Table F-3. Performance Related to Traffic Volume for Asphalt-Rubber Membranes and Conventional Seal Coats.

Lane Traffic, ADT	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			AR			SC			AR			SC			AR			SC			AR			SC			AR	SC
	AR	SC	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
0-500	0	57	0	0	0	28	11	4	0	0	0	19	4	0	0	0	0	7	2	0	0	0	0	19	14	1	0	4
501-1,000	7	48	4	1	1	15	13	8	1	3	1	16	13	5	0	0	0	3	8	5	0	0	2	11	7	0	2	0
1,001+	23	45	5	8	8	13	13	4	5	2	1	9	6	3	1	1	1	0	3	1	1	0	2	12	0	0	0	1

Table F-3. Continued

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
AR			SC			AR			SC			AR			SC			AR			SC			AR	SC
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
N	N	N	49	19	7	N	N	N	33	7	0	N	N	N	12	4	0	N	N	N	33	25	2	N	7
57	14	14	31	27	17	14	43	14	33	27	10	0	0	0	6	17	10	0	0	29	23	15	0	29	0
22	35	35	28	28	9	22	9	4	20	13	7	4	4	4	0	7	2	4	0	9	26	0	0	0	2

Table F-4. Performance Related to Traffic Volume for Asphalt-Rubber Membrane.

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Lane Traffic ADT	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			A			B			A			B			A			B			A			B				
	A	B	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	A	B
0-500	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
501-1,000	5	2	4	1	1	0	0	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1
1,001 +	11	12	0	4	3	5	4	5	3	2	1	2	0	0	1	1	1	0	0	0	1	0	2	0	0	0	0	0

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Lane Traffic ADT	Total Projects A	Total Projects B	Flushing A L	Flushing A M	Flushing A H	Flushing B L	Flushing B M	Flushing B H	Thermal Cracking A L	Thermal Cracking A M	Thermal Cracking A H	Thermal Cracking B L	Thermal Cracking B M	Thermal Cracking B H	Alligator Cracking A L	Alligator Cracking A M	Alligator Cracking A H	Alligator Cracking B L	Alligator Cracking B M	Alligator Cracking B H	Raveling A L	Raveling A M	Raveling A H	Raveling B L	Raveling B M	Raveling B H	No Distress A	No Distress B
0-5000	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
501-1,000	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1,001 +	12	1	4	1	0	0	0	0	1	1	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	5	0

Table F-4. Continued.

SAM Construction

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
A			B			A			B			A			B			A			B			A	B
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80	20	20	0	0	0	20	60	20	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	20	50
0	36	27	42	33	42	27	18	9	17	0	0	9	9	9	0	0	0	9	0	18	0	0	0	0	0

SAMI Construction

100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	8	0	0	0	0	8	8	0	100	100	0	8	0	0	8	0	0	0	0	0	0	0	0	42	0

Table F-5. Performance Related to Lifetime Traffic for Asohalt-Rubber Membrane.

SAM Construction

Lifetime Traffic, Vehicles	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			A			B			A			B			A			B			A			B				
	A	B	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	A	B
0-1,000,000	5	6	3	1	2	5	2	3	2	2	2	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1
1,000,000-2,000,000	6	4	2	2	2	3	1	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	3	0	0	0	1	1
2,000,000+	5	3	0	4	2	0	3	2	1	2	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0

Table F-5. Continued.

SAM Construction

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
A			B			A			B			A			B			A			B			A	B
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
60	20	40	83	33	50	40	40	40	16	0	0	0	0	20	0	0	0	0	0	20	0	0	0	0	16
33	33	33	75	25	0	0	0	25	25	0	0	16	0	0	25	0	0	16	0	50	0	0	0	16	25
0	80	40	0	100	67	40	0	0	0	0	0	20	20	0	0	0	0	0	20	20	0	0	0	0	0

Table F-6. Performance Related to Lifetime Traffic for Asphalt-Rubber Membranes and Conventional Seal Coats.

Lifetime Traffic Vehicles	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			AR			SC			AR			SC			AR			SC			AR			SC				
	AR	SC	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	AR	SC
0-1,000,000	11	125	8	3	5	44	31	12	3	2	2	40	18	5	0	0	1	10	10	3	0	0	1	33	21	1	1	7
1,000,000-2,000,000	10	18	5	3	2	10	4	2	1	0	0	4	1	4	2	0	0	0	1	2	1	0	3	5	0	0	2	0
2,000,000+	8	6	0	7	4	2	2	2	1	2	0	1	3	0	1	1	0	0	2	0	0	1	1	4	0	0	0	0

Table F-6. Continued.

Distress, Percent of Project																																																	
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
AR			SC			AR			SC			AR			SC			AR			SC			AR	SC
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
73	27	45	35	25	10	27	18	18	32	14	4	0	0	9	8	8	2	0	0	9	26	17	1	9	6
50	30	20	56	22	11	10	0	0	22	5	22	6	22	20	0	0	11	10	0	30	28	0	0	20	0
0	88	50	33	33	33	13	25	0	16	50	0	13	13	0	0	33	0	0	13	13	67	0	0	0	0

Table F-7. Performance Related to Age for Asphalt-Rubber Membrane.

SAM Construction

Age Years	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			A			B			A			B			A			B			A			B			A	B
	A	B	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
0-2	11	13	4	3	4	5	4	4	2	3	2	2	0	0	0	0	1	0	0	0	1	0	4	0	0	0	0	2
3-4	2	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
5-6	3	0	1	1	1	N	N	N	0	1	0	N	N	N	1	1	0	N	N	N	0	0	0	N	N	N	1	N

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0-2	10	1	6	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
3-4	3	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0
5-6	1	0	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	1	N

Table F-7. Continued.

SAM Construction

Distress, Percent of Projects																								No Distress	
Flushing						Thermal Cracking						Alligator Cracking						Raveling							
A			B			A			B			A			B			A			B			A	B
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
36	27	36	38	31	31	18	27	18	15	0	0	0	0	9	0	0	0	9	0	36	0	0	0	0	15
0	50	0	0	0	100	0	50	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
33	33	33	N	N	N	0	33	0	N	N	N	33	33	0	N	N	N	0	0	0	N	N	N	33	N

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60	10	0	0	0	0	0	10	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0
0	0	0	0	0	0	33	0	0	100	0	0	33	0	100	0	0	0	0	0	0	0	0	0	33	0
0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	100	N

Table F-8. Performance Related to Age for Asphalt-Rubber Membranes and Conventional Seal Coats.

Age Years	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			AR			SC			AR			SC			AR			SC			AR			SC			AR	SC
	AR	SC	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
0-2	24	86	9	7	8	28	25	7	4	3	2	23	11	3	0	0	1	5	7	2	1	0	4	22	15	1	2	3
3-4	3	46	0	1	1	19	10	5	0	1	0	17	8	5	0	0	0	4	5	4	0	0	1	16	4	0	0	1
5-6	3	15	1	1	1	9	2	2	0	1	0	3	4	0	1	1	0	1	1	0	0	0	0	4	2	0	1	1

Table F-8. Continued.

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
AR			SC			AR			SC			AR			SC			AR			SC			AR	SC
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
38	29	33	33	29	8	17	13	8	27	13	3	0	0	4	6	8	2	4	0	17	26	17	1	8	3
0	33	33	41	22	11	0	33	0	37	17	11	0	0	0	9	11	9	0	0	33	35	9	0	0	2
33	33	33	60	13	13	0	33	0	20	27	0	33	33	0	7	7	0	0	0	0	27	13	0	33	7

Table F-9. Performance Related to Substrate for Asphalt-Rubber Membrane.

SAM Construction.

Substrate Type	Total Projects		Distress, Total Project																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			A			B			A			B			A			B			A			B				
	A	B	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	A	B
Thin Flex	4	2	1	0	2	1	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1
Thick Flex	11	10	2	7	4	7	5	4	2	3	1	2	0	0	2	1	0	0	0	0	1	1	4	0	0	0	0	0
Rigid	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

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Substrate Type	Total Projects A	Total Projects B	Flushing A L	Flushing A M	Flushing A H	Flushing B L	Flushing B M	Flushing B H	Thermal Cracking A L	Thermal Cracking A M	Thermal Cracking A H	Thermal Cracking B L	Thermal Cracking B M	Thermal Cracking B H	Alligator Cracking A L	Alligator Cracking A M	Alligator Cracking A H	Alligator Cracking B L	Alligator Cracking B M	Alligator Cracking B H	Raveling A L	Raveling A M	Raveling A H	Raveling B L	Raveling B M	Raveling B H	No Distress A	No Distress B
Thin Flex	0	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thick Flex	10	2	4	1	1	1	0	0	2	1	0	1	1	0	2	0	0	1	0	0	0	0	0	0	0	0	3	0
Rigid	4	0	2	0	0	—	—	—	1	0	0	—	—	—	0	0	0	—	—	—	0	0	0	—	—	—	2	—

Table F-9. Continued.

SAM Construction

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
A			B			A			B			A			B			A			B			A	B
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
25	0	50	50	0	50	25	25	25	0	0	0	0	0	25	0	0	0	0	0	25	0	0	0	0	50
18	64	36	70	50	40	18	27	9	20	0	0	18	9	0	0	0	0	9	9	36	0	0	0	0	0

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40	10	10	50	0	0	20	10	0	50	50	0	20	0	0	50	0	0	0	0	0	0	0	0	30	0
50	0	0	—	—	—	25	0	0	—	—	—	0	0	0	—	—	—	0	0	0	—	—	—	50	—

Table F-10. Performance Related to Substrate for Asphalt-Rubber Membranes and Conventional Seal Coats.

Substrate Type	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			AR			SC			AR			SC			AR			SC			AR			SC				
	AR	SC	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	AR	SC
Thin Flex	6	75	2	0	3	29	13	7	1	1	1	25	5	0	0	0	1	6	3	2	0	0	1	20	15	1	1	5
Thick Flex	21	73	9	12	8	26	25	9	4	3	1	20	17	8	2	1	0	4	10	4	1	1	4	22	5	0	0	2
Rigid	0	1	—	—	—	1	0	0	—	—	—	0	0	0	—	—	—	0	0	0	—	—	—	0	1	0	—	0

Table F-10. Continued.

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
AR			SC			AR			SC			AR			SC			AR			SC			AR	SC
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
33	0	50	39	17	9	17	17	33	7	0	0	0	0	17	8	4	3	0	0	17	27	20	1	17	7
43	57	38	36	34	12	19	14		27	23	11	10	5	0	5	14	5	5	5	19	30	7	0	0	3
—	—	—	100	0	0	—	—	—	0	0	0	—	—	—	0	0	0	—	—	—	0	100	0	—	0

Table F-11. Performance Related to Climate for Asphalt-Rubber Membrane.

Climate Zone	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			A			B			A			B			A			B			A			B				
	A	B	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	A	B
SAM Construction																												
Hot, T1	4	5	1	2	1	1	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mod, T2	11	8	4	4	4	4	2	3	3	4	1	1	0	0	1	1	0	0	0	0	1	0	4	0	0	0	1	1
Cold, T3	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
SAMI Construction																												
Hot, T1	4	1	2	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Mod, T2	9	1	4	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Cold, T3	1	0	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	1	N

Table F-11. Continued.

SAM Construction

Climate Zone	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			A			B			A			B			A			B			A			B				
	A	B	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	A	B
Dry, R1	12	11	4	5	3	4	3	2	2	2	2	2	0	0	0	0	1	0	0	0	1	0	4	0	0	0	0	2
Wet, R2	4	3	1	1	2	1	0	3	1	3	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0

SAMI Construction

Dry, R1	8	2	2	0	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	5	0
Wet, R2	6	0	4	1	0	N	N	N	0	1	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	N

Table F-11. Continued

SAM Construction

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
A			B			A			B			A			B			A			B			A	B
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
25	50	25	20	20	40	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20
36	36	35	50	25	38	27	36	9	13	0	0	9	9	0	0	0	0	9	0	36	0	0	0	9	13
0	0	0	0	0	0	0	0	100	100	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
SAMI Construction																									
50	0	0	0	0	0	25	25	0	100	0	0	25	0	0	25	0	0	0	0	0	0	0	0	0	0
44	11	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	44	0
0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	100	N

Table F-11. Continued

SAM Construction

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
A			B			A			B			A			B			A			B			A	B
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
33	42	25	36	27	18	17	17	17	18	0	0	0	0	8	0	0	0	8	0	33	0	0	0	0	18
25	25	50	25	0	75	25	75	0	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0	25	0

SAMI Construction

25	0	0	0	0	0	13	0	0	50	50	0	13	0	0	50	0	0	0	0	0	0	0	0	63	0
67	17	0	N	N	N	0	17	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	N

Table F-12. Performance Related to Climate for Asphalt-Rubber Membranes and Conventional Seal Coats.

Climate Zone	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			AR			SC			AR			SC			AR			SC			AR			SC				
	AR	SC	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	AR	SC
Hot, T1	9	11	2	3	3	7	4	0	0	1	0	4	1	0	0	0	0	1	2	2	0	0	0	12	4	0	1	0
Mod, T2	19	93	8	7	7	40	17	3	4	4	1	24	12	4	1	1	0	6	5	3	1	0	4	29	19	1	2	6
Cold, T3	2	41	0	0	0	9	16	13	1	0	1	19	10	4	0	0	1	3	7	2	0	0	0	7	1	0	0	0
Dry, R1	23	115	8	8	5	43	30	15	4	2	2	40	19	8	0	0	1	8	12	7	1	0	4	40	20	1	2	4
Wet, R2	7	30	2	1	5	13	7	1	1	3	0	7	4	0	1	1	0	2	2	0	0	0	0	8	4	0	1	2

Table F-12. Continued.

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
AR			SC			AR			SC			AR			SC			AR			SC			AR	SC
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
22	33	33	64	36	0	0	11	0	36	9	0	0	0	0	9	18	18	0	0	0	91	36	0	11	0
42	37	37	43	18	3	21	21	5	26	13	4	5	5	0	6	5	3	5	0	21	31	20	1	11	6
0	0	0	22	39	32	50	0	50	45	24	10	0	0	50	7	17	5	0	0	0	17	2	0	0	0
35	35	22	37	26	13	17	9	9	35	17	7	0	0	4	10	6	1	4	0	17	35	17	1	9	3
29	14	71	43	23	3	14	43	0	23	13	0	14	14	0	7	7	0	0	0	0	25	13	0	14	7

Table F-13. Performance Related to Project Length for Asphalt-Rubber Membrane.

SAM Construction

Length, Lane Miles	Total Projects		Distress, Total Projects																								No Distress	
			Flushing						Thermal Cracking						Alligator Cracking						Raveling							
			A			B			A			B			A			B			A			B				
	A	B	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	A	B
0-3	5	4	4	1	0	1	1	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
4-6	5	4	0	2	2	1	1	2	3	1	0	0	0	0	1	1	0	0	0	0	1	0	2	0	0	0	0	1
8-56	6	6	1	3	3	3	2	3	1	2	2	1	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0

SAMI Construction

0-20	4	1	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0
24-35	3	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40-56	6	0	2	1	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	3	

Table F-13. Continued.

SAM Construction

Distress, Percent of Projects																									
Flushing						Thermal Cracking						Alligator Cracking						Raveling						No Distress	
A			B			A			B			A			B			A			B			A	B
L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H		
80	20	0	25	25	0	0	40	0	25	0	0	0	0	0	0	0	0	0	0	20	0	0	25	20	25
0	40	40	25	25	50	60	20	0	0	0	0	20	20	0	0	0	0	20	0	40	0	0	0	0	25
17	50	50	50	33	50	17	33	33	17	0	0	0	0	17	0	0	0	0	0	33	0	0	0	0	0

SAMI Construction

0	0	0	0	0	0	25	25	0	100	0	0	25	0	0	100	0	0	0	0	0	0	0	0	50	0
100	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	17	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	0	0	0	N	N	N	50	N

Appendix G

The data collected during this project has been stored in a computer file at Texas A and M University. The statistical analysis presented in this report was generated using this data and statistical techniques established for computers by the SAS Institute. The determination of statistically significant effects in the data was done using two one-way ANOVA. The first compares differences in suppliers, i.e., Product A with Product B with conventional seal coats, the second compares differences within each level of independent variable, i.e., low versus medium versus high volume traffic, etc. In this way, effects due to differences between suppliers as well as effects due to differences within each supplier could be analyzed. A Duncan multiple range test was then performed to determine which data were responsible for significant differences.

The general computer program used to determine the statistical significance of all parameters is given below for reference:

The program above, labeled 'ADT', was used to determine effects of the three ADT classes on performance of each supplier studied. Other programs used to evaluate the other independent variables are shown below:

Program Name	
DATA	Lists all seal coat data
SAS9	Compares A, B, C by three accum traffic groups
SAS10	Compares A, B, C by total grouped accum traffic
ACC TRAF	Compares accum traffic by A, B, C
SAS11	Compares A, B, C by ADT groups
ADT	Compares ADT by A, B, C
SAS12	Compares A, B, C by age

YEARS	Compares age by A, B, C
SAS13	Compares A, B, C by substrate
SUBS	Compares substrate by A, B, C
SAS14	Compares A and B by length
MILES	Compares project length by A and B
SAS15	Compares A, B, C by climate
CUME	Compares rain climates by A, B, C
TEMPS	Compares thermal climates by A, B, C

```
//SCOTT  JOB (W218,505A,S20,2,SS),'ADT '
//STEP EXEC SAS,REGION=256K
//SYSIN DD *
 DATA TEST;
  INPUT DIST 1-2 HIWAY $ 3-9 LMILES 10-13 SUPPLY $ 14 PTYPE $ 15
        YEAR 16-17 SUB 18 ADT 19-23 ACCUM 24-28 FLUSH 29-30 THERM 31-32
        ALLIG 33-34 RAVEL 35-36 ;

                    CARDS ;
                 03US 287 56.0AI803 2300  40500000000
                 05SH 114 56.0AS801 1125 140000202500
                 05SH 289L 0.6BS802 3750  52005030000
                 07US 87  4.0 AS782 1025 110012000015
                 05US 60  56.0AI802 1450  52000000000
                 07SH 208 2.5 AS791  800  58008070000
                 07SH 208 2.5 AS791 800   58011090000
                 07US 87 L 6.0BS801 2500 110000000000
                 07US 87 L 4.0AS801 2500 110018000018
                 07US 87    4.5BS812 1250  15014000000
                 07US 87    4.0AS792 2350 170000000505
                 07IH 10  35.0AI792  950  68008000000
                 07IH 10  40.0AI802  950  68008000000
                 09SH 22    4.0AS762 1550 297614070500
                 11US259   24.0AS792 1750 126018000018
                 15IH 35   20.0AS802 4500 162010000000
                 15IH 10   56.0BS802 2950 106208000000
                 15IH 37   48.0AI803 4250 153000000000
                 15IH 37   48.0AI80313250 477000000000
                 17SH 21   8.0 BS812 2675   8005000000
                 17US   79 6.0 BS812 4000  12012000000
                 17US   79 20.0BS811 1400   4213000000
                 17SH    6 48.0AI802 1500  72008030500
                 17SH   36 24.0AI782 2600 319820000000
                 17IH 45   56.0AI803 2800 151205030000
                 19US   80   4.0AS762 2750 528012152000
                 19SH   43   3.0AS760  550 105600000000
                 19SH   43   3.0AS760  550 105605000000
                 20US   59   9.0AI813 5000 135000110000
                 20IH   10 32.  AI812 5000 135005000000
                 20IH   10 24.  AI813 4350 117505000000
                 21US   83 11.  AS792 5500 396020000000
                 21US   83 11.  BS792 5500 396018000000
                 21US   83  2.  AS812 4000 108008000000
                 21US   83  2.  BS812 4000 108008000500
                 21SH   48  3.  BS792 5250 378012000000
                 21SH   48  3.  AS792 5250 378012000013
                 21US   83  8.  AS782 5500 594012110000
                 21US   83  8.  BS782 5500 594016000000
                 21  115S   3.  BI78210000108000503 1500
                 21  115S   3.  AI81210000 270000031500
                 21FM491    2.  BS810  775   4600000000
                 22US 90   44.  AS802  850  43412070015
                 24IH 10   20.  AI762 1250 240000000000
                 24IH 10   20.  AI772 1250 180000000000
                 25US 62   26.  BS802  550  34705030000
                 25US 82   24.  BI803  750  47300110000
                 03SH    79 2.0CS762  611 110005000000
                 03FM  1197 2.0CS762  130  23308000505
                 03US   183 2.0CS771  320  46105110005
                 03US   183 2.0CS761  320  57605110000
                 03FM  2651 2.0CS761   60  10805000005
                 03US   183 2.0CS802  560  20200000005
```

O3US	183	2.OCS792	560	40300110015
O5US	87	2.OCS772	1317	189612152000
O5US	84	2.OCS801	690	24815000000
O5US	84	2.OCS802	690	24820120000
O5US	84	2.OCS802	926	33312030000
O5US	84	2.OCS792	926	66718070000
O5US	84	2.OCS802	926	33312030000
O5US	84	2.OCS792	926	66718030000
O5US	84	2.OCS782	926	100018031500
O5US	385	2.OCS802	1345	48410030000
O5US	385	2.OCS792	1345	96812030000
O5US	82	2.OCS771	562	80900030000
O5US	82	2.OCS761	562	101218070000
O5US62	70	2.OCS802	814	29300030000
O5US62	70	2.OCS792	814	58612071000
O5US	84	2.OCS802	935	33708030500
O5US	84	2.OCS792	935	67315110005
O5US	84	2.OCS802	952	34305030000
O5US	84	2.OCS792	952	68620000005
O5US	87	2.OCS762	1417	255112110000
O5SH	194	2.OCS771	820	118110030000
O5FM	400	2.OCS781	473	51108110000
O5FM	400	2.OCS771	473	68110030500
O5FM	1612	2.OCS791	80	5800000010
O5FM	1612	2.OCS781	80	8605000005
O5US	87	2.OCS792	1275	91800110000
O5US	87	2.OCS782	1275	137718030000
O5US	385	2.OCS782	700	75600150005
O5FM	1585	2.OCS801	238	8600070000
O5US	87	2.OCS792	1001	72000000008
O5US	84	2.OCS771	1257	181008001500
O5US	84	2.OCS761	1257	226320071005
O5US	84	2.OCS802	1310	47212030000
O5US	84	2.OCS792	1310	94312030000
O5US	84	2.OCS782	1310	141515000000
O5US	84	2.OCS802	711	25608072000
O5US	84	2.OCS802	785	25620071500
O5US	84	2.OCS802	785	25615071000
O5US	87	2.OCS802	1025	36912000000
O5US	87	2.OCS782	1025	110715030000
O5US	87	2.OCS772	1025	147615120005
O5SH	86	2.OCS781	675	72905122000
O5FM	1424	2.OCS781	105	11310000000
O5SH	214	2.OCS771	180	25920031000
O5FM	1780	2.OCS801	155	5612000000
O5FM	1780	2.OCS791	155	11220000000
O7US	67	2.OCS791	665	47910000000
O7US	83	2.OCS792	505	36412000000
O7US	83	2.OCS801	345	12410030500
O7FM	2402	2.OCS761	50	9000000000
O7SH	163	2.OCS801	65	2312000000
O7SH	163	2.OCS791	65	4618000000
O7FM	2092	2.OCS761	120	21605000000
O7US	67	2.OCS802	695	25012000000
O7FM	2111	2.OCS801	112	4010031000
O9IH	35	2.OCS792	3620	260610000000
O9SH	6	2.OCS802	1357	48905000000
O9FM	935	2.OCS801	278	10000000000
O9FM	935	2.OCS791	278	20000000000
O9FM	935	2.OCS781	278	30000000005
O9FM	434	2.OCS801	155	5600000015

09SH	31	2.0CS802	1410	101508000000
09SH	31	2.0CS792	1410	203008070005
09SH	31	2.0CS782	1410	304518111505
09FM	309	2.0CS801	188	6805000000
09FM	1243	2.0CS771	70	10100000000
09US	80	2.0CS802	2908	104708000008
11SH	94	2.0CS802	690	24800000000
11SH	94	2.0CS792	690	49712000005
11SH	94	2.0CS782	690	74508070510
11US	287	2.0CS802	1890	68005000000
11US	287	2.0CS792	1890	136100150008
11FM	1733	2.0CS761	50	9000000015
11FM	1280	2.0CS801	200	7205000015
11US	96	2.0CS801	1155	41600030000
11US	96	2.0CS791	1155	83210070000
15SH	16	2.0CS801	390	14000000000
15SH	16	2.0CS791	390	28005000000
15SH	16	2.0CS781	390	42110030008
15SH	16	2.0CS771	390	56112000008
15FM	2146	2.0CS781	180	19405000000
15FM	2146	2.0CS771	180	25912000005
15FM	1044	2.0CS801	225	8100000012
15FM	1044	2.0CS791	225	16200000015
15IH	35	2.0CS802	1016	36608070005
15IH	35	2.0CS802	953	34308110010
15SH	97	2.0CS771	222	32000000005
15FM	468	2.0CS791	90	6510000010
17FM	60	2.0CS802	675	24312030500
17FM	60	2.0CS792	675	48608030005
17FM	60	2.0CS782	675	72912071500
17US	190+	2.0CS792	875	63015030000
17FM	1374	2.0CS761	150	27005070000
19FM	2088	2.0CS801	383	13805000000
19FM	2088	2.0CS791	383	27608000000
20SH	73	2.0CS802	1352	48712000000
20SH	73	2.0CS792	1352	97315000005
21US	77	2.0CS802	1905	68605000005
21US	77	2.0CS782	1905	205705000008
21US	281	2.0CS802	1207	43408000005
21US	281	2.0CS782	1207	130408000000
21US	281	2.0CS772	1207	173812000000
21FM	493	2.0CS802	558	20105001508
21FM	493	2.0CS792	558	40212001505
21FM	716	2.0CS791	90	6505030500
21FM	2687	2.0CS793	140	10105000010
22FM	186	2.0CS801	143	5100030012
22FM	674	2.0CS761	50	9008000000
22US	277	2.0CS771	820	118105000005
22US	277	2.0CS761	820	147605030005
22FM	1021	2.0CS801	350	12600000005
22FM	1021	2.0CS791	350	25205000005
22FM	1021	2.0CS781	350	37818030008
22US	57	2.0CS801	580	20900000005
22US	57	2.0CS791	580	41800000012
22US	57	2.0CS781	580	62600071510
22FM	1025	2.0CS801	130	4700002005
24US	180	2.0CS802	502	18100151000
24US	180	2.0CS792	502	36205201512
24US	90	2.0CS802	780	28100030000
24US	90	2.0CS792	780	56208000012
24FM	2185	2.0CS781	80	8605110500

```
24SH    17 2.0CS801  175   6305030010
24SH    17 2.0CS791  175  12605070008
24SH    17 2.0CS781  175  18912030005
24FM   505 2.0CS801   30   1005000008
24FM  2810 2.0CS801   50   1800000010
25SH   256 2.0CS771  142  20500070008
25FM  1065 2.0CS791   38   2700000010
25FM  1065 2.0CS781   38   4100000012
25FM  1065 2.0CS771   38   5505030012
25FM  1065 2.0CS761   38   6810000012
25SH    86 2.0CS771  350  50405000000
25US    82 2.0CS772  365  51005110005
25US    82 2.0CS772  365  51008071500
25FM  2362 2.0CS801   25   1300000005
25US   287 2.0CS802 1198  43100000000
25SH    70 2.0CS771  180  26000070000
25SH    70 2.0CS761  180  32405070000
25US   287 2.0CS772 1184 170508150000
25US    82 2.0CS782  730  78800150000
25US    82 2.0CS772  730 105105202500
25US    82 2.0CS782  815  88000110000

DATA ALL ;
  SET TEST ;
  IF FLUSH  =  0 THEN FLUSH = . ;
  IF THERM = 0 THEN THERM = . ;
  IF ALLIG = 0 THEN ALLIG = . ;
  IF RAVEL = 0 THEN RAVEL = . ;
   DATA ACCUM1 ACCUM2 ACCUM3 ; SET ALL ;
  IF ADT   LT 501 THEN Y=1              ;
  IF ADT   GT 500  AND  ADT   LT 1001 THEN Y=2          ;
  IF ADT   GT 1000 THEN Y=3;
  IF SUPPLY='A'   THEN OUTPUT ACCUM1 ;
  IF SUPPLY='B'                          THEN OUTPUT ACCUM2 ;
  IF SUPPLY='C'    THEN OUTPUT ACCUM3 ;
     MACRO MEAND
     PROC SORT DATA=TDATA ; BY PTYPE ;
     PROC MEANS ; BY PTYPE ;
     PROC GLM DATA =  TDATA ;
     BY PTYPE ;
     CLASSES Y       ;
     MODEL FLUSH THERM ALLIG RAVEL = Y       ;
      MEANS Y       / DUNCAN ;
%
   DATA TDATA ; SET ACCUM1 ;TITLE ADT ANALYSIS FOR SUPPLY A       ; MEAND ;
   DATA TDATA ; SET ACCUM2 ;TITLE ADT ANALYSIS FOR SUPPLY B       ; MEAND ;
   DATA TDATA ; SET ACCUM3 ;TITLE ADT ANALYSIS FOR CONVENTIONAL ; MEAND ;
/*END
```