TEN YEAR PERFORMANCE OF ASPHALT ADDITIVE TEST SECTIONS
LAVA BUTTE – FREMONT HIGHWAY JUNCTION SECTION

THE DALLES - CALIFORNIA HIGHWAY (US#97)
DESCHUTES COUNTY, OREGON

FHWA Test and Evaluation Project #3

by

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for

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16. Abstract

The durability of hot mix asphalt concrete (HMAC) overlays is important to the Oregon Department of Transportation (ODOT), as this is the most common form of surface rehabilitation on state roads. To see if several HMAC additives available in Oregon increased overlay life, test sections were paved in 1985.

The eight test and two control sections are located on US Route 97, 31 km (19.25 m) south of Bend, Oregon. The top course is a 38-51 mm (1.48-1.99 in) thick lift of HMAC using the experimental additives. The combined base and leveling course is a 102-114 mm (3.98-4.45 in) thick lift of HMAC, using a combination of aggregate treated with lime and Pave Bond asphalt additive as anti-stripping treatments. The pavement under the overlay was badly alligatored and had frequent thermal cracks.

The aggregate is crushed river cobbles composed mainly of basalt and other extrusive igneous rocks. The experimental mixes are: Plus Ride 12® with Pave Bond®, Arm-R-Shield®, Fiber Pave® 3010, Boni Fibers ® B, Class "C" with Pave Bond® and Lime, Class "C" with Lime, CA(P)-1 and CA(P)-1 with Lime. The Class "C" and in some cases, Class "C" with Pave Bond® pavements are the control sections.

After ten years and approximately 1,522,000 and 1,721,000 equivalent axle loads in the northbound and southbound lanes, respectively; all pavements resisted rutting, maintained a smooth ride and retained high friction numbers. The only significant distress on any sections were cracking and raveling. The Arm-R-Shield® had the highest performance rating, as it had superior resistance to fatigue cracking, block cracking, and raveling. The Fiber Pave® 3010, Boni Fibers ® B, Class "C" with Pave Bond®, Class "C" with Pave Bond® and Lime, and Class "C" pavements had similar performance. The Plus Ride with Pave Bond® section performed worse than the controls. It had a low resistance to fatigue cracking, block cracking, and raveling. The CA(P)-1 and CA(P)-1 with Lime sections also performed worse than the controls. They had a low resistance to fatigue, block and transverse cracking.

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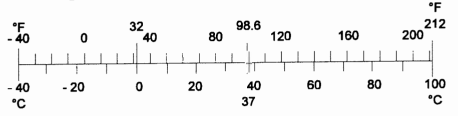
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

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DISCLAIMER

TEN YEAR PERFORMANCE OF ASPHALT ADDITIVE TEST SECTIONS

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1.0 INTRODUCTION

The durability of hot mix asphalt concrete (HMAC) overlays is important to the Oregon Department of Transportation (ODOT), as this is the most common type of rehabilitation for state highways. To see if several HMAC additives available in Oregon increase overlay life, test sections were built in August 1985. These sections have been intensively studied by the Research Unit since construction *(Hicks 1986, 1987; Miller and Scholl 1990; ODOT 1990).*

The eight test and two control sections are 400 to 1600 m long, and they are located on The Dalles - California Highway (US Route #97 or Oregon Highway #4), 31 km south of Bend, Oregon. The top course is a 38 to 51 mm thick lift of HMAC using the experimental additives. The combined base and leveling course is a 102 to 114 mm thick lift of HMAC, using a combination of aggregate treated with lime and Pave Bond® asphalt additive as antistripping treatments. The old pavement was badly alligatored and it had frequent thermal cracks.

All sections are of dense-graded asphalt concrete with a 13 mm maximum stone size. Section 1 has a special gradation, while Sections 2 through 10 and all base lifts have an ODOT Class "C" gradation. The aggregate is crushed river cobbles composed of basalt and other extrusive igneous rocks. The mixes in the sections are described in Table 1.1.

Table 1.1: Test Sections

Section 1	Plus Ride 12® with Pave Bond® - A mix of AC-20 asphalt, Pave Bond complex polyamine antistripping agent, coarse granulated tire rubber as an aggregate substitute, and gap-graded aggregate.
Section 2	Arm-R-Shield® - A mix of AR-4000W asphalt, extender oils, and finely ground tire rubber; and untreated aggregate. Some of the rubber is dissolved in the asphalt.
Section 3	Fiber Pave® 3010 - A mix of AC-20, polypropylene fibers, and untreated aggregate.
Section 4	Boni Fibers® B - A mix of AC-20, polyester fibers, and untreated aggregate.
Section 5	Class "C" with Pave Bond® - A mix of AC-20, Pave Bond, and untreated aggregate.
Section 6	Class "C" with Pave Bond® and Lime - A mix of AC-20, Pave Bond, and lime treated aggregate.
Section 7	Class "C" with Lime - A mix of AC-20 and lime treated aggregate.
Section 8	Class "C" - A mix of AC-20 and untreated aggregate.
Section 9	CA(P)-1 - A mix of CA(P)-1 polymerized binder containing Elvax® 150 ethylene-vinyl-acetate (EVA) polymer blended with AC-20 asphalt, and untreated aggregate.
Section 10	CA(P)-1 with Lime - A mix of CA(P)-1 and lime treated aggregate.

This report summarizes the results of the ten-year performance evaluation, which included a visual inspection, ride testing, and friction testing. Based on historical and projected traffic data, it is estimated that 1,522,000 northbound and 1,721,000 southbound equivalent 80 kN (18-kip) single axle loads (ESALs) have traveled over the road following the construction ten years ago.

An exception to both of these traffic loadings occurred on the Plus Ride with Pave Bond section and the north end of the Arm-R-Shield section. Slow moving vehicle lanes were built adjacent to these pavements in 1990 and reduced the volume of traffic on the inner travel lanes used for testing. The Arm-R-Shield section was not affected, as the south end of this section was unaltered and continued to carry the full traffic loading.

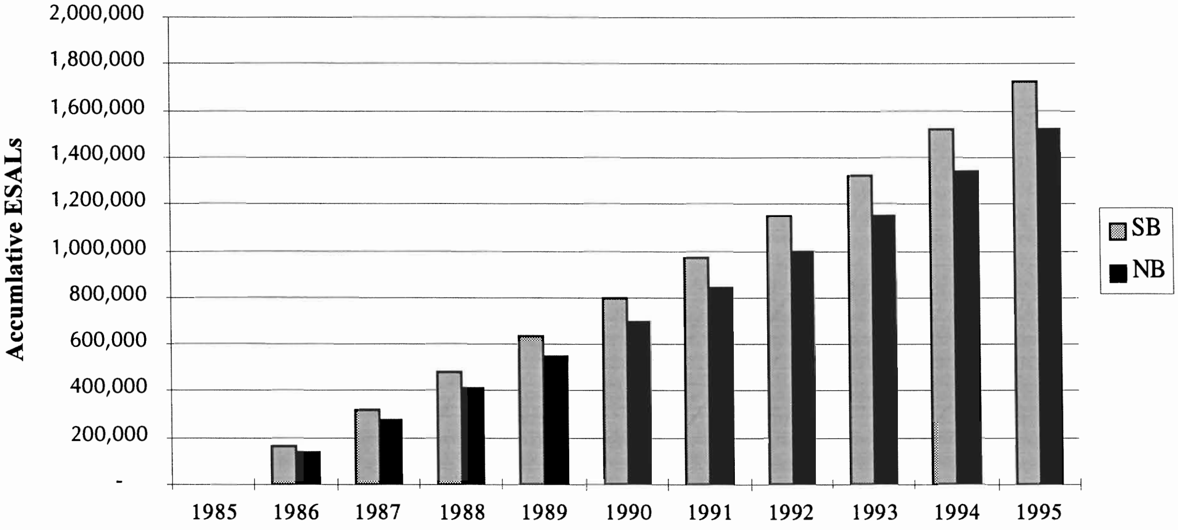

Figure 1.1: Accumulative ESALs by Year

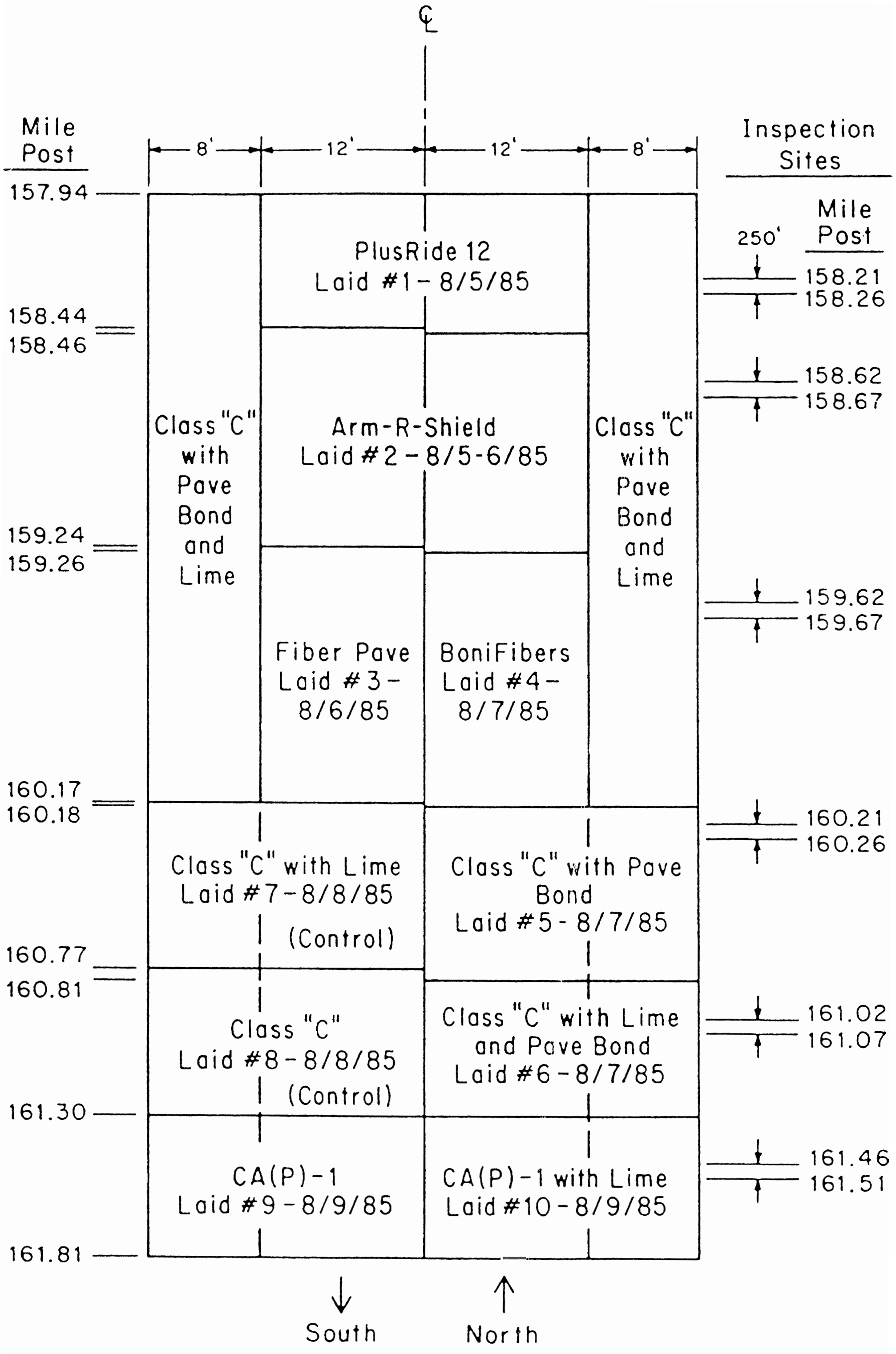

Figure 1.2: Test Section Layout

2.0 FIELD PERFORMANCE

2.1 RATING CRITERIA

A rating criteria was developed specifically for this study and was used in earlier reports *(Miller and Scholl 1990; ODOT 1990)*. Tables 2.2 through 2.7 show the rating criteria for each type of distress. The ratings of the test and control sections were then compared using the following scale:

Table 2.1: Comparison Scale

Difference in Ratings Between Control and Test Section	Comparison to Control
0	Same
1	Slightly Better or Slightly Worse
2	Better or Worse
3	Much Better or Much Worse
4	Very Much Better or Very Much Worse

As an example, if the control section had a rating of five and the test section had a rating of three, there would be a difference of two between the sections' ratings. Consequently, the control section would be "better" than the test section.

2.2 RESISTANCE TO RUTTING

On each section, rut depths were measured in at least six locations in the inner wheel path and six locations in the outer wheel path. The measurements were taken at 15.2 m intervals within a 760 m section using a 1.52 m straight edge. The average rut depths are listed in Table 2.2 and graphically displayed in Figure 2.1. These depths indicate the pavement's resistance to permanent deformation and wear from studded tires.

2.2.1 Comments

The traffic loadings experienced by each lane differ, as traffic data indicates that the southbound lanes carry about 13% more ESALs than the northbound lanes. Consequently, as rutting is a traffic-induced distress, differences in traffic loading require the northbound sections to be compared separately from the southbound sections.

The sections had rut depths between 6 to 16 mm.

With the exception of the Plus Ride section, the rutting resistance on all sections was the same as, or slightly better than, the control sections. The Plus Ride rut depth in 1995 was less than the other sections, but this was due to the reduction in traffic caused by the construction of slow moving vehicle lanes in 1990. Since the Plus Ride rut depths were similar to the control sections in 1989 and 1990, it is assumed that the overall rutting resistance of Plus Ride is similar to the control section (see Figure 2.1).

It should also be noted that Plus Ride had a much lower Hveem stability (stability=4) than the other mixes. The Evaluation of Asphalt Additives final report stated this may be due to the resilience imparted to the mix by the rubber particles, rather than an indicator of potential distress *(Hicks 1987)*. However, after 10 years of service, the section has shown no distress related to low stability.

Table 2.2: Rut Depths (Fall 1995 Inspections)

Section	Name	Average Rut Depth in mm (inches)	Rating	Comparison to Control
		Northbound Lanes		
1	Plus Ride with Pave Bond	6 (1/4)	4	Same *
2	Arm-R-Shield	13 (1/2)	3	Slightly Better
4	Boni Fibers	16 (5/8)	2	Same
5	**Class "C" with Pave Bond**	**16 (5/8)**	**2**	**Control**
6	Class "C" with Lime and Pave Bond	10 (3/8)	3	Slightly Better
10	CA(P)-1 with Lime	10 (3/8)	3	Slightly Better
		Southbound Lanes -		
1	Plus Ride with Pave Bond	6 (1/4)	4	Same *
2	Arm-R-Shield	10 (3/8)	3	Same
3	Fiber Pave	13 (1/2)	3	Same
7	Class "C" with Lime	11 (7/16)	3	Same
8	**Class "C"**	**10 (3/8)**	**3**	**Control**
9	CA(P)-1	10 (3/8)	3	Same

*Rating is based on 1989 and 1990 data. See text for explanation.

Rating Criteria: Rutting

5	3 mm or less rut depth.
4	6 mm or less rut depth.
3	13 mm or less rut depth.
2	25 mm or less rut depth.
1	More than 25 mm rut depth.

2.3 RESISTANCE TO CRACKING

The extent of the transverse, block and fatigue cracking are summarized in Tables 2.3 and 2.4, and shown graphically in Figures 2.3, 2.6, and 2.7.

2.3.1 Transverse Cracking

Only the transverse cracks which cross at least half of a travel lane were counted. The vast majority of these transverse cracks extended from pavement edge to pavement edge, and most were routed to a width of 13 to 19 mm as a preparation for filling with a rubber-asphalt crack sealer. However, due to the onset of winter in 1991, only a third of the cracks were sealed. The field survey in 1995 found some of the cracks still open. Some of the cracks were not routed, and they were 6 to 13 mm wide. This maintenance activity needs to be considered when future

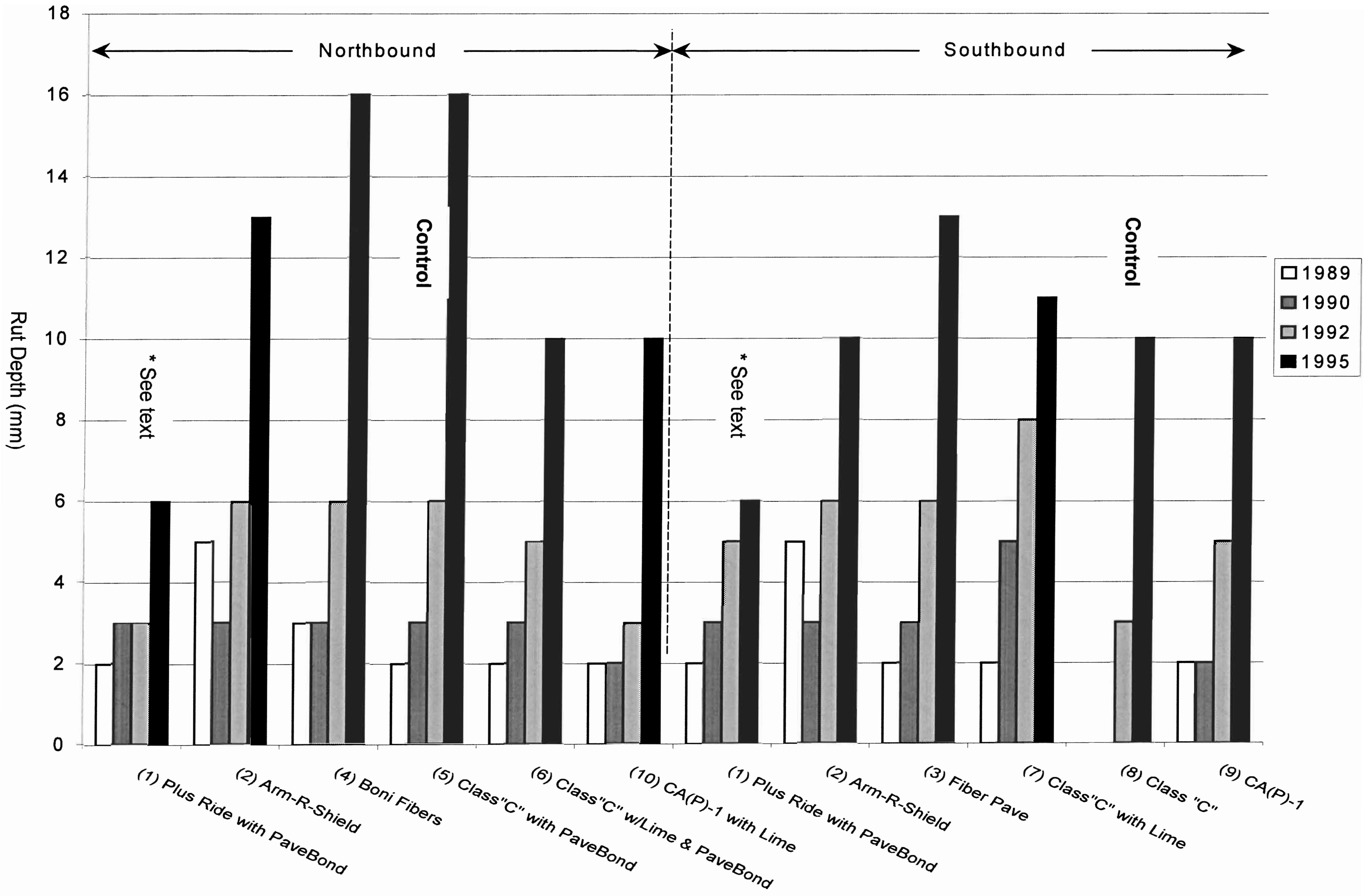

Figure 2.1: Average Rut Depths 1989-1995

pavement evaluations are performed. Most of the cracks (69%) were of a low severity level (0 to 6 mm), 26% were moderate (6 to 19 mm) and 4% were of high (over 19 mm) severity *(SHRP 1993)*. The cracks had little or no spalling around their edges and did not significantly affect the ride of the sections. Examples of routed cracks are shown in Figure 2.2.

2.3.1.1 Comments

On many sections, the shoulders had much more transverse cracking than the travel lanes, but most were not counted because they didn't extend into the travel lanes. As most sections had shoulders made from conventional "C" mix, this shoulder cracking may have been due to properties of the "C" mix, rather than the experimental mixes in the travel lanes.

Throughout the study, observations were made of the pattern of the transverse cracking and the times of the year when the cracks occurred. The majority of the transverse cracking may be thermal cracks caused by the contraction of the base and/or wearing course. The remainder of the cracking may be due to cracks in the old roadway reflecting up through the new overlay.

The test and control section's transverse crack counts ranged from 5 to 39 cracks per lane kilometer. Consequently, all of the sections had much less transverse cracking than the 93 large transverse cracks per lane kilometer on the road before the overlay.

Plus Ride had the least amount of transverse cracking, followed by Class "C" with Pave Bond and Arm-R-Shield. CA(P)-1 had the most cracking. The low number of cracks in the Plus Ride and Arm-R-Shield sections was expected, as these sections contain rubber which is usually resistant to thermal cracking. The lack of transverse cracking in the Class "C" with Pave Bond mix is puzzling, as this section is alongside the Class "C" with Lime section which has about twice as much transverse cracking. It was initially thought that the Pave Bond improved transverse crack resistance. However, this may not be true. The Class "C" with Pave Bond and Lime section had more transverse cracking than the Class "C" section that is alongside it.

It should be noted that the frequency of transverse cracks generally increased with each section from north (Section 1) to south (Section 10). There is no explanation for this observation and it is assumed to be a coincidence.

Figure 2.2a: Typical Transverse Crack that was Routed and Sealed.
CA(P)-1 with Lime pavement is in the near lane, and CA(P)-1 pavement is in the far lane.
Location: MP 161.5 looking west.

Figure 2.2.b: Typical Transverse Crack that was Routed, but Not Sealed.
Arm-R-Shield is in the two travel lanes, and Class "C" with PaveBond and Lime is in the shoulder.
Location: MP 158.6.

Figure 2.2: Transverse Cracking Examples

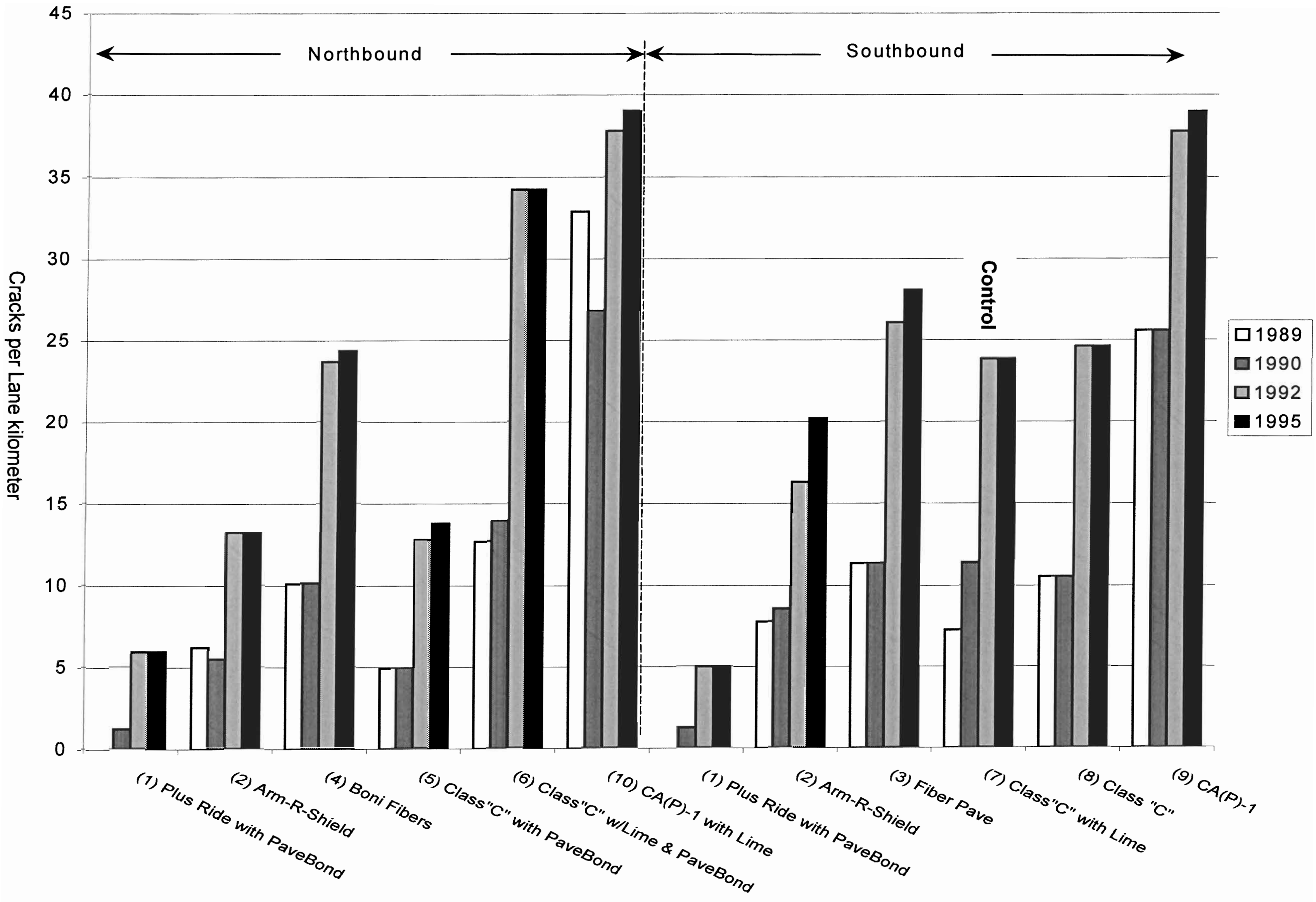

Figure 2.3: Transverse Cracking

Table 2.3: Transverse and Block Cracking (Fall 1995 Inspection)

Section	Name	Transverse Cracking - Cracks per Lane km	Rating	Comparison to Control	Block Cracking	Rating	Comparison to Control
1	Plus Ride with Pave Bond	6 [1]	4	Same	66% [3]	1	Slightly Worse
2	Arm-R-Shield	17 [2]	4	Same	0%	5	Much Better
3	Fiber Pave	28	4	Same	0%	5	Much Better
4	Boni Fibers	24	4	Same	5%	4	Better
5	Class "C" with Pave Bond	14	4	Same	10%	4	Better
6	Class "C" with Lime and Pave Bond	34	3	Slightly Worse	9%	4	Better
7	Class "C" with Lime	24	4	Same	37%	2	Same
8	**Class "C"**	**25**	**4**	**Control**	**41%**	**2**	**Control**
9	CA(P)-1	39	3	Slightly Worse	20%	3	Slightly Better
10	CA(P)-1 with Lime	39	3	Slightly Worse	56%	1	Slightly Worse

Notes: [1] Transverse cracks for northbound = 6/km, southbound = 5/km.

[2] Transverse cracks for northbound = 13/km, southbound = 20/km.

[3] Percent block cracking for northbound = 47%, southbound = 86%.

Rating Criteria:	**Transverse Cracking**
5	No transverse cracks
4	Less than 30 transverse cracks per lane km.
3	Less than 60 transverse cracks per lane km.
2	Less than 120 transverse cracks per lane km.
1	More than 120 transverse cracks per lane km.

Rating Criteria:	**Block Cracking**
5	No block cracking.
4	Less than 10% block cracking over the travel lane area.
3	Less than 30% block cracking over the travel lane area.
2	Less than 50% block cracking over the travel lane area.
1	More than 50% block cracking over the travel lane area.

2.3.2 Block Cracking

The SHRP-P-338 guideline describes block cracking as a pattern of cracks divided into rectangular pieces ranging in size from 0.1 to 10.0 m^2 *(SHRP1993)*. Pieces smaller than 0.1 m^2 that are found in the wheel path area are considered fatigue cracks.

These cracks are sometimes referred to as "shrinkage" or "ladder" cracking. They are not load associated. Instead, they are often linked to the shrinkage of asphalt concrete and fatigue caused by the pavement's expansion and contraction due to daily temperature cycling *(Smith 1979)*.

Transverse cracks approximately 0.3 to 0.6 m long were found near the centerline of many sections. An example of this cracking is shown in Figure 2.4. These cracks were counted as block cracking rather than transverse cracks. The remainder of the cracks may be reflective cracks, cracks in the old roadway reflecting up through the overlay. The presence of this block cracking near the centerline is accounted for in Table 2.3. Block cracking on the shoulder is not included in this rating, as many sections paved with experimental mixes have shoulders of conventional mix.

2.3.2.1 Comments

All test sections can be compared to the Class "C" control section in the southbound lane, as this type of cracking is not load associated.

Only the Arm-R-Shield section had no block cracking. All other sections had block cracking of a "low" severity level. *(SHRP 1993).*

2.3.3 Fatigue Cracking

This cracking is often called "wheeltrack" or "alligator" cracking and is associated with repeated traffic loading. The cracks usually begin as a series of short non-connected longitudinal cracks, progressing to a series of interconnected cracks and then developing into an alligator crack pattern comprised of small blocks usually less than 0.1 m^2. The following forms of cracking, even if they were in the wheelpath, are not included in the rating: transverse thermal cracking, reflective cracking, block cracking, and longitudinal cracking over joints between pavement panels. Typical cracking in the wheel tracks is shown in Figure 2.5.

2.3.3.1 Comments

Fatigue cracking is a load-related distress. Differences in traffic loading require the northbound sections to be compared separately from the southbound sections.

The Arm-R-Shield section had excellent resistance to fatigue cracking. There was no cracking in either the southbound lane with the higher truck traffic, or the northbound lanes with the lower truck traffic. All other sections had some fatigue cracking, though it was of a "low" severity level *(SHRP 1993).*


'98 6 16

Figure 2.4: Typical Block Cracking and Fatigue Cracking. The Class "C" pavement is on the left, and the Class "C" with Lime and Pave Bond pavement is at the right. Location: MP 61.05 looking south.


'98 6 16

Figure 2.5: Wheeltrack Cracking on Plus Ride. About 7% of the wheeltracks were raveled. The newly constructed slow-moving-vehicle lanes are on the outside lanes. Location: MP 158.2

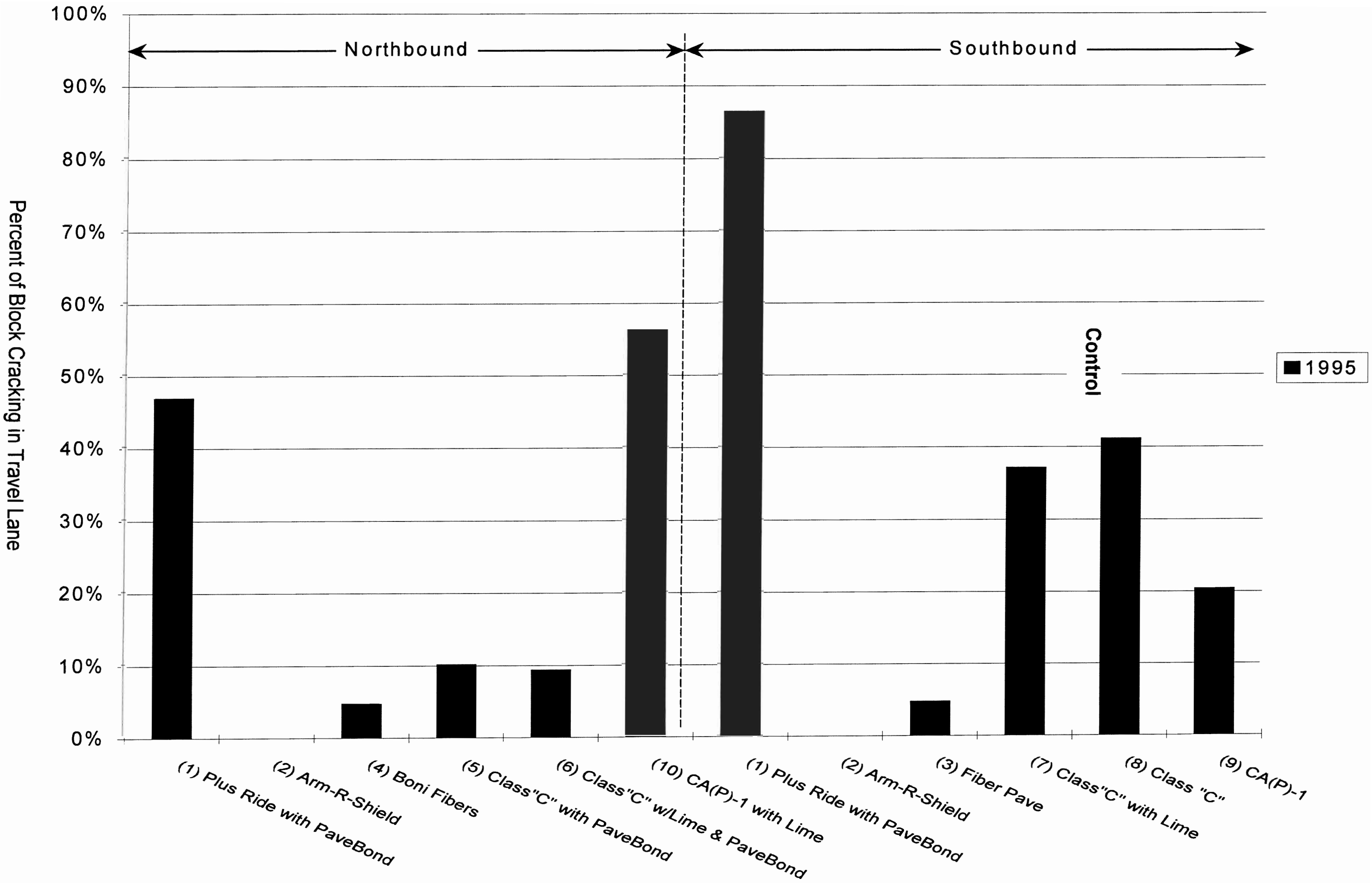

Figure 2.6: Block Cracking

Table 2.4: Fatigue Cracking (Fall 1995 Inspection)

Section	Name	% of Wheeltracks Cracked	Rating	Comparison to Control
		Northbound Lanes		
1	Plus Ride with Pave Bond	43	2	Worse
2	Arm-R-Shield	0	5	Slightly Better
4	Boni Fibers	1	4	Same
5	**Class "C" with Pave Bond**	**3**	**4**	**Control**
6	Class "C" with Lime and Pave Bond	17	2	Worse
10	CA(P)-1 with Lime	65	1	Much Worse
		Southbound Lanes		
1	Plus Ride with Pave Bond	33	2	Same
2	Arm-R-Shield	0	5	Much Better
3	Fiber Pave	14	2	Same
7	Class "C" with Lime	52	1	Slightly Worse
8	**Class "C"**	**44**	**2**	**Control**
9	CA(P)-1	75	1	Slightly Worse

Rating Criteria: Fatigue Cracking

5	No longitudinal cracking in the wheelpaths.
4	Some longitudinal cracking in the wheelpaths. Cracks do not connect to form alligator or map cracking.
3	Alligator and/or map cracking on less than 10% of the wheelpath length.
2	Alligator and/or map cracking on less than 50% of the wheelpath length.
1	Alligator and/or map cracking on more than 50% of the wheelpath length.

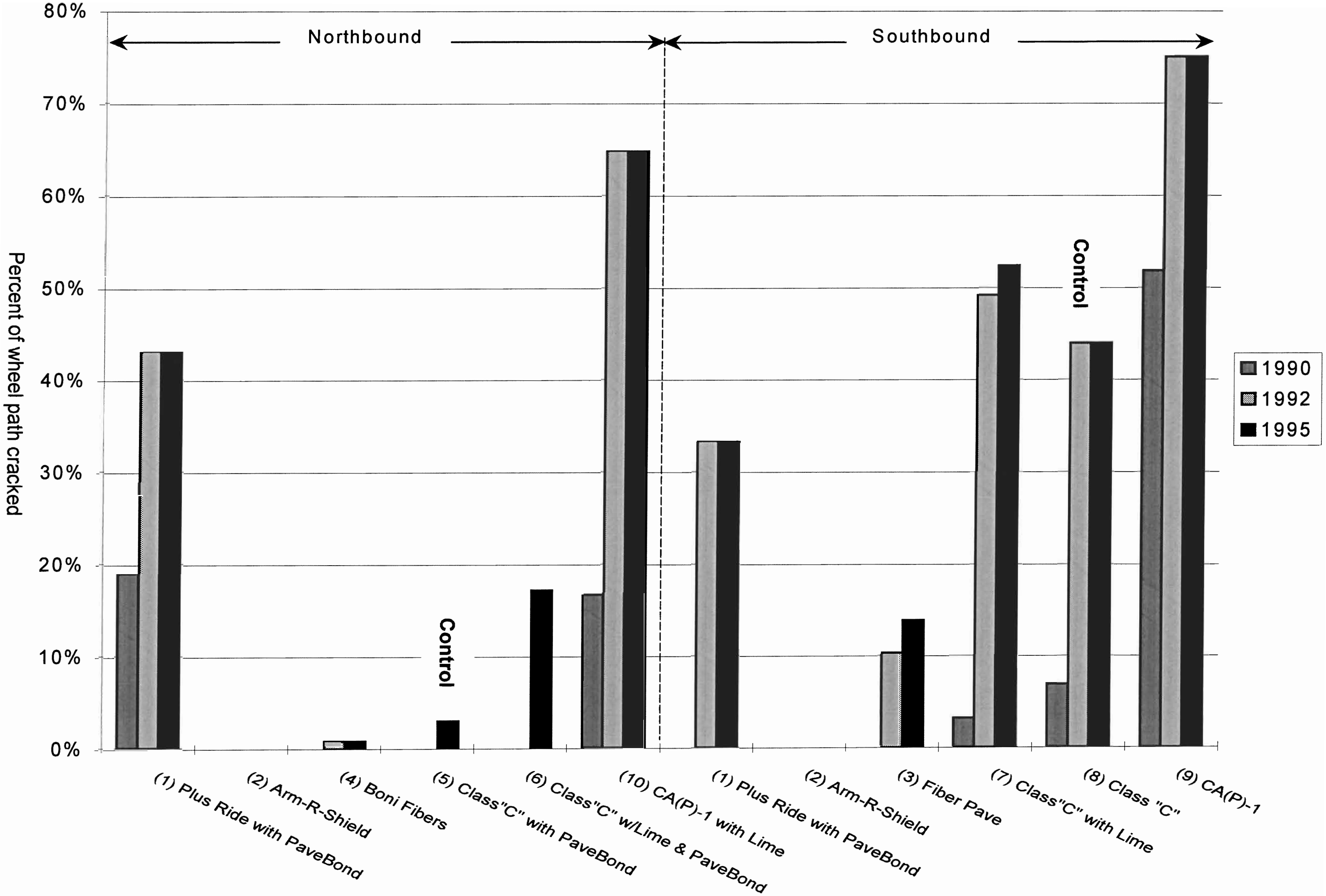

Figure 2.7: Fatigue Cracking

2.4 RESISTANCE TO RAVELING

The SHRP-P-338 guideline describes raveling as the wearing of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder *(SHRP 1993)*. The results are shown in Table 2.5.

Table 2.5: Raveling (Fall 1995 Inspection)

Section	Name	Raveling Rating	Comparison to Control
	Northbound Lanes		
1	Plus Ride with Pave Bond	3	Worse
2	Arm-R-Shield	5	Same
4	Boni Fibers	5	Same
5	**Class "C" with Pave Bond**	**5**	**Control**
6	Class "C" with Pave Bond and Lime	5	Same
10	CA(P) with Lime	5	Same
	Southbound Lanes		
1	Plus Ride with Pave Bond	3	Worse
2	Arm-R-Shield	5	Same
3	Fiber Pave	5	Same
7	Class "C" with Lime	5	Same
8	**Class "C"**	**5**	**Control**
9	CA(P)-1	5	Same

Rating Criteria: Raveling

5	Low severity level. The aggregate or binder has begun to wear away but has not progressed significantly. Some loss of fine aggregate.
3	Moderate severity level. Aggregate and/or binder has worn away and the surface texture is becoming rough and pitted; loose particles generally exist; loss of fine aggregate and some loss of coarse aggregate.
1	High severity level. Aggregate and/or binder has worn away and the surface texture is very rough and pitted; loss of coarse aggregate.

2.4.1 Comments

Raveling is related to both weathering and traffic volume. Weathering can contribute to the loss of binder and fine aggregate and traffic volume contributes to fine and coarse aggregate loss. Differences in traffic volumes requires northbound sections to be compared separately from southbound sections.

All sections, except the Plus Ride, had low severity raveling. The surface texture on the Plus Ride section was considerably rougher than the other sections and is of a moderate severity level. Inspections made in 1989 found the Plus Ride section already in poor condition, which had worsened by 1992. Portions of the section have been patched to correct the problem.

Shortly after construction of the Plus Ride section, large amounts of rubber particles were seen along the shoulder of the road. This loss of rubber may have left the remaining surface aggregate vulnerable, causing the aggregate to eventually come loose. Although the initial loss of material was high, the rate of loss appears to have slowed to an acceptable rate, as large amounts of rubber particles are no longer found on the shoulder. However, there is a possibility the loss occurs in cycles. As the aggregate wears down, new rubber particles are exposed and may ravel. The cycle may begin again, causing another "layer" of material to ravel.

2.4.2 Additional Comments on Surface Texture

No rubber was visible on the Arm-R-Shield surface. Crumb rubber is very visible on the Plus Ride surface and easy to pick out by hand. Low severity bleeding was found on the Arm-R-Shield (1780 m^2), Fiber Pave (4300 m^2) and AC-20 with Lime (260 m^2) sections.

2.5 FRICTION

All friction testing was done at speeds near 64 km/h in the left wheelpath using a K.J. Law trailer. The data from these tests were converted to standard 64 km/h friction numbers using correlation equations. The test methods, calibration techniques, and equipment conformed to AASHTO requirements. The test and control section's friction ratings are compared in Table 2.6.

Table 2.6: Friction (Summer 1992)

Section	Name	Comparison to Control
	Northbound Lanes	
1	Plus Ride with Pave Bond	Same
2	Arm-R-Shield	Same
3	Fiber Pave	Same
4	Boni Fibers	Same
5	**Class "C" with Pave Bond**	**Control**
6	Class "C" with Lime and Pave Bond	Same
10	CA(P)-1 with Lime	Same
	Southbound Lanes	
1	Plus Ride with Pave Bond	Same
2	Arm-R-Shield	Same
3	Fiber Pave	Same
7	Class "C" with Lime	Same
8	**Class "C"**	**Control**
9	CA(P)-1	Same

2.5.1 Comments

As pavement frictional qualities are influenced by traffic volumes, the northbound sections must be compared separately from the southbound sections.

There were no significant differences between the friction numbers of the sections. In addition, all pavements had adequate friction numbers, and they were typical of ODOT dense-graded pavements.

2.6 ROUGHNESS

The roughness, or ride, of the pavement was measured in the summer of 1992 and 1995 with a "South Dakota" type profilometer. The average ride values are in Table 2.7. The rating criteria is based on the ODOT Paving Award Criteria from the late 1980's. This award criteria was used in earlier reports on these test pavements, and it was based on Mays Inches/Mile. For this report, the earlier Mays criteria were converted to International Roughness Index (IRI) values by conversion equations *(Laylor and Pierce 1990)*.

Table 2.7: Roughness

Section	Name	Average Pavement Roughness in IRI cm/km (inches/mile) 1992	1995	Rating	Comparison to Control
		Northbound Lanes			
1	Plus Ride with Pave Bond	12 (73)	11 (70)	5	Same
2	Arm-R-Shield	7.3 (46)	11 (70)	5	Same
4	Boni Fibers	8.2 (52)	13 (84)	5	Same
5	**Class "C" with Pave Bond**	**6.3 (40)**	**10 (66)**	**5**	**Control**
6	Class "C" with Pave Bond and Lime	5.4 (34)	8.7 (55)	5	Same
10	CA(P)-1 with Lime	7.6 (48)	12 (78)	5	Same
		Southbound Lanes			
1	Plus Ride with Pave Bond	10 (64)	11 (68)	5	Same
2	Arm-R-Shield	9.8 (62)	13 (80)	5	Same
3	Fiber Pave	10 (66)	14 (86)	5	Same
7	Class "C" with Lime	9.9 (63)	13 (80)	5	Same
8	**Class "C"**	**8.8 (56)**	**13 (82)**	**5**	**Control**
9	CA(P)-1	9.0 (57)	9.6 (61)	5	Same

Rating Criteria (Based on ODOT Paving Award Criteria)

Description	Ride (Mays Inches/Mile)	Ride* {International Roughness Index (IRI) in cm/km (inches/mile)}	Rating
Smooth	0 - 74	1-17 (8 – 111)	5
Average	75 - 99	17-23 (112 - 146)	4
Slightly Rough	100 - 149	23-34 (147 – 215)	3
Rough	150 - 199	34-45 (216 – 285)	2
Very Rough	200 +	45+ (286+)	1

* The ODOT Paving Award criteria was expressed in Mays Inches/Mile. Conversion equations are used to calculate the equivalent IRI values *(Laylor and Pierce 1990)*.

2.6.1 Comments

As the ride of a pavement is often affected by its traffic loading, the northbound sections must be compared separately from the southbound sections.

All sections had smooth surfaces and similar ride values. The Plus Ride section would probably have had a "slightly worse" ride than the other sections if ODOT maintenance forces had not patched many of the severely raveled areas.

OVERALL PERFORMANCE COMPARED TO CONTROLS

The "Comparison to Control" ratings for each pavement in each category are shown in Table 3.1, and they are averaged to get the "Overall Performance Compared to Control" values in the last column of the table.

3.1 Comments

The Arm-R-Shield had the highest performance rating, as it had no fatigue cracking in either the more heavily used southbound lane nor in the more lightly used northbound lane. Also, it had no block cracking and slightly better resistance to raveling than the other sections.

The Boni Fibers, Fiber Pave, Class "C" with Pave Bond, Class "C" with Pave Bond and Lime, Class "C" with Lime, and Class "C" sections had similar performance. The Class "C" pavement, and in some cases Class "C" with Pave Bond, were the control sections.

The CA(P)-1 and CA(P)-1 with Lime sections have not performed as well as the control sections. They had low resistance to transverse, block, and fatigue cracking.

The Plus Ride with Pave Bond section has also not performed as well as the control sections. Although it had fewer transverse cracks than the other sections, it was very susceptible to raveling, block cracking, and fatigue cracking. The distress on this section would have been worse if there had not been patching by maintenance crews or if it were carrying a full traffic loading.

Table 3.1: Ten Year Performance Comparison of Asphalt Additive Sections Versus Control Sections: Lava Butte - Fremont Highway Junction Section of The Dalles-California Highway

		Load Related Distress[1,3]					Non-Load Related Distress[2,3]		
Section No.	**Section Name**	**Resistance to Rutting**	**Resistance to Fatigue Cracking**	**Ride**	**Resistance to Raveling**	**Friction**	**Resistance to Transverse Cracking**	**Resistance to Block Cracking**	**Overall Performance Compared to Control**
1	Plus Ride w/Pave Bond (Northbound Lane)	Same	Worse	Same	Worse	Same	Same	Slightly Worse	Slightly Worse
1	Plus Ride w/Pave Bond (Southbound Lane)	Same	Same	Same	Worse	Same			
2	Arm-R-Shield (Northbound Lane)	Slightly Better	Slightly Better	Same	Same	Same	Same	Much Better	Same
2	Arm-R-Shield (Southbound Lane)	Same	Much Better	Same	Same	Same			
3	Fiber Pave (Southbound Lane)	Same	Same	Same	Same	Same	Same	Much Better	Same
4	Boni Fibers (Northbound Lane)	Same	Same	Same	Same	Same	Same	Better	Same
5	Class "C" with Pave Bond (Northbound Lane)	Northbound Control	Northbound Control	NB Control	Northbound Control	Northbound Control	Same	Better	Same
6	Class "C" with Pave Bond and Lime (NB Lane)	Slightly Better	Worse	Same	Same	Same	Slightly Worse	Better	Same
7	Class "C" with Lime (Southbound Lane)	Same	Slightly Better	Same	Same	Same	Same	Same	Same
8	Class "C" (Southbound Lane)	Southbound Control	Southbound Control	SB Control	Southbound Control	Southbound Control	Control	Control	Control
9	CA(P)-1 (Southbound Lane)	Same	Slightly Worse	Same	Same	Same	Slightly Worse	Slightly Better	Same
10	CA(P)-1 with Lime (Southbound Lane)	Slightly Better	Much Worse	Same	Same	Same	Slightly Worse	Slightly Worse	Same

[1] For load related distress, all pavements in the northbound lane were compared to the Class "C" with Pave Bond section (No. 5), and all pavements in the southbound lane were compared to the Class "C" section (No. 8).

[2] For non-load related distress, all pavements were compared to the Class "C" control section.

[3] The numerical ratings of the pavements were compared using the scale shown in Table 2.1.

4.0 REFERENCES

Hicks et al, Evaluation of Asphalt Additives: Lava Butte Road - Fremont Highway Junction, Interim Report (Salem, Oregon: Oregon Department of Transportation, July 1986).

Hicks et al, "Evaluation of Asphalt Additives: Lava Butte Road - Fremont Highway Junction", in Transportation Research Record 1115 (Washington D.C.: Transportation Research Board, 1987), pp 75-88.

Bo Miller and L.G. Scholl, Evaluation of Asphalt Additives: Lava Butte to Fremont Highway Junction, Final Report (Salem, Oregon: Oregon Department of Transportation, October 1990).

Oregon Department of Transportation, Research Unit, Five Year Performance of Asphalt Additive Test Sections, Research Note 90-4 (Salem, Oregon: Oregon Department of Transportation, October 1990).

Roger E. Smith et al, Highway Distress Identification Manual, Interim Report (Urbana, Illinois: University of Illinois, March 1979).

Laylor and Geri Pierce, Procedures Manual for the Determination of International Roughness Index on HPMS Sites in Oregon: Operations and Calibration (Salem, Oregon: Oregon Department of Transportation, January 1990).

SHRP-P-338, Distress Identification Manual for the Long-Term Pavement Performance Project, (National Research Council, Washington D.C., 1993)