

# ANALYSIS OF SKID VALUES OF DIAMOND GROUND CEMENT CONCRETE PAVEMENTS WITH NO TRANSVERSE GROOVING

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The purpose of this report is to analyze skid resistance data obtained from cement concrete pavement sections that have been diamond ground but not transverse grooved to restore the transverse tining texture found on Pennsylvania's concrete pavements.

The Department is very concerned about the safety of the motoring public on Pennsylvania's roadways. Obviously, low skid resistance is a safety hazard. Therefore, the Department is committed to not only identifying and correcting areas of low skid resistance but also to not inadvertently create any new potential skid problem areas. A policy letter was issued by the Department on August 13, 1996 establishing guidelines for identifying frictional characteristics for select segments of highway, defining appropriate remedial improvements, and establishing procedures for corrective action. The letter recommended erecting a "Slippery When Wet" warning sign, until surface friction improvements could be made available, on sites which meet all of the following criteria.

- Site is on the wet pavement accident cluster list or a known skid problem exists (eight or more wet pavement accidents in 3000 feet, wet/total accident rate equals or exceeds 0.30).
- One or more high friction needs exists within the cluster area.
- Either the ribbed tire skid number is less than 35 or the smooth tire skid number is less than 20.

Sites that were diamond ground but not transverse grooved were located and tested by the Roadway Management Division. The

sites' skid resistance was tested with both a blank tire and ribbed tire using an International Cybernetics Two Wheel Test Trailer (Trailer Model 5042) in accordance with ASTM E274-90. Control sections were located on an area of the same concrete pavement that had NOT been ground. These sections were tested on the same date as the ground sections with the same equipment and according to the same parameters.

## DISCUSSION OF SKID VALUES

A summary of the skid values obtained from the testing can be viewed in the Summary Table and bar charts on the following pages. The skid values shown for each state route (SR) are the averages of the segments tested on that section of roadway. Pavement History for each section can be viewed in Appendix A and the average skid value by segment can be viewed for each SR in Appendix B.

The average smooth tire skid value for all the pavement sections tested was 40.7. The average ribbed tire skid value was 53.6. When compared to the numbers established as the cut-offs for acceptable skid resistance, 20 for smooth tire and 35 for ribbed tire, these values demonstrate very good skid resistance.

The overall average smooth tire skid value for the ground sections was actually higher than the controls'. However, the overall average ribbed tire skid value for ground sections was slightly lower than the average control sections'. This differentiation could be due to any or all of the following reasons: normal variation in testing, additional data from SR 15 for the ribbed tire value but not for the smooth tire value, or the large variation between the control and ground sections on SR 81. If the SR 81 project is eliminated, the average difference between the control and ground sections (Control - Ground) is 0.8 for the smooth tire and 4.1 for the ribbed tire.

The extremely small difference in the average skid resistance values between the ground sections and the control sections demonstrates that most of the time the skid resistance of a concrete pavement that has been diamond ground will not be significantly different than if it had not been diamond ground. An exception occurs in cases where there is an extremely low skid value prior to grinding, in which case grinding will significantly increase the skid resistance.

It is worth noting, that on the roadway that exhibited the highest control section values compared to the ground section, SR 79, the section chosen as the control was not

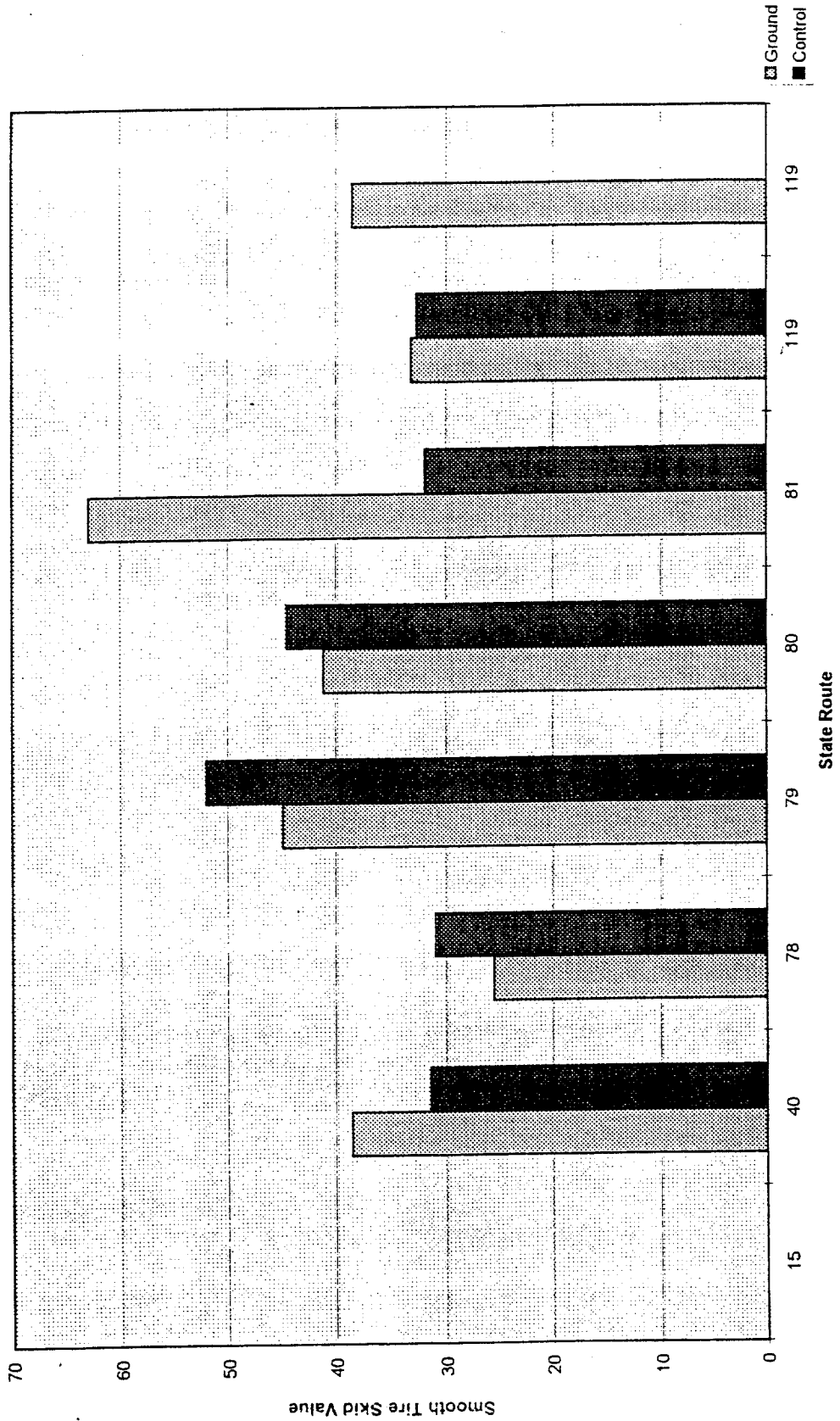
Summary Table

Smooth Tire Skid Values		Travel Lane		Passing Lane		Average Ground		Diff.	
SR	Age of Grinding	Ground	Control	Ground	Control	Ground	Control	Ground	Control
15	8	*	*	*	*	*	*	*	*
40	4	33.8	29.5	43.3	33.5	38.5	31.5	-9.8	31.5
78	8	20.0	25.0	31.0	37.0	25.5	31.0	6.0	31.0
79	4	37.7	47.0	52.0	57.0	44.8	52.0	5.0	52.0
80	6	34.5	38.0	47.7	51.0	41.1	44.5	3.3	44.5
81	3	58.0	32.0	68.0	32.0	63.0	32.0	-36.0	32.0
119	5	26.3	30.5	40.2	35.0	33.3	32.8	-5.2	32.8
119	4	33.1	*	43.9	*	38.5	*	*	*
Average	5.3	34.8	33.7	46.6	40.9	40.7	37.3	-6.1	37.3
<b>Ribbed Tire Skid Values</b>									
SR	Age of Grinding	Ground	Control	Ground	Control	Ground	Control	Ground	Control
15	8	58.0	64.0	59.2	61.0	58.0	64.0	6.0	64.0
40	4	50.6	54.5	43.0	53.0	54.9	57.8	3.9	57.8
78	8	33.0	41.0	43.0	53.0	38.0	47.0	8.0	47.0
79	4	49.9	62.0	58.9	65.5	54.4	63.8	12.1	63.8
80	6	50.0	52.0	59.4	64.0	54.7	58.0	2.0	58.0
81	3	61.0	48.0	71.0	53.0	66.0	50.5	-13.0	50.5
119	5	40.7	48.0	52.5	55.0	46.6	51.5	7.3	51.5
119	4	49.6	*	61.1	*	55.3	*	*	*
Average	5.3	49.1	52.8	57.9	58.6	53.6	55.4	3.8	55.4
								1.2	2.8

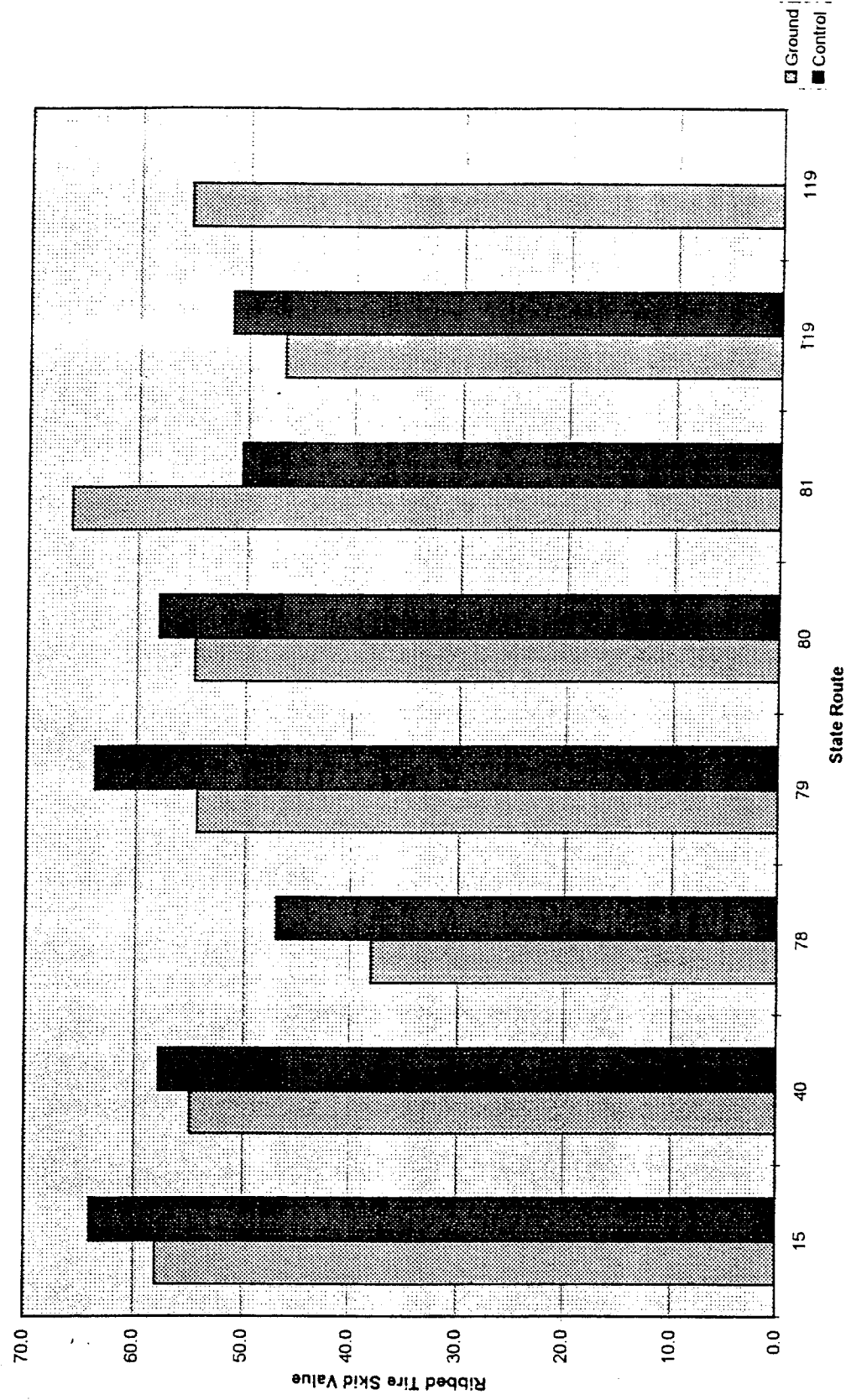
\* No Available Data

Diff. = Control - Ground; Therefore, a negative number indicates that the control section has a lower skid value than the ground section

Diamond Ground Concrete Pavement Smooth Tired Skid Values



Diamond Ground Concrete Pavement Ribbed Tire Skid Values



actually the same pavement. The ground pavement tested was a 1975 Reinforced Concrete Pavement that was diamond ground in 1993. The values obtained for the control section are from an adjacent 1996 Plain Cement Concrete Pavement.

There was only one site that had a skid number below the acceptable level, SR 78. The ribbed tire skid value for this site was 33. However, the control value for this site was only 41. That control value alone, for a 1989 concrete pavement, suggests that the project itself contains some low friction attributing factors.

Table 1 shows that the skid values obtained from the subject testing are significantly higher than the average skid value of concrete pavement surfaces in Pennsylvania that have NOT been diamond ground (based on Roadway Management System data).

**TABLE 1**  
**Ribbed Tire Skid Values**

Age Range (Years)	Average of all PA's Concrete Pavements W/O Grinding	Average of Subject Diamond Ground Sites W/O Transverse Grooving
All Ages	40.2	53.6
Less than 5	47.5	57.7
5 to 10	42.7	49.3

A further point to be considered is that none of the sites skid tested were listed on the wet pavement accident cluster list. This is to be expected since the average skid value of the sites was relatively high.

In addition to the cost saving benefits that could be realized by eliminating the requirement of transverse grooving, there are environmental benefits. An example of such a benefit is the reduction of pavement/tire interaction noise. The elimination of transverse grooving could eliminate some of the "high pitched whining" noise experienced on transverse grooved pavements. It would also eliminate the need to dispose of the concrete refuse resulting from grooving. An additional benefit of transverse grooving elimination is the possibility of reduced concrete pavement surface spalling. Transverse grooving increases the potential for surface spalling due to the exposure

of more unsupported corners.

## CONCLUSIONS

Diamond grinding does not significantly reduce the skid resistance of concrete pavements. It can be further concluded that transverse grooving is not necessary to maintain acceptable skid levels on concrete pavements that have been ground. The skid values obtained from testing the subject sites are not significantly lower than the control sections and in some cases higher. Also, the subject sites exhibited higher skid values than the average non-diamond ground pavement, as shown in Table 1.

# APPENDIX A



## Pavement History

State Route	Segments	County	Pavement Section
15	150 & 220	Adams	1989 - 10" PCCP 1989 - 8" 2A Subbase
40	282-333	Fayette	1993 - CPR (With Diamond Grinding) 1972 - 9" RCCP 1972 - 8" OGS Subbase
78	644	Northampton	1989 - 12" PCCP 1989 - 5" Lean Cement Concrete Base 1989 - 4" OGS Subbase 1989 - 4" 2A Subbase
79	40-75	Greene	1993 - CPR (With Diamond Grinding) 1975 - 10" RCCP 1975 - 12" Special Subbase
80	2624-2660	Luzerne	1991 - 13" PCCP
81	1511	Luzerne	1994 - 13" PCCP 1994 - 4" OGS Subbase 1994 - 8" 2A Subbase
119	730-781	Fayette	1992 - CPR (With Diamond Grinding) 1966 - 9" RCCP 1966 - 6" Special Subbase
119	410-487	Fayette	1993 - CPR (With Diamond Grinding) 1972 - 9" RCCP 1972 - 8" OGS Subbase

# APPENDIX B

# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR	DIAMOND GROUND		AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>								
15	150	1989					57	64
15	220	1989					59	64
<b>Project Avg.</b>							<b>58.0</b>	<b>64.0</b>
<b>Difference</b>								<b>6.0</b>

# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR	DIAMOND GROUND		AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>								
40	282	1993			36	31	51	57
40	292	1993			36	31	54	57
40	302	1993			31	31	50	57
40	312	1993			32	31	50	57
40	322	1993			33	31	51	57
40	332	1993			33	31	51	57
40	333	1993			33	28	51	52
40	323	1993			35	28	52	52
40	313	1993			33	28	49	52
40	303	1993			34	28	49	52
40	293	1993			37	28	51	52
40	283	1993			32	28	48	52
Average					33.8	29.5	50.6	54.5
Difference						-4.3		3.9
<b>Passing Lane</b>								
40	282	1993			45	32	60	59
40	292	1993			44	32	57	59
40	302	1993			39	32	58	59
40	312	1993			38	32	57	59
40	322	1993			42	32	57	59
40	332	1993			44	32	61	59
40	333	1993			46	35	59	63
40	323	1993			45	35	61	63
40	313	1993			45	35	60	63
40	303	1993			45	35	61	63
40	293	1993			44	35	60	63
40	283	1993			43	35	59	63
Average					43.3	33.5	59.2	61.0
Difference						-9.8		1.8
<b>Project Avg.</b>					<b>38.5</b>	<b>31.5</b>	<b>54.9</b>	<b>57.8</b>
Difference						-7.0		2.9

# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR DIAMOND GROUND	AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>						
78	644	1989	20	25	33	41
<b>Passing Lane</b>						
78	644	1989	31	37	43	53
<b>Project Avg.</b>			<b>25.5</b>	<b>31.0</b>	<b>38.0</b>	<b>47.0</b>
<b>Difference</b>				<b>5.5</b>		<b>9.0</b>

# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR	DIAMOND GROUND		AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>								
79	75	1993			34	47	47	63
79	71	1993			36	47	51	63
79	65	1993			41	47	52	63
79	61	1993			40	47	56	63
79	55	1993			37	47	54	63
79	51	1993			37	47	55	63
79	45	1993			40	47	53	63
79	41	1993			43	47	56	63
79	40	1993			35		47	61
79	44	1993			32		46	61
79	50	1993			35		45	61
79	54	1993			39		45	61
79	60	1993			41		47	61
79	64	1993			36		48	61
79	70	1993			40		48	61
79	74	1993			37		49	61
Average					37.7	47.0	49.9	62.0
Difference						9.3		12.1
<b>Passing Lane</b>								
79	75	1993			48	57	58	66
79	71	1993			49	57	58	66
79	65	1993			50	57	59	66
79	61	1993			51	57	62	66
79	55	1993			52	57	61	66
79	51	1993			53	57	62	66
79	45	1993			49	57	61	66
79	41	1993			50	57	60	66
79	40	1993			43	57	57	65
79	44	1993			44	57	57	65
79	50	1993			54	57	58	65
79	54	1993			51	57	57	65
79	60	1993			57	57	56	65
79	64	1993			58	57	58	65
79	70	1993			59	57	57	65
79	74	1993			64	57	62	65
Average					52.0	57.0	58.9	65.5
Difference						5.0		6.6
<b>Project Avg.</b>					<b>44.8</b>	<b>52.0</b>	<b>54.4</b>	<b>63.8</b>
<b>Difference</b>						<b>7.2</b>		<b>9.3</b>

# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR	DIAMOND GROUND		AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>								
80	2624	1991			44	38	56	52
80	2630	1991			34	38	49	52
80	2634	1991			29	38	44	52
80	2640	1991			28	38	43	52
80	2654	1991			35	38	55	52
80	2660	1991			37	38	53	52
Average					34.5	38.0	50.0	52.0
Difference						3.5		2.0
<b>Passing Lane</b>								
80	2624	1991			52	51	62	64
80	2630	1991			46	51	60	64
80	2634	1991			41	51	54	64
80	2640	1991			44	51	59	64
80	2644	1991			50	51		
80	2660	1991			53	51	62	64
Average					47.7	51.0	59.4	64.0
Difference						3.3		4.60
<b>Project Avg.</b>					<b>41.1</b>	<b>44.5</b>	<b>54.7</b>	<b>58.0</b>
<b>Difference</b>						<b>3.4</b>		<b>3.3</b>

# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR DIAMOND GROUND	AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>						
81	1511	1994	58	32	61	48
<b>Passing Lane</b>						
81	1511	1994	68	32	71	53
<b>Project Avg.</b>			<b>63.0</b>	<b>32.0</b>	<b>66.0</b>	<b>50.5</b>
<b>Difference</b>				<b>-31.0</b>		<b>-15.5</b>



# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR	DIAMOND GROUND		AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>								
119	781	1992			30	31	40	48
119	771	1992			26	31	39	48
119	761	1992			29	31	40	48
119	751	1992			26	31	41	48
119	741	1992			26	31	40	48
119	731	1992			27	31	41	48
119	730	1992			25	30	43	48
119	740	1992			23	30	41	48
119	750	1992			28	30	42	48
119	760	1992			26	30	42	48
119	770	1992			25	30	41	48
119	780	1992			25	30	38	48
Average					26.3	30.5	40.7	48.0
Difference						4.2		7.3
<b>Passing Lane</b>								
119	781	1992			41	35	52	56
119	771	1992			45	35	54	56
119	761	1992			41	35	52	56
119	751	1992			41	35	54	56
119	741	1992			41	35	54	56
119	731	1992			37	35	53	56
119	730	1992			39	35	52	54
119	740	1992			40	35	53	54
119	750	1992			39	35	53	54
119	760	1992			38	35	50	54
119	770	1992			40	35	53	54
119	780	1992			41	35	50	54
Average					40.2	35.0	52.5	55.0
Difference						-5.2		2.5
<b>Project Avg.</b>								
Average					33.3	32.8	46.6	51.5
Difference						-0.5		4.9

# Skid Values for Diamond Ground Sections W/O Transverse Grooving

SR	SEGMENT	YEAR	DIAMOND GROUND		AVG. SMOOTH SKID VALUE		AVG. RIBBED SKID VALUE	
			GROUND	CONTROL	GROUND	CONTROL	GROUND	CONTROL
<b>Travel Lane</b>								
119	487	1993			36			51
119	481	1993			36			50
119	471	1993			32			51
119	461	1993			35			52
119	451	1993			32			50
119	441	1993			34			50
119	431	1993			30			49
119	421	1993			32			47
119	411	1993			28			45
119	410	1993			38			52
119	420	1993			32			49
119	430	1993			35			49
119	440	1993			35			52
119	450	1993			35			51
119	460	1993			31			50
119	470	1993			30			48
119	480	1993			33			49
119	486	1993			32			47
Average					33.1			49.6
Difference								
<b>Passing Lane</b>								
119	487	1993			38			57
119	481	1993			42			59
119	471	1993			41			61
119	461	1993			42			64
119	451	1993			45			63
119	441	1993			46			61
119	431	1993			44			63
119	421	1993			41			63
119	411	1993			42			68
119	410	1993			40			57
119	420	1993			41			59
119	430	1993			43			60
119	440	1993			47			61
119	450	1993			52			61
119	460	1993			47			62
119	470	1993			46			61
119	480	1993			45			61
119	486	1993			48			58
Average					43.9			61.1
Difference								
<b>Project Avg.</b>					<b>38.5</b>			<b>55.3</b>
<b>Difference</b>								