Fly Ash as Mineral Filler in Traffic Marking Paint: A Feasibility Study

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A feasibility study was a cooperative effort between the Nebraska Department of Roads (NDOR), American Electric Power Company, and FHWA. The goal of the study was to give the highway community an indication of the feasibility of using fly ash in traffic marking paint. The study was an initial field test to verify the possibilities of using fly ash as an abrasion-resistant mineral filler pigment in traffic paint to improve the paint's durability and performance. Five types of paint were compared in the study: the standard NDOR yellow traffic paint and four other oil-alkyd yellow traffic paints specially formulated for the test by two different companies. Two of the paints contained fly ash. All of the paints performed satisfactorily in the laboratory tests in comparison with NDOR standard traffic paint specifications. The five traffic paints were applied with glass beads to Portland Cement Concrete pavement with a hand-pushed mechanical paint sprayer on October 6, 1992. The reflectivity readings of the paint stripes were taken and the paints were visually monitored for film failure for 1 year. In most cases the paint containing fly ash performed better than the other paints. The study was a small feasibility study to evaluate fly ash as a mineral filler pigment in traffic marking paint. The satisfactory performance of the paint containing fly ash indicates that fly ash could be used in traffic paint to improve its durability and performance. Further field testing of traffic marking paint containing fly ash is justified.

The feasibility study described here was a cooperative effort between the Nebraska Department of Roads (NDOR), the American Electric Power Company (AEP), and FHWA. The goal of the test program was to give the highway community an indication of the feasibility of using fly ash in traffic marking paint. It was believed that paint traffic formulated with fly ash as a mineral filler pigment would be more wear resistant and would therefore last longer on pavements than the typical sprayed-applied paints currently being used. A more durable traffic paint will allow motorists to see the stripes longer and will require less repainting, hence less risk for highway maintenance workers. This will increase the safety on the nation's highways and streets and decrease costs.

Fly ash's ceramic composition of silica, alumina, and other metal oxides makes it one of the hardest and most abrasionresistant mineral fillers available. In mineralogy the hardness of a mineral is generally defined as its resistance to scratching. The Mohs Hardness Scale categorizes materials from 1 to 10, rating talc, a soft mineral, as 1 and diamond as 10. Fly ash particles are judged to have ratings of between 7 and 8. Fly ash is an excellent paint extender (filler) material that helps to provide body, mechanical strength, and abrasion resistance, and it assists with opacity. Fly ash also fits other filler pigment requirements. It exhibits low resin and oil absorption properties (which permits high levels of loading without inordinate thickening), has a fine particle size, provides insolubility, is easy to disperse, and is chemically inert.

Calcium carbonate $(CaCO_3)$ is one of the most widely used mineral filler pigments in traffic marking paints. Calcium carbonate is a soft, chalklike material, and fly ash is a much harder material. In theory by replacing part of the calcium carbonate with fly ash in traffic paint the paint would be more durable.

Fly ash originates from the residual inorganic matter contained in coal. Coal is burned in steam generators (boilers). Fly ash-laden flue gas is a by-product of coal combustion. As flue gas cools and flows through the steam generator, ash forms into spherical ceramic particles in the range of 1 to 20 μ m. The particles are collected in electrostatic precipitators.

The use of Class F fly ash as an abrasion-resistant filler in a variety of protective coatings, including alkyds, acrylics, epoxies, asphalts, vinyls, and polyurethane vehicle systems, has been extensively evaluated by AEP. Ash-filled paint is currently the standard paint used on AEP's transmission towers, railcars, barges, structural steel, tanks, piping, equipment, and architectural structures. AEP also uses fly ash in traffic marking paints on the roads and parking lots at their facilities. Preliminary indications led AEP to believe that it is more durable than the traffic paint that they previously used. The feasibility study described here was the first time that field testing and comparative evaluations of traffic paint containing fly ash were initiated.

One of the shortcomings of fly ash is that it is not white in color. Its color can vary greatly, typically from light to dark grey (depending on the carbon content of the fly ash) or brown. This limits its use in paint when the final color is important, especially if the desired color is a light shade. There are also two types of fly ash, Class C and Class F. The two types have different properties, and each type can vary from source to source. The formulation of paint containing fly ash needs to take into account the type being used, Class C or Class F, and which power plant the fly ash comes from.

There have been many discussions in the past concerning hazardous waste and fly ash and whether it was appropriate to put fly ash in paints. A recent Final Regulatory Determination published in the *Federal Register* (1, p. 42466) stated:

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Environmental Protection Agency (EPA) has concluded that regulation under Subtitle C of the Resource Conservation and Recovery Act (RCRA) is inappropriate for the four large-volume fossil-fuel combustion waste streams—fly ash, bottom ash, boiler slag, and flue gas emission control waste—because of the limited risks posed by them and the existence of generally adequate State and Federal regulatory programs. The EPA also believes that the potential for damage

from these wastes is most often determined by site- or region-specific factors and that the current State approach to regulation is thus appropriate. Therefore, the EPA will continue to exempt these wastes from regulation as hazardous wastes under RCRA Subtitle C.

This determination became effective September 2, 1993. EPA does not consider fly ash to be a hazardous waste, and the authors believe there is very low risk of damage to the environment by putting fly ash in traffic marking paint.

With the national consciousness focused on recycling and utilization of domestic resources, the utilization of fly ash, an abundant U.S. mineral resource, appears to be warranted. Most other mineral fillers in paints (i.e., talc, calcium carbonate, silica, feldspar, and clay) are mined, crushed, and further processed before they can be used. Many of them are also imported. Approximately 506 million L (50 million gal) of paint is used each year to mark roads, highways, streets, and parking lots in the United States. Since traffic marking paints typically contain mineral filler at levels of 0.6 to 0.7 kg/L (5 to 6 lb/gal), fly ash-based traffic paint may pave the way to an environmentally favorable use of this abundant domestic mineral resource.

DISCUSSION OF RESULTS

Five types of paint were compared in the study: the standard NDOR yellow traffic paint and four other oil and alkyd yellow traffic paints specially formulated for the test by two different companies (referred to here as P-S and Y-M). The paint companies each formulated two identical paints that met the NDOR traffic paint specifications, except that one paint had Class F fly ash replacing a percentage of the calcium carbonate as a mineral filler pigment and one did not. The five paints were designated as follows: NDOR standard, P-S with fly ash, P-S without fly ash, Y-M with fly ash, and Y-M without fly ash. The chemical and physical properties of the fly ash used are given in Table 1. The NDOR traffic paint and the Y-M paints contained a lead pigment, chrome yellow. The P-S paints were made with an organic pigment, arylide yellow. The pigment compositions of the paints are presented in Tables 2 through 6. Pigment percentages of total weight for Tables 2 through 6 are 59.6, 55.37, 55.68, 65.03, and

 TABLE 1
 Chemical and Physical Properties of Fly

 Ash

Chemical	% of Total Weight
Silicon Dioxide (SiO ₂)	59.6
Aluminum Oxide (Al ₂ O ₃)	29.9
Iron Oxide (Fe ₂ O ₃)	4.2
Titanium Dioxide (TiO ₂)	1.6
Calcium Oxide (CaO)	0.8
Magnesium Oxide (MgO)	6.9
Sodium Oxide (NaO ₂)	0.3
Potassium Oxide (K ₂ O)	2.4
Sulphur Trioxide (SO ₁)	0.2
Phosphorus Pentoxide (P ₂ O ₅)	0.1
Other	0.6
Total (rounded)	100 %

 $\mathbf{pH}=6.1$

Specific Gravity = 2.17 % Retained on #325 Sieve = 16.13%

TABLE 2 Pigment Composition of NDOR Standard

Pigment	Percent of pigment by weight
Medium Chrome Yellow	8.7
Titanium Dioxide	2.7
Yellow Iron Oxide	0.4
Magnesium Silicate	13.4
Aluminum Silicate	26.8
Calcium Carbonate	46.9
Anti Settling Agent	. 1.1

TABLE 3 Pigment Composition of P-S with Fly Ash

Pigment	Percent of pigment by weight
Calcium Carbonate	71.18
Treated Fly Ash	10.95
Arylide Yellow Pigment	9.39
Titanium Dioxide	5.99
HDPE	2.04
Thixotrope	0.45

TABLE 4 Pigment Composition of P-S without Fly Ash

Pigment	Percent of pigment by weight
Calcium Carbonate	82.12
Arylide Yellow Pigment Titanium Dioxide	9.39 5.99
HDPE	2.05
Thixotrope	0.45

TABLE 5 Pigment Composition of Y-M with Fly Ash

Pigment	Percent of pigment by weight
Calcium Carbonate	72.98
Chrome Yellow Medium	12.28
Titanium Dioxide	3.04
Fly ash - yellow	11.70

TABLE 6 Pigment Composition of Y-M without Fly Ash

Pigment	Percent of pigment by weight
Calcium Carbonate	84.68
Chrome Yellow Medium	12.28
Titanium Dioxide	3.04

65.03 percent, respectively. The percentage of fly ash placed in the two special paints was determined by using the maximum amount possible while still maintaining the desired yellow color for traffic marking paint.

Traffic paint containing fly ash is a relatively new concept and is still in the test and evaluation stages. The two paint companies that formulated the special test paints made small prototype quantities and supplied the paint for the test at no charge. These companies typically do not make traffic paint, so the cost for them to make the test paint (although not specifically calculated) was relatively expensive. They purchased small quantities of ingredients used in traffic paints that they do not normally use in the paints that they manufacture. To reduce the particle size the fly ash had to be processed in a steel ball mill. Calcium carbonate is also ground before it is sold as a mineral filler. After the grinding process the fly ash was introduced into the manufacturing process for the paint in the same manner as calcium carbonate. It is believed that if manufactured on a larger scale by a traffic marking paint manufacturer, the cost of traffic paint containing fly ash would be comparable to the cost of commercially available traffic paint. It could perhaps be even less costly in areas where fly ash is given away by power plants. The average cost of NDOR traffic paint is \$0.87/L (\$3.30/gal) of paint.

The four special paints were tested at the NDOR laboratory for mixing characteristics, color, finish, consistency, flexibility, bleeding, water resistance, settling properties, dry hiding power, paint composition, pigment composition, X-ray diffractogram of pigment, infrared spectrum of vehicle, nonvolatile content, and luminous reflectance. All of the paints performed satisfactorily in comparison with NDOR standard traffic paint specifications. The laboratory test results of the four special paints are listed in Tables 7 through 10.

The five traffic paints with glass beads were applied to Portland Cement Concrete pavement with a hand-pushed mechanical paint sprayer on October 6, 1992. The bead application rate was 0.72 kg/L (6 lb/gal) of paint. The pavement was dry and the air temperature was 21°C (70°F). Four 10-cm (4-in.)-wide stripes of each paint were applied perpendicularly to the centerline of the road for evaluation. The road is near the NDOR headquarters, which allowed for easy observation of the test paint, and has an average daily traffic of 500 vehicles. Each stripe was 3.35 m (11 ft) in length and extended from the pavement edge to the centerline of the road.

No modifications to the mechanical paint sprayer were required for the application of the two paints containing fly ash. The two paints performed normally during the application process; neither showed signs of clogging or settling in the sprayer or running after application on the road. These two paints also did not require special cleanup procedures.

In the initial observations the four specially formulated paints did not meet the NDOR drying time (no pickup) requirements of

	Actual	Nebraska 1991
······································	Results	Requirements
Appearance and Mixing Characteristics	satisfactory	Well Ground and Readily Mixed
Color	_satisfactory	No. 33538 or Federal 595.a
Finish Drying Time, 25°C [*] (ASTM D711), minutes:	_satisfactory	Flat or Eggshel
No Pickup	24	15 Max.
Thoroughly Dry & Free From Tackiness.	30	
Consistency, 25°C *, 1/2" Krebs Unit	86	70 to 80
Flexibility, 25°C *, 1/2" Mandrel	<u>satisfactory</u>	
Bleeding (Bituminous Surface)	no bleeding	
Water Resistance	9	
Settling Properties, 2 weeks, (ASTM D 1390)		6 Min.
Dry Hiding Power	complete hiding	Complete Hiding
Paint Composition:		
Pigment, percent by weight	53.10	55 Min.
Vehicle, percent by weight	46.90	45 Max.
Weight, kg/L **, 25°C	1.39	1.40 Min.
Coarse Particles, Lumps, & Skins (Retained		
No. 325 sieve), percent by weight	0.10	1 Max.
Pigment Composition, percent by weight:		
Chrome Yellow (PbCrO ₄)		5 to 25
Titanium Dioxide (TiO ₂)		5 Max.
Calcium Carbonate (CaCO ₃)		10 to 65
Siliceous Inerts (by difference)		10 to 85
X-Ray Diffractogram of Pigment	satisfactory	Satisfactory
Infrared Spectrum of Vehicle	satisfactory	Satisfactory
Non-Volatile, percent by weight of paint.	70.5	73 Min.
Luminous Reflectance	49.2	48 to 52

TABLE 7 P-S with Fly Ash Paint, Laboratory Test Results

* 25°C = 77°F

** 1 kg/L = 0.119 1b/gal

	Actual	Nebraska 1991
	Results	Requirements
Appearance and Mixing Characteristics	satisfactory	Well Ground and Readily Mixed
Color	satisfactory	No. 33538 or Federal 595.a
Finish	satisfactory	Flat or Eggshell
Drying Time, 25°C *(ASTM D711), minutes:	0.2	15 M.
No Pickup Thoroughly Dry & Free From Tackiness.	23	15 Max.
Consistency, 25°C [*] , 1/2" Krebs Unit	87	 70 to 80
Flexibility, 25°C [*] , 1/2" Mandrel	satisfactory	70 10 80
Bleeding (Bituminous Surface)	no bleeding	
Water Resistance	9	
Settling Properties, 2 weeks, (ASTM D 1390)	8	6 Min.
Dry Hiding Power	complete hiding	Complete Hiding
Paint Composition:		·····
Pigment, percent by weight	54.0	55 Min.
Vehicle, percent by weight	46.0	45 Max.
Weight, kg/L **, 25°C	1.39	1.40 Min.
Coarse Particles, Lumps, & Skins (Retained		
No. 325 sieve), percent by weight	0.10	1 Max.
Pigment Composition, percent by weight:		
Chrome Yellow (PbCrO ₄)		5 to 25
Titanium Dioxide (TiO ₂)		5 Max.
Calcium Carbonate (CaCO ₃)		10 to 65
Siliceous Inerts (by difference)	<u> </u>	10 to 85
X-Ray Diffractogram of Pigment	<u>satisfactory</u>	Satisfactory
Infrared Spectrum of Vehicle	<u>satisfactory</u>	Satisfactory
Non-Volatile, percent by weight of paint.	70.9	73 Min.
Luminous Reflectance	55.0	48 to 52

TABLE 8 P-S without Fly Ash Paint, Laboratory Test Results

* 25°C = 77°F ** 1 kg/L = 0.119 1b/gal

 TABLE 9
 Y-M with Fly Ash Paint, Laboratory Test Results

	Actual	Nebraska 1991
	Results	Requirements
Appearance and Mixing Characteristics	satisfactory	Well Ground and Readily Mixed
Color	satisfactory	No. 33538 or Federal 595.a
Finish	satisfactory	Federal 595.a Flat or Eggshell
Drying Time, 25°C * (ASTM D711), minutes:	<u>Successfactory</u>	FIAC OF EXESHELT
No Pickup	27	15 Max.
Thoroughly Dry & Free From Tackiness.	32	
Consistency, 25°C * 1/2" Krebs Unit	77	70 to 80
Flexibility, 25°C * 1/2" Mandrel	satisfactory	
Bleeding (Bituminous Surface)	no bleeding	
Water Resistance	7-8	
Settling Properties, 2 weeks, (ASTM D 1390)	8	6 Min.
Dry Hiding Power	complete hiding	Complete Hiding
Paint Composition:		
Pigment, percent by weight	65.3	55 Min.
Vehicle, percent by weight	34.7	45 Max.
Weight, kg/L **, 25°C	1.56	1.40 Min.
Coarse Particles, Lumps, & Skins (Retained		
No. 325 sieve), percent by weight	0.5	1 Max.
Pigment Composition, percent by weight:		
Chrome Yellow (PbCr0 ₄)		5 to 25
Titanium Dioxide (TiO ₂)		5 Max.
Calcium Carbonate (CaCO ₃)		10 to 65
Siliceous Inerts (by difference)		10 to 85
X-Ray Diffractogram of Pigment	satisfactory	Satisfactory
Infrared Spectrum of Vehicle	satisfactory	Satisfactory
Non-Volatile, percent by weight of paint.	77.0	73 Min.
Luminous Reflectance	50.0	48 to 52
		-

* 25°C = 77°F ** 1 kg/L = 0.119 1b/gal

	Actual Results	Nebraska 1991 Requirements
	<u>Results</u>	Requirements
Appearance and Mixing Characteristics		Well Ground and
Color		Readily Mixed No. 33538 or Federal 595.a
Finish Drying Time, 25°C * (ASTM D711), minutes:	satisfactory	Flat or Eggshell
No Pickup Thoroughly Dry & Free From Tackiness.	<u> 18 </u>	15 Max.
Consistency, 25°C [*] , 1/2" Krebs Unit Flexibility, 25°C [*] , 1/2" Mandrel	80 satisfactory	70 to 80
Bleeding (Bituminous Surface)	no bleeding 9	
Settling Properties, 2 weeks, (ASTM D 1390) Dry Hiding Power	7 complete hiding	6 Min. Complete Hiding
Paint Composition: Pigment, percent by weight	60.1	55 Min.
Vehicle, percent by weight Weight, kg/L **, 25°	<u>39.9</u> 1.49	45 Max. 1.40 Min.
Coarse Particles, Lumps, & Skins (Retained No. 325 sieve), percent by weight		1 Max.
Pigment Composition, percent by weight: Chrome Yellow (PbCrO ₄)		5 to 25
Titanium Dioxide (TiO_2) Calcium Carbonate $(CaCO_3)$		5 Max. 10 to 65
Siliceous Inerts (by difference) X-Ray Diffractogram of Pigment	satisfactory	10 to 85 Satisfactory
Infrared Spectrum of Vehicle Non-Volatile, percent by weight of paint.	satisfactory 76.0	Satisfactory 73 Min.
Luminous Reflectance	54.5	48 to 52

TABLE 10 Y-M without Fly Ash Paint, Laboratory Test Results

* 25°C = 77°F 1 kg/L = 0.119 lb/gal

15 min maximum. Their drying times ranged from 18 to 27 min. The P-S with fly ash paint's drying time was 1 min longer than that of the P-S without fly ash paint. The fly ash did not significantly affect the drying time of the P-S paints. The Y-M with fly ash paint's drying time was 9 min longer than that of the Y-M without fly ash paint. In the case of the Y-M paints fly ash did significantly affect the drying times of the paints. It is unclear at this time why the fly ash affected the drying time in one manufacturer's paint and not the other manufacturer's paint. The paint manufacturers believe that the drying time for all four paints could be reduced to below the NDOR requirement of 15 min with minor paint formulation adjustments.

The paints went through a typical Nebraska winter. The average temperature and precipitation for the months of October 1992 to February 1993 are given in Table 11. The paints were visually monitored for film failure for 1 year. Film failure is a visual determination of the percentage of paint in each stripe that is no longer adhered to the road. This is an indication of the paint's durability. Film failure of 0 percent means that no paint has worn off the pavement. Film failure of 100 percent means that all of the paint has worn off the pavement. The actual film failure readings for all four stripes of each type of paint and the averages are given in Table 12. The average film failure values for each type of paint are graphically compared in Figure 1. After 1 year the

TABLE 11 Average Monthly Temperatures and Precipitation

	Temperature		Precipitat	ion
Month	<u>°F</u>	<u>°C</u>	Inches	Millimeter
Oct 1992	53.7	12.1	1.70	42.5
Nov 1992	33.9	1.1	1.44	36.0
Dec 1992	26.4	-3.1	0.87	21.8
Jan 1993	17.3	-8.3	1.34	33.5
Feb 1993	20.7	-6.3	0.67	16.8

Y-M with fly ash paint, at an average of 40 percent film failure, performed better than the Y-M without fly ash paint, at 50 percent. However, the P-S with fly ash, at an average of 39 percent film failure, performed worse than the P-S without fly ash, at 31 percent. All of the special paints performed better than the NDOR standard paint, which had an average of 78 percent film failure 1 year after application.

The reflectivity readings of the paints were taken monthly for a period of 1 year with a retroreflectometer (Mirolux 12) in the inside wheeltrack, the middle, and the outside wheeltrack of the stripes. Reflectivity is an indication of the paint's bead retention capability. The higher the reading the better the reflectivity. This

10/21/93

30

28

48

48

38.5

30

38

28

28

75

75

80

80

50

50

30

30

50

50

50

50

50.0

40.0

77.5

31.0

TABLE 12 Actual and Average Film Failure Readings of Test Paints FILM FAILURE: APPROX. 11 FEET STRIPE LENGTH THEREFORE 1 FOOT = 9% FILM FAILURE (VISUALLY DETERMINED) 10/7/92 11/6/92 12/6/92 1/10/93 3/6/93 10/20/92 4/6/93 7/6/93 8/11/93 PRUETT SCHAFFER WITH FLYASH NORTH B1 2 2 ٥ 4 6 20 22 25 25 82 0 2 2 4 6 15 17 20 20 SOUTH 81 0 2 2 3 5 15 22 40 45 **B**2 0 2 2 з 5 15 22 40 40 0.0 2.0 AVG 2.0 3.5 5.5 16.3 20.8 31.3 32.5 PRUETT SCHAFFER WITHOUT FLYASH NORTH C1 0 з з 4 6 20 22 25 25 C2 0 3 3 4 6 20 25 22 25 SOUTH C1 0 2 2 з 5 12 16 20 20 C2 0 2 2 з 5 12 16 20 20 AVG 0.0 2.5 2.5 3.5 5.5 16.0 19.0 22.5 22.5 NDOR STANDARD PAINT FROM CENTERLINE INDUSTRIES NORTH D1 0 5 10 45 50 60 65 0 D2 1 з 6 45 50 60 65 1 SOUTH D١ 0 1 2 7 50 55 70 75 0 D2 2 8 50 55 70 75 AVG 0.0 1.0 1.0 3.0 7.8 47.5 52.5 65.0 70.0 YENKIN MAJESTIC WITH FLYASH NORTH E1 0 2 2 з 30 35 45 6 40 E2 0 2 2 з 6 25 40 30 40

2

з

5

5

5

5

5.0

2.8

shows how well the paint stripes can be seen at night by a driver with the vehicle's headlights shining on the stripe. The luminous reflectance unit of measure for reflectivity is millicandelas per square meter. The actual reflectivity readings for all four stripes of each type of paint and the averages are listed in Table 13. The average test reflectivity readings for the inside wheeltrack, the

SOUTH

NORTH

SOUTH

E1

E2

F1

F2

F1

F2

AVG

AVG

YENKIN MAJESTIC WITHOUT FLYASH

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0.0

0.0

1

2

1.8

2

2

2

2

2.0

1

2

1.8

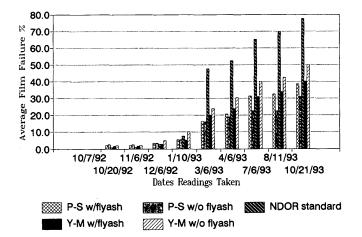
2

2

2

2

2.0





middle, and the outside wheeltrack of each type of paint are compared in Figures 2 through 4, respectively.

15

15

40

32

25

25

30.5

23.8

22

22

31.0

45

45

35

35

40.0

25

25

45

45

40

40

42.5

33.8

12

12

19.8

30

25

20

20

23.8

4

5

5.3

10

10

10

10

10.0

At the end of 1 year the following is a comparison of average reflectivity readings for the P-S paints. In the inside wheeltrack, P-S with fly ash (average reflectivity = 50.5) performed better than P-S without fly ash (average reflectivity = 46.3); in the middle of the stripe, P-S with fly ash (average reflectivity = 86.5) performed better than P-S without fly ash (average reflectivity = 77.5); in the outside wheeltrack, P-S with fly ash's average reflectivity at 43.8 was less than P-S without fly ash's average reflectivity at 58.8.

For the Y-M paints, in the inside wheeltrack, Y-M with fly ash (average reflectivity = 55.8) performed better than the Y-M without fly ash (average reflectivity = 24.3); in the middle of the stripe, Y-M with fly ash (average reflectivity = 112.0) performed better than the Y-M without fly ash (average reflectivity = 69.5); in the outside wheel track, Y-M with fly ash (average reflectivity = 61.5) also performed better than Y-M without fly ash (average reflectivity = 24.8).

For the NDOR standard paint, in the inside wheeltrack, all special paints except the Y-M without fly ash performed better than the NDOR standard; in the middle of the stripe, only YM with fly ash performed better than the NDOR standard; in the outside wheeltrack, all of the other paints performed better than the NDOR standard.

Summarizing the reflectivity readings of the four special test paints, in five of six cases the special paints containing fly ash had higher 1-year average reflectivity readings than the special

EFLECT		10/6/92	1/6/92 1				4/6/93	7/6/93	8/11/93	10/21/93
RUETT	SCHAFFER P	AINT WITH FL	YASH	-						
ISIDE V S N	VHEELTRK B1	259	163	139	70	60	81	68	61	45
211	B2	239	169	138	73	71	102	102	80	71
ss	B1	298	185	145	86	66	66	64	57	38
	B2	279	160	136	80	62	72	50	53	48
	AVG	269.0	169.3	139.5	77.3	64.8	80.3	71.0	62.8	50.5
IDDLE										
SN	B1	232	193	167	101	89	129	124	90	106
	B2	238	180	117	101	101	140	129	105	103
SS	B1	294	197	175	102	98	125	81	99	62
	B2	278	214	120	102	85	102	88	83	75
UTOID		260.5	196.0	144.8	101.5	93.3	124.0	105.5	94.3	86.5
SN	E WHEELTRK B1	276	174	117	72	56	79	53	72	40
5 11	B2	252	148	145	70	73	94	75	90	58
ss	B2 B1	270	148	146	70	63	84	77	77	33
33	B2	226	130	158	74	65	110	57	63	44
	AVG	256.0	150.0	141.5	71.8	64.3	91.8	65.5	75.5	43.8
							01.0			
RUETT	SCHAFFER P	AINT WITHOU	JT FLYASH							
SIDE V	VHEELTRK									
SN	C1	183	122	131	70	81	102	83	62	4
	C2	219	180	138	80	76	74	67	59	4
SS	C1	230	203	152	76	63	63	56	61	4:
	C2	245	172	170	83	74	75	75	75	4
	AVG	219.3	169.3	147.8	77.3	73.5	78.5	70.3	64.3	46.
IDDLE	-									
SN	C1	204	140	95	98	94	109	114	77	8
	C2	216	175	130	108	102	126	96	80	6
SS	C1	200	214	180	114	106	137	101	108	7
	C2	225	219	178	97	96	147	143	111	8
	AVG	211.3	187.0	145.8	104.3	99.5	129.8	113.5	94.0	77.
	E WHEELTRK									_
SN	C1	184	126	144	77	79	104	73	76	64
	C2	221	120	147	86	76	95	64	67	59
~ ~								.		-
SS	C1	210	151	131	64	67	79	81	66	
		210 275 222.5	151 121 129.5	131 176 149.5	72 74.8	70 73.0	111 97.3	81 65 70.8	66 69 69.5	4
EBRAS	C1 C2 AVG	210 275 222.5	151 121 129.5	131 176 149.5	72 74.8	70 73.0	111 97.3	65	69	4
	C1 C2 AVG SKA DEPARTM WHEELTRK D1	210 275 222.5 IENT OF ROA 142	151 121 129.5 IDS STAND 90	131 176 149.5 ARD PAINT 102	72 74.8 BY CENTE 66	70 73.0 RLINE INDI 75	111 97.3 JSTRIES 52	65	69	49 58.1
IEBRAS NSIDE V IE N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2	210 275 222.5 IENT OF ROA 142 195	151 121 129,5 NDS STAND 90 140	131 176 <u>149.5</u> ARD PAINT 102 152	72 74.8 BY CENTE 66 79	70 73.0 RLINE INDI 75 68	111 97.3 JSTRIES 52 70	65 70.8 42 50	69 <u>69.5</u> 47 44	44 58.1 2 3
IEBRAS NSIDE N IE N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1	210 275 222.5 IENT OF ROA 142	151 121 129,5 IDS STAND 90 140 184	131 176 149.5 ARD PAINT 102 152 159	72 74.8 BY CENTE 66 79 85	70 73.0 RLINE INDI 75 68 64	111 97.3 JSTRIES 52 70 64	65 70.8 42	69 <u>69.5</u> 47	4(58.1 2 3 3 3
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 D1 D2	210 275 222.5 NENT OF ROA 142 195 262 316	151 121 129.5 IDS STAND 90 140 184 209	131 176 149.5 ARD PAINT 102 152 159 156	72 74.8 BY CENTE 66 79 85 99	70 73.0 RLINE INDI 75 68	111 97.3 JSTRIES 52 70	65 70.8 42 50	69 <u>69.5</u> 47 44	4(58.1 2 3 3 3
NSIDE N NE N NE S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG	210 275 222.5 IENT OF ROA 142 195 262	151 121 129,5 IDS STAND 90 140 184	131 176 149.5 ARD PAINT 102 152 159	72 74.8 BY CENTE 66 79 85	70 73.0 RLINE INDI 75 68 64	111 97.3 JSTRIES 52 70 64	65 70.8 42 50 48	69 69.5 47 44 56	44 58.1 2 3 3 2
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8	151 121 129.5 DS STAND 90 140 184 209 155.8	131 176 149.5 ARD PAINT 102 152 159 156 142.3	72 74.8 BY CENTE 66 79 85 99 82.3	70 73.0 RLINE INDI 75 68 64 51 64.5	111 97.3 JSTRIES 52 70 64 46 58.0	65 70.8 42 50 48 38 44.5	69 69.5 47 44 56 49 49.0	44 58.1 2 3 3 2 29.
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1	210 275 222.5 DENT OF ROA 142 195 262 316 228.8 123	151 129,5 DS STAND 90 140 184 209 155.8 86	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97	72 74.8 BY CENTE 66 79 85 99 82.3 88	70 73.0 RLINE INDI 75 68 64 51 64.5 80	111 97.3 JSTRIES 52 70 64 48 58.0 85	65 70.8 42 50 48 38 44.5 63	69 69.5 47 44 56 49 49.0 71	44 58.1 2 3 3 2 29. 4
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196	151 121 129.5 NDS STAND 90 140 184 209 155.8 86 163	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127	72 74.8 BY CENTE 66 79 85 99 82.3 88 109	70 73.0 RLINE INDI 75 68 64 51 64.5 51 64.5 80 115	111 97.3 JSTRIES 52 70 64 46 58.0 85 151	65 70.8 42 50 48 38 44.5 63 111	69 69.5 47 44 56 49 49.0 71 118	44 58. 2 3 3 2 29. 4 11
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 D1 D2 D1 D2 D1	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268	151 121 128.5 JDS STAND 90 140 184 209 155.8 86 163 222	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160	65 70.8 42 50 48 38 44.5 63 111 145	69 69.5 47 44 56 49 49.0 71 118 128	44 58. 2 3 3 2 29. 29. 4 11 9
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 D1 D2 D1 D2 D1 D2 D1 D2 D1 D2 D1 D2 D1 D2 D1 D2 D1 D2	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 353	151 121 129,5 UDS STAND 90 140 184 209 155.8 86 163 222 273	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113 126	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162	65 70.8 42 50 48 38 44.5 63 111 145 132	69 69.5 47 44 56 49 49.0 71 118 128 126	44 58. 2 3 3 2 29. 29. 4 11 9 10
EBRAS	C1 C2 AVG SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 D1 D2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268	151 121 128.5 DS STAND 90 140 184 209 155.8 86 163 222	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160	65 70.8 42 50 48 38 44.5 63 111 145	69 69.5 47 44 56 49 49.0 71 118 128	44 58. 2 3 3 2 29. 29. 4 11 9 10
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 D1 D2 AVG E WHEELTRK	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113 126 108.5	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8	4 58. 2 3 3 2 29. 29. 4 11 9 100 90.
EBRAS	C1 C2 AVG SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59	131 176 149.5 ARD PAINT 102 152 156 142.3 97 127 179 199 150.5 70	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113 126 108.5 57	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45	4 58. 2 3 3 2 29. 29. 4 11 9 10 90. 2
EBRAS	C1 C2 AVG C2 SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 D1 D2 D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK D1 D2 D2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 196 268 353 235.0 103 220	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59	69 69.5 47 44 56 49 49.0 71 118 128 128 126 110.8 55	44 58. 2 3 3 2 29. 29. 4 11 9 10 90. 22. 4
EBRAS	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK D1 D2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73	70 73.0 RLINE INDI 75 68 64 51 64 5 51 68 0 115 113 126 108.5 57 70 62	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 55 56	44 58.0 2 3 3 2 29 4 11 9 10 90. 2 2 3 3 3 3 2 2 9 10 3 10 3 3 3 3 2 2 9 10 10 10 10 10 10 10 10 10 10 10 10 10
EBRAS	C1 C2 AVG C2 SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 D1 D2 D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK D1 D2 D2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 196 268 353 235.0 103 220	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59	69 69.5 47 44 56 49 49.0 71 118 128 128 126 110.8 55	4 58. 2 3 3 3 2 29. 4 11 11 9 0. 90. 2 4 4 3 2 2 2 2 9. 2 9. 2 9. 2 9. 2 9. 2 9. 2
EBRAS ISIDE N E S IDDLE E N E S UTSIDD E N E S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 D1 D2 AVG E WHEELTRK D1 D2 D2 D1 D2 D2 D1 D2 D2 D1 D2 D2 D1 D2 D2 D1 D2 D2 D1 D2 D2 D1 D2 D2 D1 D2 D2 D2 D1 D2 D2 D2 D1 D2 D2 D2 D2 D2 D1 D2 D2 D2 D2 D2 D2 D2 D2 D2 D2 D2 D2 D2	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 235.0 103 220 283 339 236.3	151 129,5 IDS STAND 90 140 184 209 155,8 86 163 222 273 186.0 59 131 156 193 134,8	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 70 130 150 150 130 191	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76	70 73.0 RLINE INDI 75 68 64 51 51 68 64 51 51 108 5 7 70 62 56	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 947 40	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 55 65 55 64 7	4 58. 2 3 3 3 2 29. 29. 4 11 19 100 900. 2 4 4 3 2 2 2 2 2 2 2 2 9 2 9 2 9 2 9 2 9 2 9
EBRAS NSIDE N E N E S NIDDLE E N E S UTSIDI E N E S	C1 C2 AVG SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1 D2 E WHEELTRK D1 D2 AVG I D2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 235.0 103 220 283 339 236.3	151 129,5 IDS STAND 90 140 184 209 155,8 86 163 222 273 186.0 59 131 156 193 134,8	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 70 130 150 150 130 191	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76	70 73.0 RLINE INDI 75 68 64 51 51 68 64 51 51 108 5 7 70 62 56	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 947 40	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 55 65 55 64 7	4 58. 2 3 3 3 2 29. 29. 4 11 19 100 900. 2 4 4 3 2 2 2 2 2 2 2 2 9 2 9 2 9 2 9 2 9 2 9
EBRAS ISIDE V E N E S IDDLE E N E S UTSIDI E N E S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG AVG D1 D2 AVG D1 D2 AVG AVG AVG AVG AVG AVG AVG AVG AVG AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70 62 56 61.3	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 56 56 47 53.3	4 58. 2 3 3 2 29 29 4 11 90 90 2 4 3 30
EBRAS ISIDE V E N E S IDDLE E N E S UTSIDD E N E S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1 D2 AVG U1 D2 AVG VG U1 D2 AVG VG VG VG VG VG VG VG VG VG VG VG VG V	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5	70 73.0 RLINE INDI 75 68 64 51 64 55 80 115 113 126 108.5 57 70 62 56 61.3 82	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 55 6 5 56 47 53.3	4 58. 2 3 3 2 29. 4 11 11 9 90. 20. 20. 30. 30. 30.
EBRAS ISIDE V E N E S IDDLE E N E S UTSID E N E S <u>TENKIN</u> NSIDE M N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK E1 E2	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 235.0 103 220 283 339 236.3 AINT WITH FL	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156.0 59 131 153 134.8 YASH	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 56 57 53.3 45 53.3	44 58. 2 3 3 29. 29. 4 11 9 10 90. 2 4 3 30. 30. 2 4 4 3 2 30. 30. 30. 30. 30. 30. 30. 30.
EBRAS ISIDE V E N E S IDDLE E N E S UTSID E N E S <u>TENKIN</u> NSIDE M N	C1 C2 AVG SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 D1 D2 AVG EWHEELTRK D1 D2 AVG U1 AVG U1 AVG U1 D2 AVG U1 AVG U1 VI VI VI VI VI VI VI VI VI VI VI VI VI	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 153 183 198	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89 109	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98	111 97.3 JSTRIES 52 70 64 466 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 141	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 48.8 61 73 86	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 55 56 47 53.3 45 561 97	4 58. 2 3 3 2 29. 29. 4 111 9 10 90. 20. 2 90. 2 90. 2 30. 30. 30. 30. 30. 30. 30. 30. 30. 30.
EBRAS ISIDE V E N E S IDDLE E N E S UTSID E N E S <u>TENKIN</u> NSIDE M N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 AVG D1 D2 AVG D1 D2 AVG U1 D2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 339 236.3 AINT WITH FL	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247 242	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 183 183 183 198 204	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89 109 127	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98 8102	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 67.3	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 56 47 53.3 45 61 97 98	44 58. 2 3 3 2 29. 4 11 9 10 90. 2 4 3 3 2 3 0 4 4 3 3 2 3 3 3 2 2 9 4 4 3 3 2 2 9 4 4 3 3 2 2 9 9 9 9 9 9 9 9 9 9 9 9 9
EBRAS ISIDE V E N E S IIDDLE E N E S IUTSID E S (ENKIN NSIDE (M N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG E WHEELTRK D1 D2 D1 D2 AVG E WHEELTRK E1 E2 E1 E2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 153 183 198	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89 109	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98	111 97.3 JSTRIES 52 70 64 466 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 141	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 48.8 61 73 86	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 55 56 47 53.3 45 561 97	44 58. 2 3 3 2 29. 4 11 9 10 90. 2 4 3 3 2 3 0 4 4 3 3 2 3 3 3 2 2 9 4 4 3 3 2 2 9 4 4 3 3 2 2 9 9 9 9 9 9 9 9 9 9 9 9 9
EBRAS ISIDE V E N E S IDDLE N E S UTSID E N E S VITSID E N NSIDE (M N (M S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK E1 E2 E1 E2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156.0 59 131 153 134.8 YASH 125 210 247 242 206.0	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 198 204 184.5	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89 109 127 99.0	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98 102 96.8	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 141 124 119.0	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 65 56 47 53.3 45 61 97 98 75.3	44 58. 2 3 3 2 29. 29. 4 11 9 10 90. 20. 29. 29. 4 30. 30. 30. 30. 30. 30. 30. 30.
EBRAS ISIDE V E N E S IDDLE N E S UTSID E N E S VITSID E N NSIDE (M N (M S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1 D2 AVG U1 D2 AVG U1 D2 AVG U1 D2 AVG U1 D2 AVG E WHEELTRK E1 E2 E1	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247 242 206.0 146	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 198 204 184.5 118	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89 109 127 99.0 101	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98 102 96.8 94	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 67.3 75 136 141 124 119.0	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 56 56 47 53.3 45 61 97 98 75.3 95	44 58. 2 3 3 2 29. 4 111 9 10 90. 20. 29. 29. 29. 29. 29. 29. 29. 29
EBRAS ISIDE V E N E S IDDLE E N E S UTSIDI E N E S (M N (M N (M N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1 D2 AVG U1 D2 AVG U1 D2 AVG U1 D2 AVG U1 D2 AVG E WHEELTRK E1 E2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237	151 129,5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247 242 206.0 146 231	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 191 143.3 183 198 204 184.5	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 73 76 70.5 71 89 109 127 99.0 101 137	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98 80 61.3 82 105 98 80 98 8102 96.8	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 67.3 75 136 61.41 124 119.0	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88 102	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 56 47 53.3 45 61 97 98 75.3 95 128	44 58.4 2 3 3 29 29 4 11 9 10 90 20 4 4 3 30. 20 29 29 4 4 3 3 20 29 29 4 4 3 3 20 29 29 29 29 10 29 29 29 29 29 29 29 29 29 29
EBRAS ISIDE V E N E S IDDLE E N E S UTSIDI E N E S (M N (M N (M N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG E WHEELTRK D1 D2 D1 D2 AVG E WHEELTRK E1 E2 E1 E2 E1 E1 E1 E1 E1 E1 E1	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237 274	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247 247 210 247 247 210 247 247 251	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 193 183 198 204 184.5 118	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 73 76 70.5 71 89 109 127 99.0 101 137 140	70 73.0 RLINE INDI 75 68 64 51 51 113 126 108.5 57 70 62 56 61.3 82 105 98 82 105 96.8 102 96.8 94 110 132	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 141 124 119.0 123 141 197	65 70.8 42 50 48 38 44.5 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88 8102 151	69 69.5 47 44 56 49 49.0 71 118 128 128 128 128 55 56 47 53.3 45 61 97 98 75.3 95 128 154	44 58.4 22 3 3 29 4 11 9 10 90. 22 4 3 30. 25 55 11 11 11
EBRAS ISIDE V E N E S IDDLE E N E S UTSIDI E N E S (M N (M N (M N	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK E1 E2 E1 E2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237 274 313	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156.0 59 131 156.0 59 131 155.8 193 134.8 YASH 125 210 247 242 206.0 146 231 251 270	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 153 183 198 204 184.5 118 140 198 201	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89 109 127 99.0 101 137 140 109	70 73.0 RLINE INDI 75 68 64 51 64.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98 105 98 105 98 105 98 105 98 105 98 105 98	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 141 124 119.0 123 141 197 176	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88 102 151 1144	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 65 56 47 7 53.3 45 61 97 98 75.3 95 128 154 139	44 58. 2 3 3 29. 29. 4 11 1 9 90. 20. 29. 4 30. 30. 30. 30. 30. 30. 30. 30.
EBRAS VSIDE V E N E S UTSIDDLE E N E S VTSIDE E N SIDE V M N VM S	C1 C2 AVG SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK E1 E2 E1 E2 E1 E2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237 274 313 245.5	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247 247 210 247 247 210 247 247 251	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 193 183 198 204 184.5 118	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 73 76 70.5 71 89 109 127 99.0 101 137 140	70 73.0 RLINE INDI 75 68 64 51 51 113 126 108.5 57 70 62 56 61.3 82 105 98 82 105 96.8 102 96.8 94 110 132	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 141 124 119.0 123 141 197	65 70.8 42 50 48 38 44.5 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88 8102 151	69 69.5 47 44 56 49 49.0 71 118 128 128 128 128 55 56 47 53.3 45 61 97 98 75.3 95 128 154	44 58. 2 3 3 29. 29. 4 11 9 10 90. 20. 29. 4 3 30. 2 5 5 5 5 5 5 5 5 5 5 5 5 5
IEBRAS VISIDE V IE S VIDDLE E S VITSIDE E S VIDDLE N SIDE V E S VIDDLE M N SIDE V M N SIDE V M N M S VIDDLE N S VIDDLE N S VID S VIDDLE N S VID S VIDDLE N S VIDDLE N S VIDD S VID S N S VID S S VID S S N S N S S VID S S N S S S S N S S S S S S S S S S S	C1 C2 AVG SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 AVG D1 D2 AVG E WHEELTRK E1 E2 E1 E2 AVG E1 E2 E1 E2 AVG DE WHEELTRK	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237 274 313 245.5	151 129,5 IDS STAND 90 140 184 209 155,8 86 163 222 273 186,0 59 131 156 193 134,8 YASH 125 210 247 242 206,0 146 231 251 270 224,5	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 193 204 184.5 118 140 198 201 164.3	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 73 76 70.5 71 89 109 127 99.0 101 137 140 109 121.8	70 73.0 RLINE INDI 75 68 64 51 84.5 80 115 113 126 108.5 57 70 62 56 61.3 82 105 98 102 96.8 94 110 132 119 113.8	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 67.3 75 136 61 141 124 119.0 123 141 197 176 159.3	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88 102 151 144 121.3	69 69.5 47 44 56 49 49.0 71 118 128 128 128 128 55 56 45 56 47 53.3 45 61 97 98 75.3 95 128 154 139 129.0	44 58.4 2 3 3 2 29. 4 4 11 9 10 90. 2 29. 4 4 3 30. 30. 30. 30. 31. 11 112 112 112 112 112 112 11
IEBRAS VISIDE V IE S VIDDLE E S VITSIDE E S VIDDLE N SIDE V E S VIDDLE M N SIDE V M N SIDE V M N M S VIDDLE N S VIDDLE N S VID S VIDDLE N S VID S VIDDLE N S VIDDLE N S VIDD S VID S N S VID S S VID S S N S N S S VID S S N S S S S N S S S S S S S S S S S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG D1 D2 AVG E WHEELTRK E1 E2 E1 E1 E2 E1 E2 E1 E2 E1 E2 E1 E1 E1 E2 E1 E1 E1 E2 E1 E1 E1 E1 E2 E1 E1 E1 E1 E2 E1 E1 E1 E2 E1 E1 E1 E1 E1 E1 E1 E1 E1 E1 E1 E1 E1	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237 274 313 245.5 226	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156 193 134.8 YASH 125 210 247 247 247 206.0 146 231 251 270 224.5 160	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 193 183 198 204 184.5 118 180 198 201 164.3 136	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 58 75 73 76 70.5 71 89 109 127 99.0 101 137 140 109 121.8 87	70 73.0 RLINE INDI 75 68 64 51 80 115 113 126 108.5 57 70 62 56 61.3 82 105 59 8 82 105 98 80 296.8 92 96.8 94 110 132 119 113.8 72	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 58 82 64 65 67.3 75 136 141 124 119.0 123 141 197 176 159.3 82	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 695 78.8 88 102 151 144 121.3 53	69 69.5 47 44 56 49 49.0 49.0 71 118 128 126 110.8 45 56 47 53.3 45 61 97 98 75.3 95 128 154 139 129.0 49	44 58.4 2 3 3 2 29.9 4 11 90. 90. 2 4 3 30. 30. 30. 31. 11. 11. 11. 11. 11. 11. 11
EBRAS ISIDE V E N E S IDDLE N E S UTSID E N E S VITSID E N NSIDE M N M N M S DUTSID	C1 C2 AVG SKA DEPARTM D1 D2 D1 D2 AVG D1 D2 AVG D1 D2 AVG E WHEELTRK E1 E2 E1 E2 AVG E1 E2 E1 E2 AVG DE WHEELTRK	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237 274 313 245.5	151 129,5 IDS STAND 90 140 184 209 155,8 86 163 222 273 186,0 59 131 156 193 134,8 YASH 125 210 247 242 206,0 146 231 251 270 224,5	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 183 193 204 184.5 118 140 198 201 164.3	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 73 76 70.5 71 89 109 127 99.0 101 137 140 109 121.8	70 73.0 RLINE INDI 75 68 64 51 64.5 108.5 57 70 62 56 61.3 108.5 57 70 62 56 61.3 82 105 98 102 96.8 94 110 132 96.8 94 110 132 72 73	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 67.3 75 136 67.3 75 136 61 141 124 119.0 123 141 197 176 159.3	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88 102 151 144 121.3	69 69.5 47 44 56 49 49.0 71 118 128 128 128 128 55 56 45 56 47 53.3 45 61 97 98 75.3 95 128 154 139 129.0	44 58. 2 3 3 29. 29. 4 11 9 10 90. 90. 2 4 3 30. 2 5 5 5 5 5 5 5 5 5 5 5 5 5
IEBRAS VISIDE V IE S VIDDLE IE N IE S VITSIDI E S VITSIDI E S VITSIDI E S VINSIDE YM N YM S	C1 C2 AVG SKA DEPARTM WHEELTRK D1 D2 D1 D2 AVG E WHEELTRK D1 D2 AVG E WHEELTRK E1 E2 E1 E2 AVG E1 E2 E1 E2 AVG E1 E2 E1 E2 AVG	210 275 222.5 IENT OF ROA 142 195 262 316 228.8 123 196 268 353 235.0 103 220 283 339 236.3 AINT WITH FL 163 256 261 295 243.8 158 237 274 313 245.5 226 307	151 129.5 IDS STAND 90 140 184 209 155.8 86 163 222 273 186.0 59 131 156.0 59 131 156.0 59 131 155.8 210 247 242 206.0 146 231 251 270 224.5 160 216	131 176 149.5 ARD PAINT 102 152 159 156 142.3 97 127 179 199 150.5 70 132 180 191 143.3 153 183 198 204 184.5 118 140 198 201 164.3 136	72 74.8 BY CENTE 66 79 85 99 82.3 88 109 121 102 105.0 58 75 73 76 70.5 71 89 109 127 99.0 101 137 140 109 121.8 87 93	70 73.0 RLINE INDI 75 68 64 51 80 115 113 126 108.5 57 70 62 56 61.3 82 105 59 8 82 105 98 80 296.8 92 96.8 94 110 132 119 113.8 72	111 97.3 JSTRIES 52 70 64 46 58.0 85 151 160 162 139.5 58 82 64 65 87.3 75 136 141 124 119.0 123 141 197 176 159.3 82 101	65 70.8 42 50 48 38 44.5 63 111 145 132 112.8 41 59 47 40 46.8 61 73 86 95 78.8 88 102 151 144 121.3 53 59	69 69.5 47 44 56 49 49.0 71 118 128 126 110.8 45 65 56 47 7 53.3 45 61 97 98 75.3 95 128 154 139 129.0 49 61	

(continued on next page)

TABLE 13 (continued)

REFLECTIVITY		10/6/92	11/6/92	12/11/92	1/19/93	3/9/93	4/6/93	7/6/93	8/11/93	10/21/93
YENKIN	MAJESTIC PA	INT WITHO	UT FLYAS	1						
INSIDE	WHEELTRK									
YM N	F1	214	184	148	63	62	52	51	47	21
	F2	257	207	149	81	71	64	48	50	22
YM S	F1	244	183	167	67	56	49	44	54	26
	F2	265	202	171	80	60	49	44	51	28
	AVG	245.0	194.0	158.8	72.8	62.3	53.5	46.8	50.5	24.3
MIDDLE							<u> </u>			
YM N	F1	237	194	136	103	96	74	63	83	61
	F2	265	230	183	127	121	146	93	94	69
YMS	F1	253	212	164	91	104	120	81	77	67
	F2	291	252	196	117	99	124	100	109	81
	AVG	261.5	222.0	169.8	109.5	105.0	116.0	84.3	90.8	69.5
OUTSID	E WHEELTRK									
YM N	F1	232	179	140	63	65	51	40	46	23
	F2	255	191	151	68	60	51	40	47	20
YM S	F1	290	141	167	66	69	78	50	54	27
	F2	230	142	119	67	70	68	51	56	29
	AVG	251.8	163.3	144.3	66.0	66.0	62.0	45.3	50.8	24.8

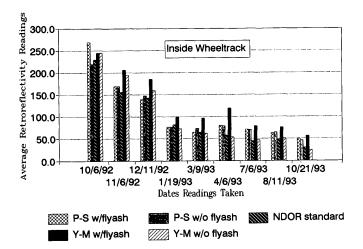


FIGURE 2 Average reflectivity readings inside wheeltrack in daytime using retroreflectometer.

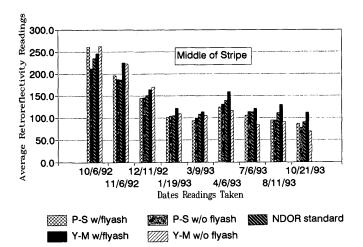


FIGURE 3 Average reflectivity readings in middle of stripe in daytime using retroreflectometer.

Retroreflectivity Readings 300.0 250.0 Outside Wheeltrack 200.0 150.0 100.0 50.0 Average 0.0 3/9/93 7/6/93 10/21/93 10/6/92 12/11/92 4/6/93 8/11/93 11/6/92 1/19/93 Dates Readings Taken NDOR standard P-S w/flyash P-S w/o flyash Y-M w/o flyash Y-M w/flyash

FIGURE 4 Average reflectivity readings outside wheeltrack in daytime using retroreflectometer.

paints not containing fly ash. It was only in the outside wheeltrack where P-S without fly ash had a higher average reflectivity reading than P-S with fly ash. Comparing the two paints containing fly ash with the NDOR standard, in five of the six cases the paints containing fly ash had higher 1-year average reflectivity readings than the NDOR standard paint. It was only in the middle of the stripe where the NDOR standard paint had a higher average reflectivity reading than the P-S with fly ash paint.

CONCLUSIONS

1. In five of six cases the two paints containing fly ash had greater 1-year average reflectivity readings than the special paints not containing fly ash. The paints containing fly ash also had greater 1-year average reflectivity readings than the NDOR standard paint in five of six cases. This is a good indication that the addition of fly ash may help increase the reflectivity of traffic paint. 2. After 1 year the two paints containing fly ash had approximately the same percentage of film failure. Y-M with ash performed better than Y-M without fly ash, yet P-S with fly ash performed worse than P-S without fly ash. The fly ash had both a positive and a negative effect on the percentage of film failure of the special paint, depending on the paint's manufacturer. Yet both paints with fly ash had approximately 40 percent less film failure than the NDOR standard. This is inconsistent evidence of the possibility that fly ash increases the durability of traffic marking paint. More field testing on a larger scale would probably lead to more conclusive comparisons.

3. None of the special paints met the NDOR drying time requirement of 15 min. The presence of fly ash did not significantly affect the drying time (no pickup) in the P-S paint, yet fly ash significantly increased the drying time in the Y-M paint.

4. As with film failure the effect of fly ash on the drying time was different for P-S and Y-M paints, depending on the manufacturer. Y-M with fly ash took 9 min longer to dry and also had a lower percentage of film failure than Y-M without fly ash. P-S with fly ash took only 1 min longer to dry but had a higher percentage of film failure than P-S without fly ash. Perhaps the drying time affected the film failure rate of the paint.

5. The paint containing fly ash performed well in the laboratory tests. In general it also showed promising results on the road, especially in the increase in reflectivity readings. This indicates the feasibility of using fly ash as a mineral filler in traffic marking paint.

RECOMMENDATIONS

The creative use of fly ash, an abundant artificial material, in technically sound applications such as traffic marking paints is a prudent endeavor. This is especially true with the pressing national concern for effective resource management. From the indications of the test program described here it is recommended that an extensive field test of traffic paint containing fly ash be conducted. The test should be done with various types of fly ash, both Class C and Class F from different sources, to determine how the different types perform in traffic paint.

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REFERENCE

1. Final Regulatory Determination. Federal Register, Vol. 58, No. 151, Aug. 9, 1993.

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