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 abrasion-resistant 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 μm. 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:

> 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

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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_2O_3)	29.9
Iron Oxide (Fe_2O_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_2O)	2.4
Sulphur Trioxide (SO_3)	0.2
Phosphorus Pentoxide (P_2O_5)	0.1
Other	0.6
Total (rounded)	100 %

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	9.39
Titanium Dioxide	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

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

	Actual Results	Nebraska 1991 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:		
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..........	satisfactory	--
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............	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

* 25°C = 77°F

** 1 kg/L = 0.119 lb/gal

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

	Actual Results	Nebraska 1991 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:		
No Pickup............................	23	15 Max.
Thoroughly Dry & Free From Tackiness.	28	--
Consistency, 25°C *, 1/2" Krebs Unit.......	87	70 to 80
Flexibility, 25°C *, 1/2" Mandrel..........	satisfactory	--
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).......	---	10 to 85
X-Ray Diffractogram of Pigment..........	satisfactory	Satisfactory
Infrared Spectrum of Vehicle............	satisfactory	Satisfactory
Non-Volatile, percent by weight of paint.	70.9	73 Min.
Luminous Reflectance	55.0	48 to 52

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

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

	Actual Results	Nebraska 1991 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:		
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 ($PbCrO_4$)................	---	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.	77.0	73 Min.
Luminous Reflectance	50.0	48 to 52

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

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

	Actual Results	Nebraska 1991 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:		
No Pickup............................	18	15 Max.
Thoroughly Dry & Free From Tackiness.	24	--
Consistency, 25°C *, 1/2" Krebs Unit......	80	70 to 80
Flexibility, 25°C *, 1/2" Mandrel.........	satisfactory	--
Bleeding (Bituminous Surface)...........	no bleeding	--
Water Resistance........................	9	--
Settling Properties, 2 weeks, (ASTM D 1390)	7	6 Min.
Dry Hiding Power........................	complete hiding	Complete Hiding
Paint Composition:		
Pigment, percent by weight.............	60.1	55 Min.
Vehicle, percent by weight............	39.9	45 Max.
Weight, kg/L **, 25°....................	1.49	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.	76.0	73 Min.
Luminous Reflectance	54.5	48 to 52

* 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

Month	Temperature °F	Temperature °C	Precipitation Inches	Precipitation 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

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	10/20/92	11/6/92	12/6/92	1/10/93	3/6/93	4/6/93	7/6/93	8/11/93	10/21/93
PRUETT SCHAFFER WITH FLYASH											
NORTH	B1	0	2	2	4	6	20	22	25	25	30
	B2	0	2	2	4	6	15	17	20	20	28
SOUTH	B1	0	2	2	3	5	15	22	40	45	48
	B2	0	2	2	3	5	15	22	40	40	48
	AVG	0.0	2.0	2.0	3.5	5.5	16.3	20.8	31.3	32.5	38.5
PRUETT SCHAFFER WITHOUT FLYASH											
NORTH	C1	0	3	3	4	6	20	22	25	25	30
	C2	0	3	3	4	6	20	22	25	25	38
SOUTH	C1	0	2	2	3	5	12	16	20	20	28
	C2	0	2	2	3	5	12	16	20	20	28
	AVG	0.0	2.5	2.5	3.5	5.5	16.0	19.0	22.5	22.5	31.0
NDOR STANDARD PAINT FROM CENTERLINE INDUSTRIES											
NORTH	D1	0	1	1	5	10	45	50	60	65	75
	D2	0	1	1	3	6	45	50	60	65	75
SOUTH	D1	0	1	1	2	7	50	55	70	75	80
	D2	0	1	1	2	8	50	55	70	75	80
	AVG	0.0	1.0	1.0	3.0	7.8	47.5	52.5	65.0	70.0	77.5
YENKIN MAJESTIC WITH FLYASH											
NORTH	E1	0	2	2	3	6	30	35	40	45	50
	E2	0	2	2	3	6	25	30	40	40	50
SOUTH	E1	0	1	1	2	4	12	15	22	25	30
	E2	0	2	2	3	5	12	15	22	25	30
	AVG	0.0	1.8	1.8	2.8	5.3	19.8	23.8	31.0	33.8	40.0
YENKIN MAJESTIC WITHOUT FLYASH											
NORTH	F1	0	2	2	5	10	30	40	45	45	50
	F2	0	2	2	5	10	25	32	45	45	50
SOUTH	F1	0	2	2	5	10	20	25	35	40	50
	F2	0	2	2	5	10	20	25	35	40	50
	AVG	0.0	2.0	2.0	5.0	10.0	23.8	30.5	40.0	42.5	50.0

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

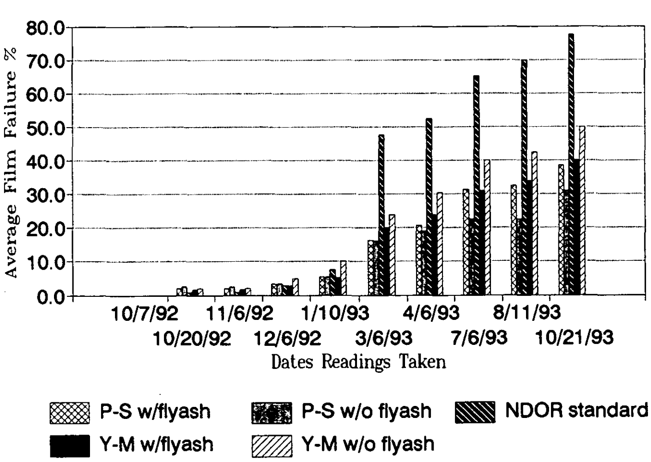

FIGURE 1 Film failure of traffic paint determined visually.

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

TABLE 13 Actual and Average Reflectivity Readings of Test Paints

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
PRUETT SCHAFFER PAINT WITH FLYASH										
INSIDE WHEELTRK										
PS N	B1	259	163	139	70	60	81	68	61	45
	B2	240	169	138	73	71	102	102	80	71
PS S	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
MIDDLE										
PS N	B1	232	193	167	101	89	129	124	90	106
	B2	238	180	117	101	101	140	129	105	103
PS S	B1	294	197	175	102	98	125	81	99	62
	B2	278	214	120	102	85	102	88	83	75
		260.5	196.0	144.8	101.5	93.3	124.0	105.5	94.3	86.5
OUTSIDE WHEELTRK										
PS N	B1	276	174	117	72	56	79	53	72	40
	B2	252	148	145	70	73	94	75	90	58
PS S	B1	270	148	146	71	63	84	77	77	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
PRUETT SCHAFFER PAINT WITHOUT FLYASH										
INSIDE WHEELTRK										
PS N	C1	183	122	131	70	81	102	83	62	49
	C2	219	180	138	80	76	74	67	59	45
PS S	C1	230	203	152	76	63	63	56	61	42
	C2	245	172	170	83	74	75	75	75	49
	AVG	219.3	169.3	147.8	77.3	73.5	78.5	70.3	64.3	46.3
MIDDLE										
PS N	C1	204	140	95	98	94	109	114	77	89
	C2	216	175	130	108	102	126	96	80	61
PS S	C1	200	214	180	114	106	137	101	108	78
	C2	225	219	178	97	96	147	143	111	82
	AVG	211.3	187.0	145.8	104.3	99.5	129.8	113.5	94.0	77.5
OUTSIDE WHEELTRK										
PS N	C1	184	126	144	77	79	104	73	76	64
	C2	221	120	147	86	76	95	64	67	59
PS S	C1	210	151	131	64	67	79	81	66	63
	C2	275	121	176	72	70	111	65	69	49
	AVG	222.5	129.5	149.5	74.8	73.0	97.3	70.8	69.5	58.8
NEBRASKA DEPARTMENT OF ROADS STANDARD PAINT BY CENTERLINE INDUSTRIES										
INSIDE WHEELTRK										
NE N	D1	142	90	102	66	75	52	42	47	25
	D2	195	140	152	79	68	70	50	44	31
NE S	D1	262	184	159	85	64	64	48	56	36
	D2	316	209	156	99	51	46	38	49	25
	AVG	228.8	155.8	142.3	82.3	64.5	58.0	44.5	49.0	29.3
MIDDLE										
NE N	D1	123	86	97	88	80	85	63	71	49
	D2	196	163	127	109	115	151	111	118	115
NE S	D1	268	222	179	121	113	160	145	128	97
	D2	353	273	199	102	126	162	132	126	100
	AVG	235.0	186.0	150.5	105.0	108.5	139.5	112.8	110.8	90.3
OUTSIDE WHEELTRK										
NE N	D1	103	59	70	58	57	58	41	45	25
	D2	220	131	132	75	70	82	59	65	43
NE S	D1	283	156	180	73	62	64	47	56	31
	D2	339	193	191	76	56	65	40	47	23
	AVG	236.3	134.8	143.3	70.5	61.3	67.3	46.8	53.3	30.5
YENKIN MAJESTIC PAINT WITH FLYASH										
INSIDE WHEELTRK										
YM N	E1	163	125	153	71	82	75	61	45	26
	E2	256	210	183	89	105	136	73	61	43
YM S	E1	261	247	198	109	98	141	86	97	82
	E2	295	242	204	127	102	124	95	98	72
	AVG	243.8	206.0	184.5	99.0	96.8	119.0	78.8	75.3	55.8
MIDDLE										
YM N	E1	158	146	118	101	94	123	88	95	75
	E2	237	231	140	137	110	141	102	128	117
YM S	E1	274	251	198	140	132	197	151	154	138
	E2	313	270	201	109	119	176	144	139	118
	AVG	245.5	224.5	164.3	121.8	113.8	159.3	121.3	129.0	112.0
OUTSIDE WHEELTRK										
YM N	E1	226	160	136	87	72	82	53	49	37
	E2	307	216	168	93	73	101	59	61	38
YM S	E1	300	210	174	72	113	144	105	103	92
	E2	314	202	188	125	96	201	99	104	79
	AVG	286.8	197.0	166.5	94.3	88.5	132.0	79.0	79.3	61.5

(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 PAINT WITHOUT FLYASH										
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										
YM N	F1	237	194	136	103	96	74	63	83	61
	F2	265	230	183	127	121	146	93	94	69
YM S	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
OUTSIDE 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

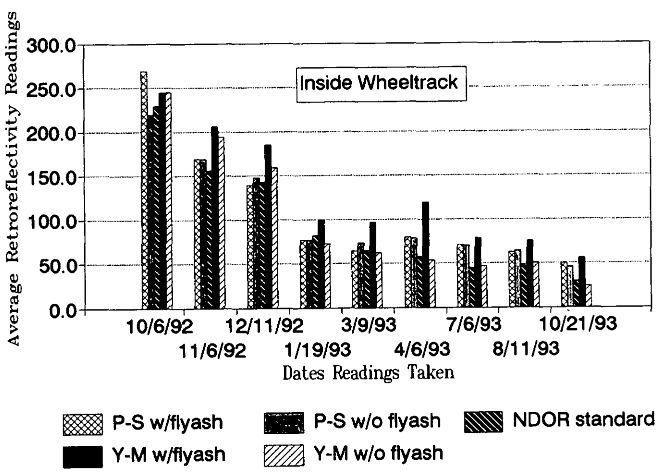

FIGURE 2 Average reflectivity readings inside wheeltrack in daytime using retroreflectometer.

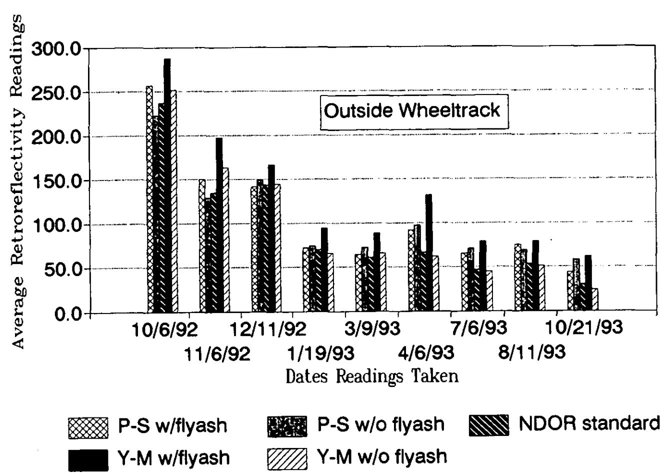

FIGURE 4 Average reflectivity readings outside wheeltrack in daytime using retroreflectometer.

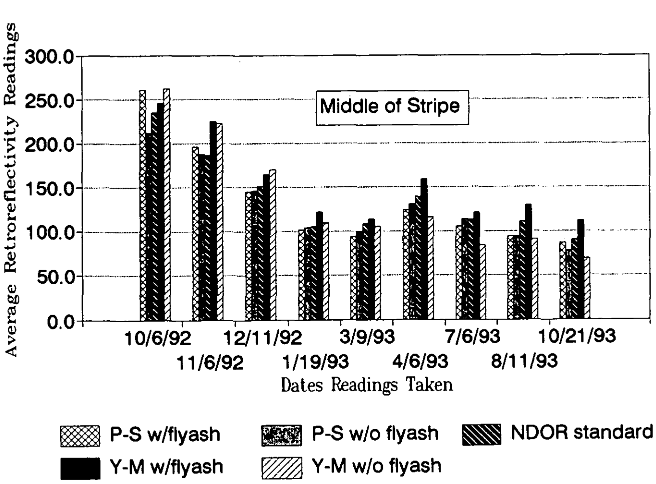

FIGURE 3 Average reflectivity readings in middle of stripe in daytime using retroreflectometer.

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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