Use of Lime-Activated Class F Fly Ash in the Full-Depth Reclamation of Asphalt Pavements: Environmental Aspects

Ryan Mackos, Tarunjit Butalia, William Wolfe, and Harold W. Walker

Ohio State University, Department of Civil and Environmental Engineering and Geodetic Science, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, Ohio 43210.

KEYWORDS: Fly ash, pavement, leaching, environmental

INTRODUCTION

The goal of this study was to evaluate the environmental aspects associated with the use of lime-activated Class F fly ash in the full-depth reclamation (FDR) of asphalt pavements. FDR is a flexible pavement reclamation process in which the full pavement section (wearing surface, base / subbase, and a pre-determined portion of underlying soil) is uniformly pulverized, blended with chemical additives (e.g. cement, fly ash, lime, emulsion) and compacted to construct a new stabilized base. The silica and alumina in fly ash reacts with lime to increase the strength, stiffness, and durability of the stabilized base layer. Fly ash also acts as mineral filler to fill the voids in the granular pulverized pavement mix, thus reducing permeability of the FDR stabilized layer.

Two field sites in Ohio, one in Warren Co. and the other in Delaware Co, were selected for examining the use of fly ash in the FDR of pavements. The field site in Warren Co. was located on Long Spurling Road. The test site in Delaware Co. was on Section-Line Road. The Warren Co. site consisted of two FDR test sections; a 6% fly ash section and a control. Six test sections were constructed in Delaware Co. on Section-Line Road, two of which contained 5-6% class F fly ash. One of the two fly ash containing test sections in Delaware Co. also contained lime kiln dust (LKD). The additional test sections in Delaware Co. did not contain coal combustion by-products and will not be discussed here, except for the control. Control sections at both sites were constructed using a typical “mill and fill” approach, without the use of fly ash or other industrial by-products. Test sections were constructed and instrumented in the summer of 2006.

The specific objectives of the environmental component of this study were (1) to determine the leaching potential of selected constituents for the various FDR base mixes; and (2) to assess the water quality in the FDR base layer at the field sites. The physical and engineering response of the test sections was also examined and is reported elsewhere (Chapman 2007).

METHODS AND PROCEDURES

The leaching potential of selected constituents was determined using TCLP and SPLP tests using standard procedures.

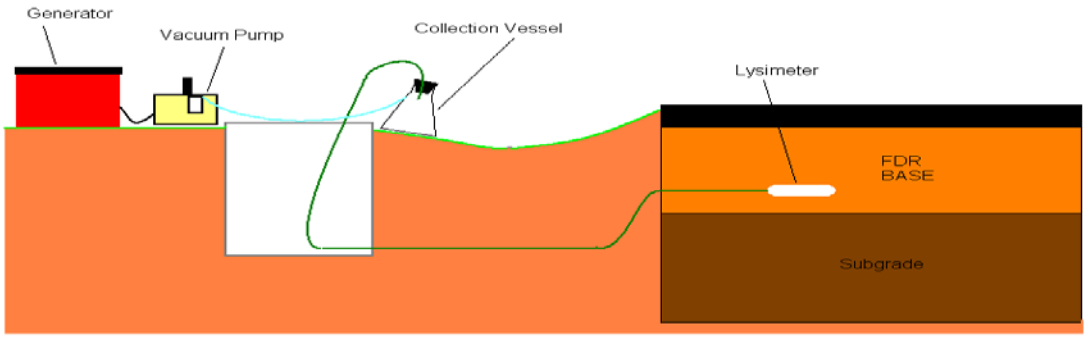

Figure 1. Field sampling set-up.

Field sampling was carried out by installing lysimeters within the FDR base layer under each asphalt test section. The set-up of the lysimeters is shown in Figure 1. Sampling was carried out at each test section on roughly a monthly basis. Samples were collected by inducing a vacuum in the lysimeter using a vacuum pump (Welch, Model No. 2545B-01) capable of producing a vacuum up to approximately 15 psi. The vacuum pump was attached to a Coleman Powermate Pulse 1800EX Generator to supply the electricity needed at the sampling sites. Samples were collected into a one liter Nalgene Buchner vacuum flask, which had been triple-rinsed with Millipore deionized water.

Inorganic elements in leachate and field samples, including As, Al, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Ni, Pd, K, Se, Si, Na, Sr, S, and Zn were determined using standard methods, by either inductively coupled plasma-atomic emission spectrometry (ICP-AES) or graphite furnace atomic absorption spectrometry (GFAA). Hg was determined by cold vapor atomic absorption spectrometry (CVAA). These constituents were chosen because many are typically found in CCPs and they are also of concern in evaluating highway runoff.

RESULTS AND DISCUSSION

Laboratory Leaching Tests

The leaching potential was determined for the FDR base materials from each of the test sections in this project. Leachate concentrations were compared to Ohio EPA's non-toxic criteria and other regulatory standards. Table 1 shows the TCLP and SPLP results for the FDR base materials from the Warren Co. test site. TCLP and SPLP test results

for the class F fly ash used in the FDR are shown for comparison. These data demonstrate that none of the leachate concentrations for the Warren Co. test site exceeded RCRA limits or the Ohio EPA's non-toxic criteria. In fact, leachate concentrations generally met US EPA maximum contaminant levels (MCLs) for drinking water.

Tables 2 and 3 show the results of the SPLP and TCLP tests for FDR base materials used at the Delaware County test site. Similar to results for the Warren Co. samples, none of the leachate concentrations exceeded the Ohio EPA's non-toxic criteria, and most generally met US EPA maximum contaminant levels (MCLs) for drinking water. Importantly, Hg was not detected in any of the leachate tests. As and Se were either not detected or observed at very low concentrations.

Although some differences can be seen, the FDR base materials containing fly ash generally showed similar TCLP or SPLP results as the control sections. TCLP and SPLP test results for the FDR mixes were similar or lower than leachate results for fly ash in most cases.

Table 1. Leaching potential of FDR base materials from Warren County test site.

Element	Warren County						Ohio Non-Toxic Criteria
	SPLP			TCLP			
	Control	4% L, 6% FA	Fly Ash	Control	4% L, 6% FA	Fly Ash	
	W-1	W-2		W-1	W-2		
$pH_{initial}$	4.22	4.22	4.24	2.84	2.83	2.83	
pH_{final}	12.47	12.37	11.62	7.13	9.15	10.24	
Al	-	-	-	-	-	-	
As	0.002	<0.001	<0.001	0.002±0.002	0.015	<0.001	0.3
Ba	0.272±0.012	0.156±0.016	0.120±0.017	0.324±0.023	0.290±0.035	0.466±0.008	60
Ca	178.5±13.4	221±24	430±4	548±25	711±24	436±10	
Cd	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.15
Cr	<0.010	<0.010	0.019±0.006	0.016±0.001	<0.010	0.018±0.003	3.0
Cu	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Fe	<0.010	0.010±0.001	<0.010	0.261±0.005	0.219±0.057	0.208±0.011	
Hg	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.06
K	-	-	-	-	-	-	
Mg	-	-	0.300±0.083	20.7±1.8	26.0±20.0	522±14	
Mn	<0.010	<0.010	<0.010	0.594±0.564	<0.010	<0.010	
Mo	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Na	7.9±2.6	8.5±2.9	13.1±0.1	14.3±1.9	18.6±1.1	20.9±0.5	
Ni	0.013±0.001	<0.010	0.021±0.006	0.018±0.004	0.029±0.003	0.016±0.003	
Pb	0.028±0.025	0.032±0.014	<0.010	0.028±0.005	0.019±0.013	0.046±0.018	1.5
S	1.2±0.1	1.6±0.1	432±4	29.6	92.8±3.7	582±5	
Se	<0.001	<0.001	0.017±0.001	0.003	0.005	0.033±0.001	1.0
Si	0.441±0.001	0.923±0.123	1.3±0.1	9.0±2.8	3.7±0.4	0.123±0.005	
Sr	0.024±0.001	0.042±0.011	0.049±0.002	0.093±0.004	0.097±0.019	0.064±0.001	
Zn	0.013±0.001	0.022±0.003	<0.010	<0.010	<0.010	<0.010	

Units: µg/mL

Field Sampling

Analysis of groundwater in the FDR base was carried out on a monthly basis upon completion of construction in the summer of 2006. Water recovery from test sections containing fly ash has been significantly less than from non-fly ash-containing test sections. At Warren Co. only one water sample has been obtained from the fly ash test section, while water samples were obtained from the control section on five out of the twelve sampling trips. At Delaware Co. the fly ash test sections have been dry, while other test sections produce water. These data suggest that the incorporation of fly ash into the FDR mix reduces permeability of the base layer, which reduces the contact of groundwater and the generation of leachate.

Table 2. SPLP leaching potential of FDR base materials from Delaware County test site.

Element	Delaware County				
	Control	5% LKD, 5% FA	4% L, 6% FA	Fly Ash	Ohio Non-Toxic Criteria
$pH_{initial}$	4.21	4.21	4.18	4.24	
pH_{final}	12.10	11.90	11.87	11.62	
Al	2.1	4.5	-	-	
As	<0.001	<0.001	0.002±0.001	<0.001	0.3
Ba	0.374±0.004	0.017±0.001	0.095±0.002	0.120±0.017	60
Ca	275±4	169±7	171±3	430±4	
Cd	<0.010	<0.010	<0.010	<0.010	0.15
Cr	<0.010	0.013±0.002	<0.010	0.019±0.006	3.0
Cu	0.042±0.022	0.062±0.024	0.013±0.004	<0.010	
Fe	<0.010	<0.010	<0.010	<0.010	
Hg	<0.001	<0.001	<0.001	<0.001	0.06
K	-	-	-	-	
Mg	0.056±0.017	0.123±0.035	<0.010	0.300±0.083	
Mn	<0.010	<0.010	<0.010	<0.010	
Mo	0.016±0.002	0.020±0.001	0.012±0.001	<0.010	
Na	8.4±0.1	24.3±0.2	5±0.1	13.1±0.1	
Ni	<0.010	0.015±0.002	<0.010	0.021±0.006	
Pb	-	-	-	<0.010	1.5
S	1.5±0.1	6.5±0.1	4.1	432±4	
Se	<0.001	0.001	<0.001	0.017±0.001	1.0
Si	0.714±0.037	1.7	1.1	1.3±0.1	
Sr	0.747±0.005	0.254±0.001	0.373±0.004	0.049±0.002	
Zn	0.017±0.002	<0.010	0.012±0.001	<0.010	

Units: µg/mL

Water quality of samples obtained at the test sites is shown in Table 4. In general, chemical analysis of the water sample obtained from the fly ash test section at Warren Co. indicated that the levels of inorganic elements were below primary drinking water standards and were similar to levels observed in control sections. Only a limited amount of sample was obtained from the Delaware county sections containing fly ash or fly ash and lime kiln dust. These samples were analyzed for As and Se and showed low levels, similar to values observed in the control section.

These results suggest that the incorporation of fly ash into the full-depth reclamation of asphalt pavement reduced the contact of water with the FDR base material, resulting in less leachate generation. The quality of the leachate collected indicated no negative impact on groundwater quality. Additional water quality sampling of the FDR base is on-going to further assess these conclusions.

Table 3. TCLP leaching potential of FDR base materials from Delaware County test site.

Element	Delaware County				
	Control	5% LKD, 5% FA	4% L, 6% FA	Fly Ash	Ohio Non-Toxic Criteria
$pH_{initial}$	2.85	2.87	2.83	2.83	
pH_{final}	9.70	7.69	7.46	10.24	
Al	0.143	0.063	-	-	
As	0.003	<0.001	0.006	<0.001	0.3
Ba	0.374±0.002	0.256±0.004	0.230±0.001	0.466±0.008	60
Ca	1190±4	1220±6	1170±8	436±10	
Cd	<0.010	<0.010	<0.010	<0.010	0.15
Cr	0.035±0.008	0.038±0.015	<0.010	0.018±0.003	3.0
Cu	0.158±0.046	0.156±0.005	0.127±0.019	<0.010	
Fe	0.256	0.308	0.175	0.208±0.011	
Hg	<0.001	<0.001	<0.001	<0.001	0.06
K	-	-	-	-	
Mg	32.4±0.1	41.1±0.2	49.8±0.4	522±14	
Mn	<0.010	0.087±0.002	0.138	<0.010	
Mo	0.043±0.002	0.031±0.001	0.048±0.001	<0.010	
Na	22.9±0.1	68.3±0.2	17.2±0.1	20.9±0.5	
Ni	0.033±0.011	0.053±0.016	0.045±0.014	0.016±0.003	
Pb	-	-	-	0.046±0.018	1.5
S	42.5±0.2	158±2.8	35.6±0.4	582±5	
Se	0.003	0.003	0.003	0.033±0.001	1.0
Si	7.8±0.1	10.8±0.1	13.2±0.1	0.123±0.005	
Sr	2.8	1.9	3.1	0.064±0.001	
Zn	<0.010	<0.010	<0.010	<0.010	

Units: µg/mL

REFERENCES CITED

Chapman, J. Stress Model Verification with Reclaimed Asphalt Pavement; Master's Thesis, The Ohio State University, 2007.

Table 4. Water quality of field samples collected from the FDR test sections.

	Warren Co.		Delaware Co.				
Element	**Control W-1**	**4% L, 6% FA W-2**	**Control D-4**	**5% LKD, 5% FA D-5**	**4% L, 6% FA D-6**	**EPA MCL**	**Ohio Non-Toxic Criteria**
pH	~7.0	~7.5	~8.0	~6.25	~7.0		
Al	0.086	<0.010	0.025	-	-		
As	<0.001	0.002	<0.001	0.002	0.003	0.010	0.3
Ba	0.056	0.080	0.027	-	-	2.0	60.0
Ca	915	935	43.5	-	-		
Cd	<0.010	<0.010	<0.010	-	-	0.005	0.15
Cr	0.012	<0.010	0.011	-	-	0.100	3.0
Cu	0.051	<0.010	0.027	-	-	1.3	
Fe	0.553	0.051	0.172	-	-		
Hg	<0.001	<0.001	<0.001	-	-	0.002	0.06
K	2.1	22.7	-	-	-		
Mg	11.5	22.1	4.4	-	-		
Mn	<0.010	<0.010	<0.010	-	-		
Mo	-	-	-	-	-		
Na	211	59.5	121	-	-		
Ni	0.025	<0.010	0.020	-	-		
Pb	<0.010	<0.010	<0.010	-	-	0.015	1.5
S	765	913	18.5	-	-		
Se	<0.001	<0.001	<0.001	<0.001	<0.001	0.050	1.0
Si	2.4	3.4	1.1	-	-		
Sr	0.308	0.312	0.103	-	-		
Zn	0.047	0.087	0.081	-	-		
Cl^-	372.8	-	262.1	-	-		
NO_3^-	1.6	-	10.1	-	-		
SO_4^{2-}	339.9	-	141.9	-	-		

Units: µg/mL