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EXECUTIVE SUMMARY

New York/New Jersey Demonstration Program: Municipal Solid Waste Combustion Residue in Asphalt Paving

February 2001

PROJECT MANAGEMENT TEAM

Kenneth C. Afferton, New Jersey Department of Transportation
Phil Dinh, Port Authority of New York and New Jersey
Thomas Fiesinger, New York State Energy Research and Development Authority
Anthony Giordano, Port Authority of New York and New Jersey
Frank Palise, New Jersey Department of Transportation
Ray Scanlon, Port Authority of New York and New Jersey
Mary Sheil, New Jersey Department of Environmental Protection
Edith Tanenbaum, Long Island Regional Planning Board

PROJECT CONSULTANTS – TECHNICAL WORK GROUP

Chesner Engineering, P.C.
Warren H. Chesner
Christopher W. Stein
Lynette Van Helden
Judy Jakobsen
Geoffrey H. Pierson

New Jersey Dept. of Environmental Protection
John Jenks
Michael McLinden
Louis Mikolajczyk
Stuart J. Nagourney
John Preczewski
Mary Rudakewyck
Mary T. Sheil
Nicholas Tummillo
Michael Winka

New York State Department of Health
Kenneth Aldous

New York State Energy Research and Development Authority
Thomas Fiesinger

National Renewable Energy Laboratory
Philip Shepherd
Carlton Wiles

Warren County Pollution Control Financing Authority
Bart Carhart
James Williams

Levine ·Fricke ·Recon Inc.
Thomas Brown

New Jersey Department of Transportation
Kenneth C. Afferton
Eileen Connolly
Jack Croteau
Victor E. Mottola
Chandresh Patel
John Salt
Fran Sutter
Nicholas Vitillo

New Jersey Department of Health
Nicholas Tummillo

Port Authority of New York and New Jersey
Dorian Bailey
Brian Burkowsky
Martin Durney
Anthony Giordano
Hank Mazurczyk
Raymond D. Scanlon
Harry Schmerl
John Varrone
Daniel Webber
Mark Wierciszewski

Chapman, Inc.
Robert Farrell

Ogden Projects
Regis Wyluda

Waste Management Institute
State University of New York at Stony Brook
Frank J. Roethel
Maryann Maertz Wente

FOREWORD

This Executive Summary highlights the activities and results of the New York/New Jersey Ash Paving Project designed to assess and demonstrate the engineering and environmental feasibility of substituting municipal waste combustor ash or components thereof for a portion of the natural aggregate normally used in road paving.

Participating agencies included the New York State Energy Research and Development Authority, the New Jersey Department of Transportation, the New Jersey Department of Environmental Protection, the Port Authority of New York and New Jersey and the Long Island Regional Planning Board. This interagency group, collectively known as the Project Management Team (PMT), provided overall project management and financial support. The National Renewable Energy Laboratory assisted by supporting the preparation and publication of the stockpile demonstration report (see below) and the U.S. Environmental Protection Agency provided funding for ash characterization activities.

The PMT undertook an examination of the engineering and environmental effects of processing, stockpiling, and using municipal solid waste combustor ash (bottom ash) in the production and paving of a well-trafficked roadway.

The effort involved a multi-year ash sampling program to characterize the engineering and environmental properties of ash from the Warren County Resource Recovery Facility in Warren County, New Jersey; field monitoring of ash processing and stockpiling operations to quantify dust emissions and runoff quality that could be expected from such operations; monitoring of air emissions and baghouse dust quality during the production of a modified ash-asphalt pavement in a commercially operating asphalt production facility; and multi-year monitoring of the engineering performance and the runoff and leachate from an ash-modified asphalt wearing surface pavement.

Four subject reports and this Executive Summary present the findings of this effort. A listing of these reports is as follows:

The New York/New Jersey Ash Paving Project: Executive Summary, February 2001

Municipal Solid Waste Combustor Bottom Ash Stockpile Runoff and Dust Emissions Evaluation, May 1997

Field Assessment of Stack Emissions when Municipal Waste Combustor Bottom Ash is Introduced as an Aggregate Material in the Hot Mix Asphalt Production Process, May 2000

Field Assessment of the Engineering Effects of Using Municipal Waste Combustor Bottom Ash as an Aggregate Substitute Material in Asphalt Concrete Pavement, May 2000

- Field Assessment of the Environmental Effects of Using Municipal Waste Combustor Bottom Ash as an Aggregate Substitute Material in an Asphalt Concrete Pavement, October 2000

To obtain copies of these reports, please submit requests to Tom Fiesinger at the New York State Energy Research and Development Authority, 286 Washington Avenue Extension, Albany, New York 12203-6399

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Section 1

INTRODUCTION

This summary report provides a synopsis of the activities, findings, and conclusions resulting from the multi-year New York/New Jersey Ash Paving Project. The project's goals were to implement a laboratory and field demonstration program designed to assess the feasibility of using bottom ash produced as a by-product from municipal solid waste combustors as an aggregate substitute in asphalt paving mixes.

Detailed descriptions of the activities and results of the effort can be found in four main technical reports referenced in the foreword to this report.

This Executive Summary is divided into eight sections:

1. Introduction,
2. Program Background,
3. Project Management Structure,
4. Bottom Ash Characteristics,
5. Stockpile Demonstration,
6. Asphalt Plant Monitoring Demonstration,
7. Roadway Demonstration, and
8. Conclusions and Recommendations.

Section 2

PROGRAM BACKGROUND

Overview

In 1987, in response to the lack of available disposal capacity for managing municipal solid waste combustor ash in the State of New Jersey, the New Jersey Department of Transportation (NJDOT) was directed by state legislation to investigate options for utilizing the residues from municipal solid waste combustors.

Similar problems in 1986 on Long Island, New York, resulted in the implementation by the Long Island Regional Planning Board (LIRPB) of a comprehensive ash characterization study to define potential uses for ash.[1]

In mid-1988 the NJDOT contacted the LIRPB to propose the possibility of establishing a bi-state, multi-agency group to further investigate and demonstrate potential uses for ash in asphalt concrete pavements. The LIRPB agreed and by late 1990 consultants were selected, a management structure devised, and contracts executed allowing the NJDOT, the LIRPB, the Port Authority of New York and New Jersey (PA), the New York State Energy Research and Development Authority (NYSERDA), and the New Jersey Department of Environmental Protection (NJDEP) to initiate a joint demonstration project.

The scope of the demonstration project was defined in a multi-task work plan. This work plan encompassed a scope that involved a series of work tasks designed to evaluate the engineering and environmental feasibility of using municipal waste combustor ash from the Warren County Resource Recovery Facility (WCRRF) as an aggregate substitute material in asphalt concrete pavements. The work plan was divided into four major programs. These included an ash characterization program, a stockpile demonstration program, an asphalt plant monitoring program, and a roadway demonstration program.

Ash Characterization Program

In 1991, three separate sampling events were undertaken to characterize bottom ash from the 400 ton per day (tpd) Warren County Resource Recovery Facility (WCRRF). Each sampling event

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[1] The Potential for Beneficial Use of Waste-to-Energy Facility Ash, Executive Summary and Volumes 1-7, Long Island Regional Planning Board, July 1993.

encompassed a four-day sample collection period. A detailed description of the sampling procedures and analytical tests to which the ash samples were subjected are presented elsewhere.[2] Summarized results of this characterization program are presented in Section 4 of this report.

Stockpile Demonstration

In December 1992, approximately 400 tons of bottom ash were collected from the WCRRF and transported to the Warren County Landfill where it was screened through a 3/4-inch screen and further processed by magnetic separation to remove ferrous metals. After processing approximately 360 tons of the minus 3/4-inch ash was placed on a specially constructed 65 foot by 65 foot asphalt concrete pad, stockpiled and monitored for a period of 12 months. During processing (screening and magnetic separation), ambient air was monitored to assess ambient air quality and worker safety. From December 1992 to December 1993, the air, stormwater runoff, and soil in the vicinity of the stockpile were monitored. An electronic weather station was also installed on site to monitor and record meteorological conditions. The data obtained during the monitoring period were used to develop a bottom ash stockpile source model to project potential air emissions and runoff loadings from the stockpile. Model generated emissions and loadings figures were used to estimate potential impacts on air, groundwater, surface water and soil quality in the vicinity of the stockpile. Periodically during the 12-month stockpile period the stockpile was turned over to simulate ash-aggregate handling activities. During these turn-over periods, ambient air was monitored to further assess potential impacts to ambient air or water air quality. A detailed description of the processing and handling activities to which the bottom ash was subjected is presented elsewhere.[2] Summarized findings and conclusions of this demonstration program are presented in Section 5 of this report.

Asphalt Plant Demonstration

On June 19, 1996, approximately 102 dry tons of processed municipal waste combustor ash collected from the stockpiled bottom ash were transported to the Mt. Hope asphalt production facility in Wharton, New Jersey and substituted for an equal amount of natural aggregate in the production of a top surface paving mix. On June 20, 1996, approximately 794 tons of a conventional top surface paving mix was also produced at the Mt. Hope asphalt drum mix plant. During this two-day period (June 19 and 20), a comprehensive air emission monitoring and baghouse dust testing program was undertaken during both the ash-modified and conventional

[2] Municipal Solid Waste Combustor Bottom Ash Stockpile Runoff and Dust Emissions Evaluation, May 1997.

pavement production operations. A detailed description of this asphalt-monitoring program is presented elsewhere.[3] Summarized findings and conclusions of this asphalt plant demonstration program are presented in Section 6 of this report.

Roadway Demonstration

Directly after production of the ash-modified and control mixes, on June 19 and 20, 1996, respectively, each of the blends was transported to Center Drive in Elizabeth, New Jersey, where they were placed and compacted as surface pavement overlays. During the 24-months following installation, both the ash-modified and control pavements were subjected to physical tests, visual surveys, and environmental testing to assist in assessing the engineering and environmental effects of introducing processed municipal waste combustor bottom ash into a New Jersey Department of Transportation (NJDOT) asphalt concrete surface mix. Detailed descriptions of this roadway demonstration program are presented elsewhere.[4,5] Summarized findings and conclusions of the roadway-monitoring program are presented in Section 7 of this report.

An overall demonstration program project time line is presented in Figure 1-1

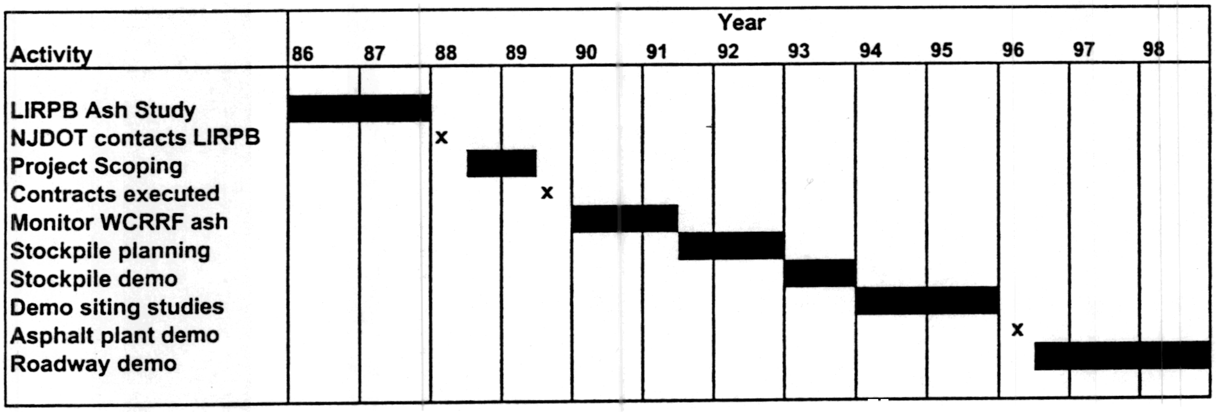

Figure 1-1. Project Time Line

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[3] Field Assessment of Stack Emissions When Municipal Waste Combustor Bottom Ash Is Introduced As An Aggregate Material in the Hot Mix Asphalt Production Process, May 2000.

[4] Field Assessment of The Engineering Effects of Using Municipal Waste Combustor Bottom Ash as an Aggregate Substitute Material in an Asphalt Concrete Pavement, May 2000.

[5] Field Assessment of the Environmental Effects of Using Municipal Waste Combustor Bottom Ash as an Aggregate Substitute Material in an Asphalt Concrete Pavement, October 2000.

Section 3

PROJECT MANAGEMENT STRUCTURE

To implement the demonstration program, an administrative structure consisting of two groups was established. These two groups were referred to as the Project Management Team, and the Technical Work Group.

The Project Management Team (PMT) was responsible for all policy, contractual, financial and technical decisions associated with the project. It consisted of the five primary participating agencies (see Figure 3-1), each of which was able to exercise a veto over any activity regarded as ill-conceived or liable to result in political or fiscal liability.

The Technical Work Group (TWG) was charged with advising the PMT regarding technical issues and for the implementation of all day-to-day activities. It consisted of a primary management-engineering consultant and supporting technical consultants from both the private sector and government agencies.

PMT and TWG participants as well as supporting agencies are shown in Figure 3-1.

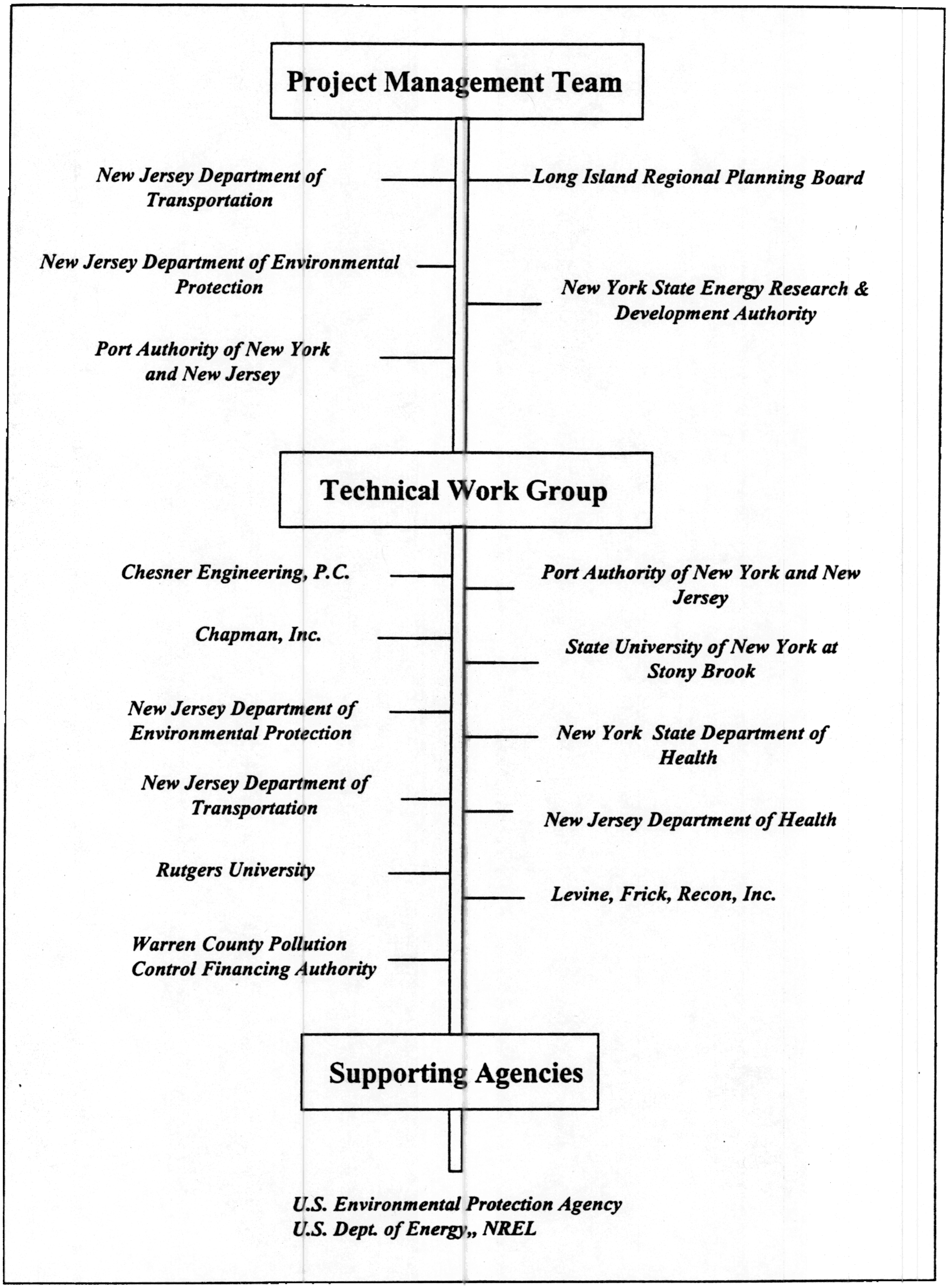

Figure 3-1. Project Management Structure

Section 4

BOTTOM ASH CHARACTERISTICS

Engineering Properties

Test Plan

Bottom ash was sampled and characterized during the course of the testing and demonstration program in order to determine the engineering properties of Warren County ash to be used in the demonstration. Engineering properties testing, undertaken by the New Jersey Department of Transportation, included gradation, particle strength, durability, particle shape, moisture content, specific gravity and adsorption, loose unit weight, adherent fines, and plasticity.

Findings

A summary of the results of the analyses for the above-referenced properties is presented in Table 4-1. More detailed discussion of the sampling procedures, analytical testing procedures, and the results of the engineering property testing program are presented elsewhere.[6]

The results of these analyses indicate that bottom ash is, in general, a sandy, silty, lightweight, nonplastic, highly absorptive material with marginal particle strength and durability. The moisture content of bottom ash is high when compared with conventional aggregate materials. Of particular interest were the high absorptive properties and moisture content of the ash. High absorptive properties of the ash could be expected to increase the asphalt cement requirement of the mix design, and high moisture contents could be expected to result in reduced production rates and greater energy requirements (drying) during the asphalt production process. These findings and conclusions were verified in subsequent asphalt mix testing conducted by the New Jersey Department of Transportation[6] and during the ash-modified mix production process.[7]

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[6] Field Assessment of the Engineering Effects of Using Municipal Waste Combustor Bottom Ash as an Aggregate Substitute Material in an Asphalt Concrete Pavement, May 2000.

[7] Field Assessment of Stack Emissions when Municipal Waste Combustor Bottom Ash is Introduced as an Aggregate Material in the Hot Mix Asphalt Production Process, May 2000

Table 4-1 Summary of Physical Properties of Warren County Bottom Ash							
Property	**Description or Value**						
Gradation	**3/4 in**	**1/2 in**	**3/8 in**	**No. 4**	**No. 8**	**No. 30**	**No. 200**
[illegible]	100	97	91	69	54	28	9.3
[illegible]							
[illegible]	23 – 40						
[illegible]							
[illegible]	7.3 – 14.4						
Specific Gravity (SG) and Adsorption							
Coarse							
Bulk SG	2.28 – 2.34						
Saturated Surface Dry SG	2.38 – 2.46						
Apparent SG	2.53 – 2.66						
Adsorption	4.4 – 5.8						
Fine							
Bulk SG	1.95 – 2.08						
Saturated Surface Dry SG	2.22 – 2.33						
Apparent SG	2.67 – 2.77						
Adsorption (%)	12.0 – 13.7						
Loose Unit Weight							
[illegible]	65.5 – 65.7						
[illegible]							
[illegible]	5 – 7						
[illegible]							
[illegible]	Non-plastic material						

Environmental Properties

<u>Test Plan</u>

Bottom ash was also sampled and characterized during the course of the testing and demonstration program in order to determine the environmental properties of the ash to be used in the demonstration. Environmental properties testing, undertaken by the New Jersey Department of Environmental Protection, the New Jersey Department of Health, the State University of New York at Stony Brook, and the New York State Department of Health, included heavy metal analyses, dioxin and furan analyses, priority pollutant analyses, and leachate analyses.

Findings

A listing of the summarized results of trace metal and trace organic analyses is presented in Table 4-2. More detailed discussion of the sampling procedures, analytical testing procedures, and the results of the environmental testing program are presented elsewhere.[8]

Table 4-2
Summary of Chemical Properties of Warren County Bottom Ash

Trace Metals (mg/kg)	As	Ba	Cd	Cu	Cr	Pb	Hg	Ni	Ag	Zn
Mean Values	17	727	28	2350	132	1450	0.55	145	10	4450
Dioxin and Furan (μg/g)										
Toxic Equivalent	.0076 - .0080									
Semi-Volatile Organics (ng/g)										
Dibenzofuran	7-8									
Diethylpthalate	17-23									
Flourene	13-17									
Phenanthrene	56-82									
Anthracene	12-14									
D-N-Butyl Pthalate	69-140									
Flouranthene	2-40									
Pyrene	27-46									
Butly Benzyl Pthalate	82-140									
Bis (2-Ethylexyl) Pthalate	580-710									
Di-N-Octyl Pthalate	49-65									
N-Nitroso-N-Propylamine[1]	≤7801									
Napthalene	49-81									
2-Methylnapthalene	13-25									
Acenapthylene	15-27									

Trace metal concentrations in bottom ash were found to be at levels that are greater than those typically encountered in conventional aggregate materials. Of particular note are concentrations of barium (Ba), copper (Cu), lead (Pb), and zinc (Zn). Concentrations of these metals in bottom ash exceed New Jersey residential soil cleanup levels. Trace organic concentrations (dioxins and furans and semi-volatile organics) were found to be significantly less than New Jersey residential soil cleanup levels.

While trace metal concentrations were found to be relatively high, leachate test results using distilled water or synthetic acid rain yielded data that showed that the expected availability or potential release of these trace metals into rainwater or runoff during storm events were very low. Concentrations of all trace metals in these leaching tests, with the exception of lead, were

[8] Municipal Solid Waste Combustor Bottom Ash Stockpile Runoff and Dust Emissions Evaluation, May 1997.

below drinking water criteria levels. Lead levels were found to be slightly higher than drinking water criteria.

When subjected to acidic conditions (e.g., pH less than 5), or to highly alkaline conditions (e.g., pH greater than 10) in laboratory tests, lead and cadmium solubility were significantly modified. Lead became more available in both acidic and alkaline environments, while cadmium became more available in acidic environments.[9]

[9] Highly acidic conditions would not be expected in a typical pavement or ash stockpile environment. However, the potential for highly alkaline conditions were found to be present when combined ash, containing highly alkaline fly ash, was introduced into bottom ash. For this reason and due to the presence of higher levels of trace metals and trace organics present in the fly ash fraction, combined ash was not considered to be a suitable material for use in pavement construction applications.

Section 5

STOCKPILE DEMONSTRATION

General Description

In the fall of 1992, two 65-foot square asphalt concrete pads were constructed at the Warren County Landfill to store the processed bottom ash during the stockpile demonstration evaluation period. One pad was used to store the 360-ton bottom ash stockpile. The second pad was used as a control test pad. Each pad was constructed with a runoff drainage and collection system and curbing along the periphery to contain and divert runoff into sampling containers and the landfill's leachate collection system. An air monitoring plan and network of air samplers were put in place to monitor air quality around the stockpile. The purpose of this demonstration program was to assess potential impacts to surface water, groundwater, air quality, and soil quality from a bottom ash stockpiling operation.

Test Plan

To prepare the ash for use in the demonstration, bottom ash from the Warren County Resource Recovery Facility (WCCRF) was collected separately from the fly ash, loaded into roll off containers and transported to the Warren County Landfill. It was stored for 14 days in order to permit it to dry sufficiently to facilitate screening and ferrous metal removal operations. Approximately 360 tons of minus 3/4-inch material was then placed on the specially constructed 65-foot by 65-foot curbed asphalt concrete pad, equipped with a leachate and runoff collection system.

Figure 5-1 presents a schematic of the plan and profile view of the pad's general design dimensions and drainage system. Construction of the pad was completed in October 1992, and bottom ash was placed on the pad on December 7, 1992. Figure 5-2 presents a photograph of the bottom ash stockpile.

A comprehensive sampling and laboratory-testing program was undertaken to characterize the bottom ash, stockpile runoff, air quality, and soil quality in the vicinity of the stockpile. Three laboratories participated in the effort. They included the New Jersey Department of Environmental Protection Laboratory in Trenton, New Jersey, the New York State Department of Health Laboratory in Albany, New York, and the State University of New York Waste Management Institute Laboratory in Stony Brook, New York. A more detailed description of

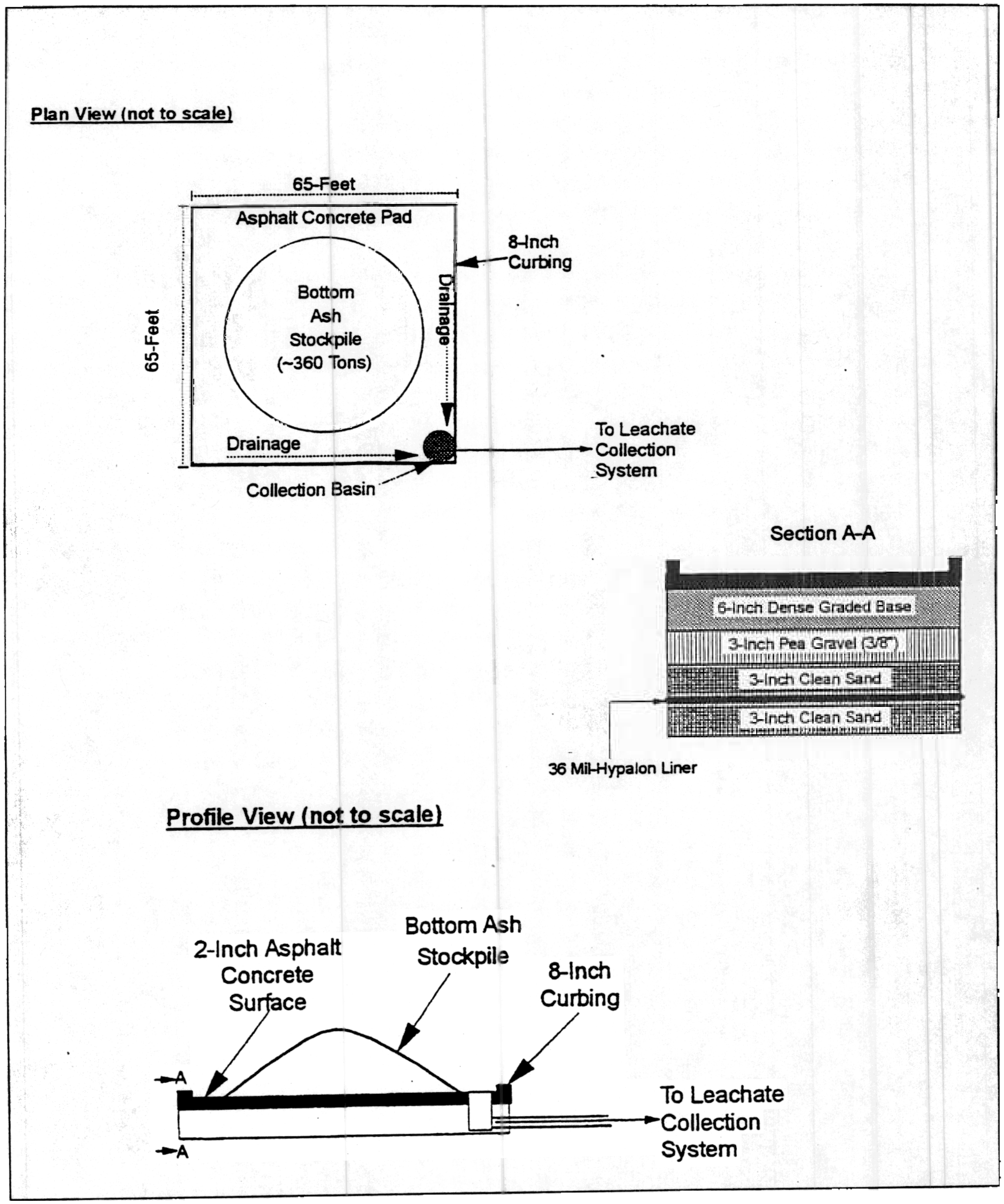

Figure 5-1. Plan and Profile View
Bottom Ash Stockpile Pad

Figure 5-2. Bottom Ash Stockpile and Stockpile Pad

sampling procedures, analytical testing procedures, and the results of the stockpile demonstration program are presented elsewhere.[10]

Bottom ash was collected from the stockpile for trace metal characterization testing on 19 separate occasions between December 1992 and December 1993. Runoff and precipitation samples were collected during a total of 35 and 10 storm events, respectively.

A soil quality sampling and testing program was conducted to assess the impact of ash stockpiling on the levels of trace metals in soils adjacent to the stockpile pad area. Soil samples adjacent to the stockpile were collected at approximately six and eleven months following stockpile construction.

An air-monitoring program was designed and implemented to measure fugitive dust emissions associated with the processing of bottom ash and the maintenance of the stockpile. Total suspended particulates (TSP) and trace metals associated with total suspended particulates were measured at monitoring stations located upwind and downwind of the bottom ash stockpile site.

[10] Municipal Solid Waste Combustor Bottom Ash Stockpile Runoff and Dust Emissions Evaluation, May 1997

In addition, respirable particulate matter (PM_{10}), total suspended particulates (TSP), particle gradation and trace metals associated with the total suspended particulates were monitored during ash processing activities (screening and magnetic separation prior to placement of the stockpile) and during stockpile turnover events.[11]

Findings

Summarized results of metal concentrations detected in stockpile runoff are presented in Table 5–1. The results indicate that average runoff concentrations of lead (Pb) were approximately three to four times higher than USEPA drinking water standards. Average sodium (Na), manganese (Mn), chloride (Cl) and sulfate (S) runoff concentrations were also higher than USEPA standards. No release of trace organics (e.g., dioxin and furan, volatile or semi-volatile organics) was detected during the demonstration.

On the two occasions when soil samples were collected in the vicinity of the stockpile (June 1993 and November 1993), elemental concentrations in the soils adjacent to the stockpile were found to be comparable to values typically present in New Jersey soils. No measurable increase in the trace metal concentration of soils adjacent to the stockpile was detected during the course of the demonstration.

Air monitoring results revealed no measurable differences between ambient air total suspended particulates (TSP) and trace metal concentrations upwind and downwind of the bottom ash stockpile site during static monitoring periods. Measured ambient air TSP concentrations in the vicinity of the bottom ash stockpile were similar to TSP concentrations reported at other air monitoring stations in New Jersey and were below the New Jersey annual average TSP criteria of 75 $\mu g/m^3$. The average TSP concentration downwind of the bottom ash stockpile was 62 $\mu g/m^3$.

During bottom ash processing periods, measured PM_{10}[12] dust concentrations and TSP trace metal concentrations were significantly below Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs). While visible dust emissions were observed during stockpile turnover periods during warm dry weather conditions and while a measurable increase in

[11] A stockpile turnover event was an activity in which the stockpile was turned for a 6 to 8 hour period with a front end loader to simulate material handling to determine the effects of heavy equipment handling activities on the air quality in the worker environment.
[12] PM_{10} – respirable particles (particles less than 10 microns in size).

ambient PM_{10}, TSP and TSP trace metals concentrations was detected during these events, the PM_{10} concentrations detected were one to two orders of magnitude, the TSP concentrations detected were at least two orders of magnitude, and the TSP trace metal concentrations detected were several orders of magnitude below OSHA PELs, respectively.

Table 5-1
Metal Stockpile Runoff Concentrations
(mg/L)

Parameter	Dissolved		Total		USEPA DWL[3]
	Avg.[1]	SD.[2]	Avg.[1]	SD.[2]	
Ag	0.010	0.001	0.010	0.001	0.1
Al	0.17	0.39	2.1	3.3	0.2
As	0.00104	0.00003	0.0029	0.0033	0.05
Ba	0.065	0.039	0.087	0.062	2
Be	0.0028[4]	0.0036	0.0031[4]	0.0036	0.004
Ca	172	80	241	310	-
Cd	0.0052[4]	0.0026	0.0066[4]	0.0065	0.005
Cr	0.026[4]	0.012	0.026[4]	0.012	0.1
Cu	0.10	0.11	0.30	0.41	1.3
Fe	0.04[4]	0.03	0.48	0.69	0.3
Hg	<0.0010	-	<0.0010	-	0.002
K	129	87	135	92	-
Mg	36	44	37	43	-
Mn	0.12	0.15	0.17	0.17	0.05
Na	390	260	390	280	50
Ni	0.049[4]	0.005	0.053[4]	0.014	0.1
Pb	0.056[4]	0.014	0.24	0.31	0.015
Se	0.0015	0.0016	0.0021	0.0030	0.05
Si	1.0	0.8	1.9	2.1	-
Zn	0.11	0.08	0.54	0.86	-
Solids	2400	1300	3500	1500	500
Cl	660	380	-	-	250
SO_4	740	430	-	-	250

1. Avg = average of 35 events.
2. SD = standard deviation of 35 events.
3. United States Environmental Protection Agency drinking water limits.
4. Over 80 percent of the values used to calculate the average concentrations were method detection limit values.

Section 6

ASPHALT PLANT MONITORING DEMONSTRATION

General Description

On June 19 and 20, 1996, an asphalt plant monitoring demonstration was undertaken at the Mt. Hope Asphalt Plant in Wharton, New Jersey. The purpose of the demonstration was to assess the impact of introducing municipal waste combustor bottom ash into an asphalt production facility and its effect on the quality of baghouse dust and air emissions produced at the asphalt facility during the asphalt production process. The Mt. Hope Asphalt Production facility used in the demonstration is a countercurrent drum mix facility with a baghouse for air pollution control. A schematic of the general process flow of the Mt. Hope Plant is presented in Figure 6-1.

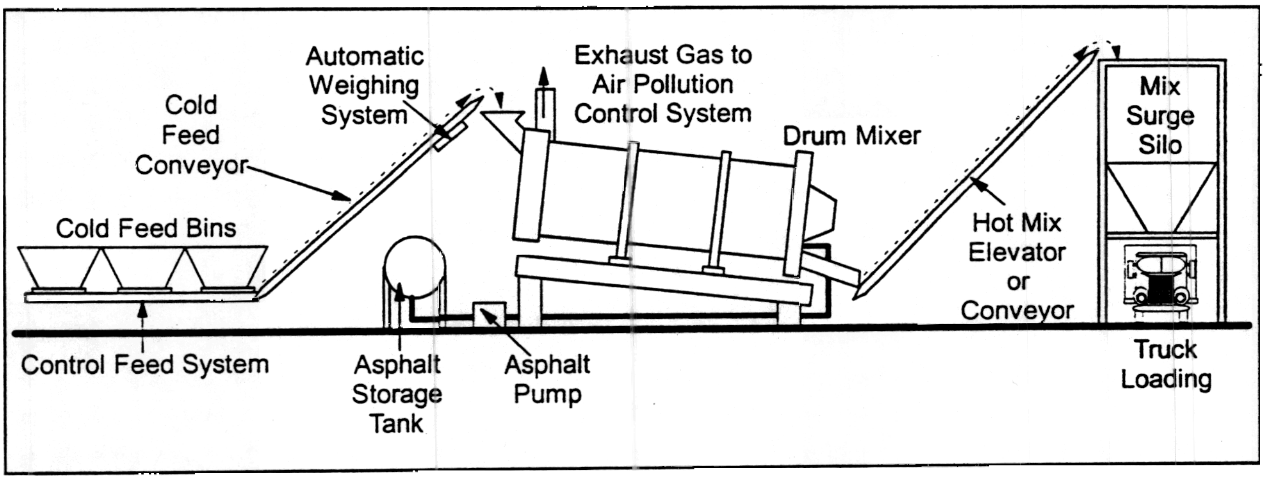

Figure 6-1. Mt. Hope Drum Mix Plant Components

The major component of an asphalt production facility is the dryer. The Mt. Hope plant dryer is 9.75 feet in diameter and 44 feet in length. The dryer is designed to dry aggregate materials prior to blending with asphalt cement. Drying is accomplished by passing hot air through the aggregate at a velocity of 800 to 1000 feet per minute. This air flow exits the dryer and is routed through the facility's air pollution control system (i.e., baghouse) to remove particulate matter prior to its release through the stack to the atmosphere. At the relatively high air flow velocities that occur within an asphalt plant dryer, a large fraction of the small, lightweight particles can be expected to be entrained and transported to the baghouse where they are filtered out of the air mass.

The June 1996 demonstration included a baghouse dust monitoring program and a stack emission monitoring program. Baghouse dust and stack emission samples were also taken during the control run, in which only natural aggregate materials were used, in order to compare the two test runs. A more detailed description of monitoring procedures, analytical testing procedures, and the results of the asphalt plant demonstration program are presented elsewhere.[13]

Findings

The results of the baghouse dust sampling and testing program indicated that a relatively high fraction (5 to 20 percent) of bottom ash particles introduced into the dryer were transported from the dryer to the baghouse. This carryover of bottom ash particles from the dryer into the baghouse resulted in the production of baghouse dust that contained levels of trace metals (cadmium, copper, lead, zinc, and mercury) that were approximately one to two orders of magnitude higher than trace metal levels detected in the baghouse dust during the control run. Concentrations of dioxin and furan toxic equivalents were also found to be approximately one order of magnitude higher in the ash-aggregate baghouse dust than in the control dust. Although trace metal concentrations were elevated, Toxicity Characteristic Leaching Procedure (TCLP) test results for both the ash-aggregate and control test runs indicated that the extracts of both dusts were within the regulatory limits of the TCLP test criteria (were non-hazardous materials).

Particulate emissions from the asphalt production facility during the production of the ash-aggregate pavement and the control pavement were found to be excessive (in excess of NJDEP permit criteria), suggesting that the air pollution control system (baghouse) was operating poorly during the demonstration. Trace metal emissions from the stack (arsenic, cadmium, lead, copper, and zinc), during the ash-aggregate test run were also found to be one to two orders of magnitude higher than during the control test run. These high trace metal emissions during the ash-aggregate test run were attributed to the carryover of fine ash particles from the dryer to the baghouse, followed by the release of metal-laden ash particles from the baghouse.

A New Jersey Department of Environmental Protection risk screening procedure was undertaken using the emission data recorded during the demonstration. The results suggested that trace metal emissions from the asphalt plant during the demonstration program, given the poor performance of the baghouse, were significantly higher than would be acceptable.

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[13] Field Assessment of Stack Emissions When Municipal Waste Combustor Bottom Ash Is Introduced As An Aggregate Material in the Hot Mix Asphalt Production Process, May 2000.

The results of this New Jersey demonstration were compared with a somewhat similar asphalt plant monitoring demonstration performed in New Hampshire. Excessive metal emissions from the stack were not evident in the New Hampshire demonstration, where particulate emissions from the stack were more efficiently controlled.

The results of the New Jersey demonstration revealed that the introduction of waste or by-product materials into an asphalt production facility with poor particulate emission controls could result in the release of by-product material particles up the stack. If such particles are enriched in trace metals or trace organics, then such emissions could result in air emission problems.

Section 7

ROADWAY DEMONSTRATION

General Description

On June 19, 1996, approximately 102 dry tons of processed municipal waste combustor ash from the Warren County Resource Recovery Facility (WCRRF), located in Warren County, New Jersey, was substituted for an equal amount of natural aggregate in the production of a surface paving mix at the Mt. Hope Asphalt facility in Wharton, New Jersey. The ash-modified asphalt concrete (a total of 835 tons) produced at this asphalt plant was transported to Center Drive in Elizabeth, New Jersey, where it was placed and compacted as a surface pavement overlay. A control pavement, manufactured using conventional aggregate materials, was produced on June 20 and installed adjacent to the ash-modified pavement. A location map identifying the site of the demonstration roadway is presented in Figure 7-1. A general site layout diagram showing the ash-modified pavement and the control pavement is presented in Figure 7-2. A view looking north at the Center Drive pavement from North Avenue is depicted in the photograph in Figure 7-3.

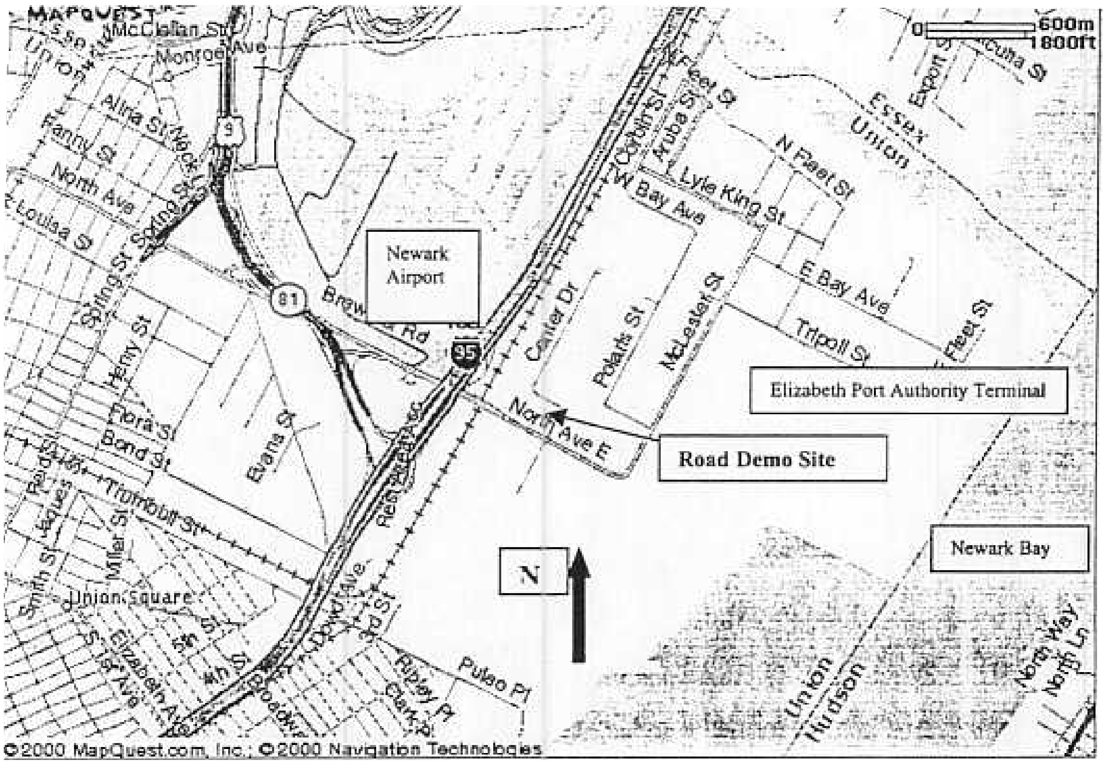

Figure 7-1: Roadway Demonstration Site Location

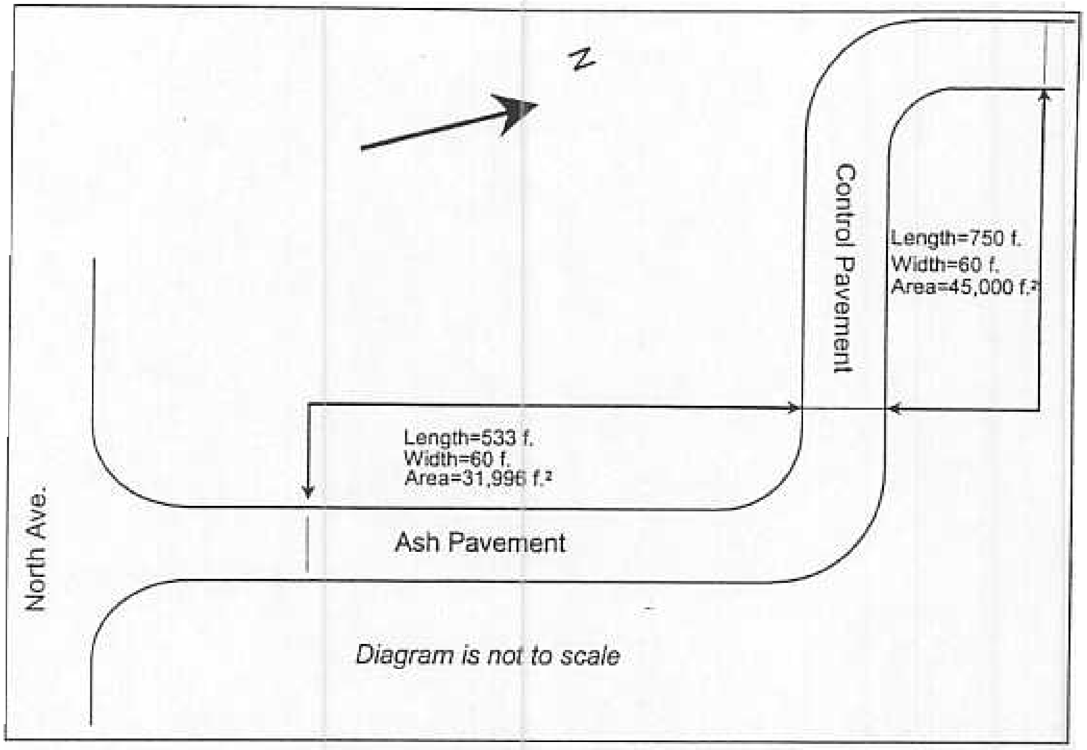

Figure 7-2: Site Layout

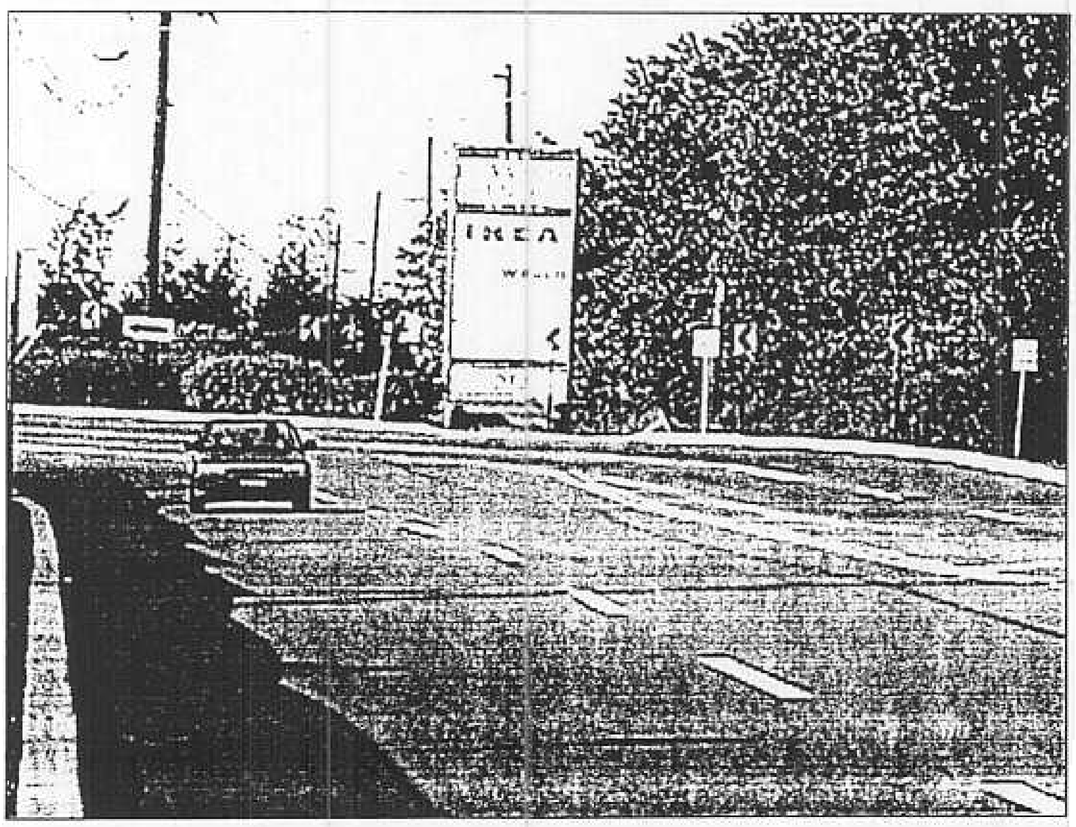

Figure 7-3: Ash-Modified Pavement Section Facing North on Center Drive

During the 24-month period following the installation of the pavements, each pavement was subjected to comprehensive engineering and environmental surveys and analyses. Traffic during this period averaged approximately 2,750 vehicles per day, with weekend traffic of approximately 7,600 vehicles per day. Passenger cars comprised approximately 90 percent of the traffic. More detailed information relative to the engineering analyses, environmental analyses, and traffic surveys conducted during the demonstration is presented elsewhere.[14]

Engineering Demonstration

Test Plan

Both the ash-modified and control pavements were subjected to physical tests and visual surveys for the 24-month period following the installation to assist in assessing the engineering effects of introducing processed municipal waste combustor bottom ash into a New Jersey Department of Transportation (NJDOT) asphalt concrete surface mix.

The engineering evaluation program included the implementation of two traffic surveys, five condition surveys, four pavement sampling periods during which roadway samples were extracted for pavement thickness, in-place voids, bulk specific gravity, maximum specific gravity, asphalt cement content and gradation testing, and five surveys in which skid testing, roughness (ride quality) testing, rutting and stiffness testing were conducted.

Findings

The results of the 24-month field evaluation indicated that the structural performance of the ash-modified pavement was very much the same as that of the control pavement. Higher in-place voids content were present in the ash-modified pavement; however, this was attributed to the asphalt cement content of the ash-modified pavement, which may not have been sufficient to coat and penetrate the highly absorptive ash particles. Care must be taken in the design and production of ash-modified pavements to ensure a proper asphalt cement content.

While screened (less than 3/4-inch size fraction) bottom ash in laboratory tests exhibited marginal particle strength when compared to conventional aggregate materials, this lower strength did not negatively manifest itself during the demonstration evaluation. The primary

[14] Field Assessment of the Engineering Effects of Using Municipal Waste Combustor Ash as an Aggregate Substitute in Asphalt Concrete Pavement, May 2000.

difference between the ash-modified and control pavement was the noticeable presence of foreign material and pop-outs in the surface of the ash-modified pavement. The foreign material that was present consisted of glass, ceramics and metal. Figure 7-4 presents a photograph of a metal wire extruding from the pavement.

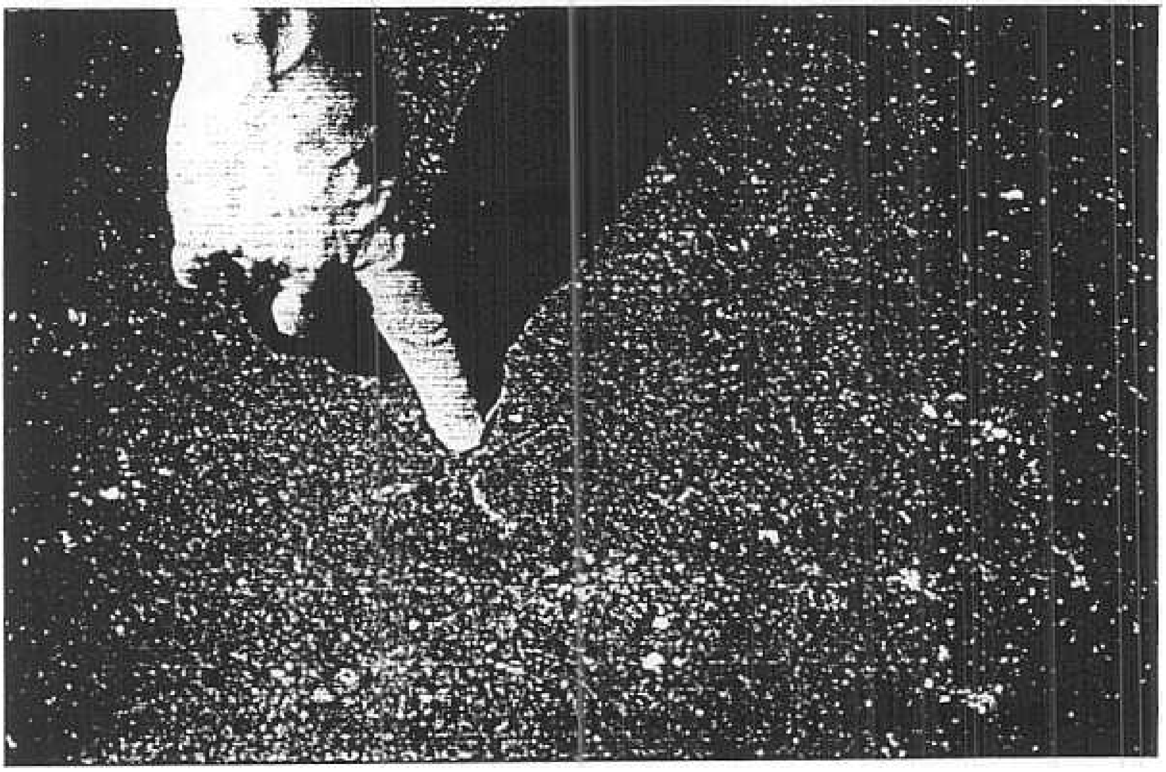

Figure 7-4: Steel Wire Protruding from Ash-Modified Pavement

Pop-outs, a term that is used to characterize the loss of aggregate or particulate matter from the pavement surface, were present and were attributed to the presence of metal and glassy particles contained in bottom ash near the surface of the pavement. Metal oxidation, which results in particle expansion, and glassy particle stripping of the asphalt binder are the two mechanisms that are believed to promote pop-out activity. Although extensive pop-out activity could eventually lead to deteriorating conditions at the pavement surface, major deterioration was not observed during the 24-month survey. This was attributed to the low fraction of bottom ash (approximately 14%) incorporated into the pavement.

Environmental Demonstration

Test Plan

Both ash-modified and control pavements were monitored for a 24-month period following the installation to determine whether any differences between the two pavements in respect to runoff quality and subsurface leaching could be detected.

The environmental monitoring program on Center Drive involved the collection and testing of rainfall and runoff samples from the demonstration pavements, the collection and testing of sediment/particulate matter associated with the runoff, the collection and testing of subsurface water samples, base course aggregates, subsurface soils, and the chemical analysis of the aggregate component of asphalt cores collected from both the ash-modified and control pavements.

Three test pavement sections were installed on Center Drive. They included, a control (conventional pavement) section (Section A), a bottom ash (ash-modified pavement) section (Section B), and a buffer section (Section C). The locations of each of these respective sections on Center Drive are shown in Figure 7-5. Sections A and B were the primary test sections. Section C, the buffer section, contained excess paving materials (i.e., both ash-modified and conventional pavement) that was available during construction and was used to overlay the pavement from the end of Section B (the ash-modified pavement) to the end of the demonstration section.

Each section was constructed with concrete curbing along the periphery of the roadway to segregate extraneous runoff from pavement runoff, and the pavements were sloped to permit isolation and collection of runoff from each section for sampling.

Rain gauges, automatic sampling, and flow monitoring equipment were installed in each section to collect precipitation and runoff samples and to record runoff flow rates. Lysimeters were also installed below the pavement sections to collect subpavement groundwaters. Figure 7-6 shows a photograph of one of three automatic samplers that were installed on Center Drive as part of the field monitoring effort.

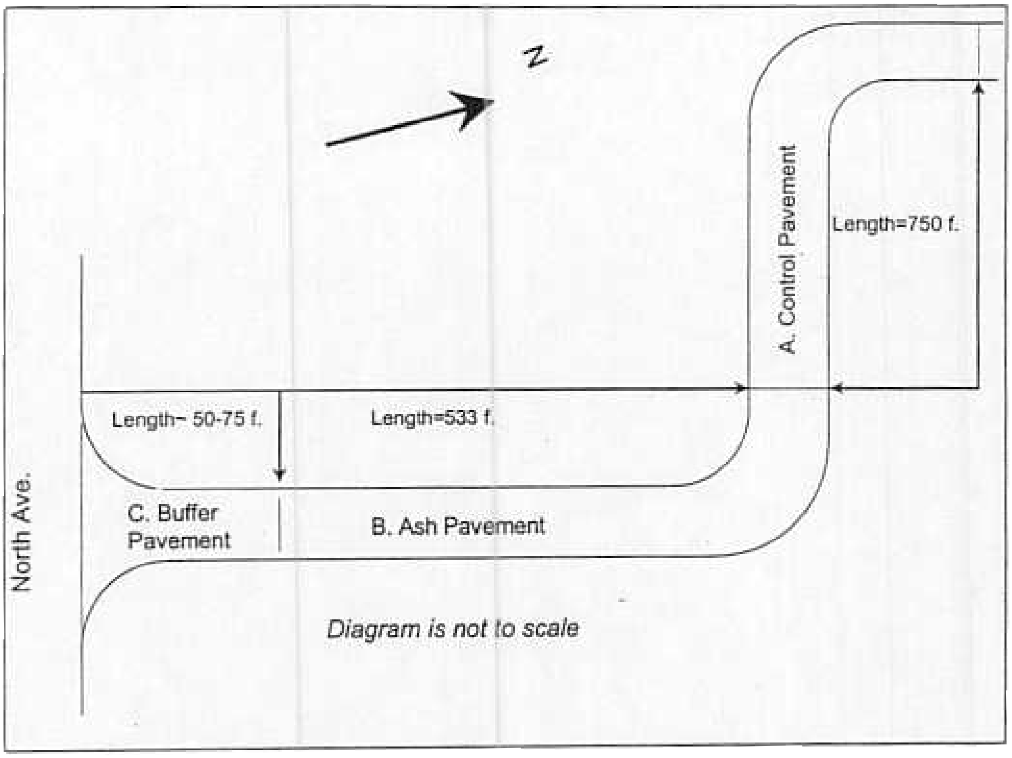

Figure 7-5. Monitored Runoff Demonstration Pavement Section

Findings

An analysis of 24 months of data revealed no statistical differences between trace metal runoff concentrations detected in the runoff from the control pavement and the runoff from the ash-modified pavement. No statistical differences were detected between concentrations of trace metals in the sediment collected from the runoff of the ash-modified pavement and concentrations detected in sediment collected from the runoff of the control pavement.

While some statistical differences were detected in the subsurface water samples beneath the ash-modified and control pavements for selected elements, and some statistical differences were found for selected elements in the dense graded aggregate base and subbase soils below the ash-modified and the control pavements, these differences were not attributed to the introduction of ash into the pavement.

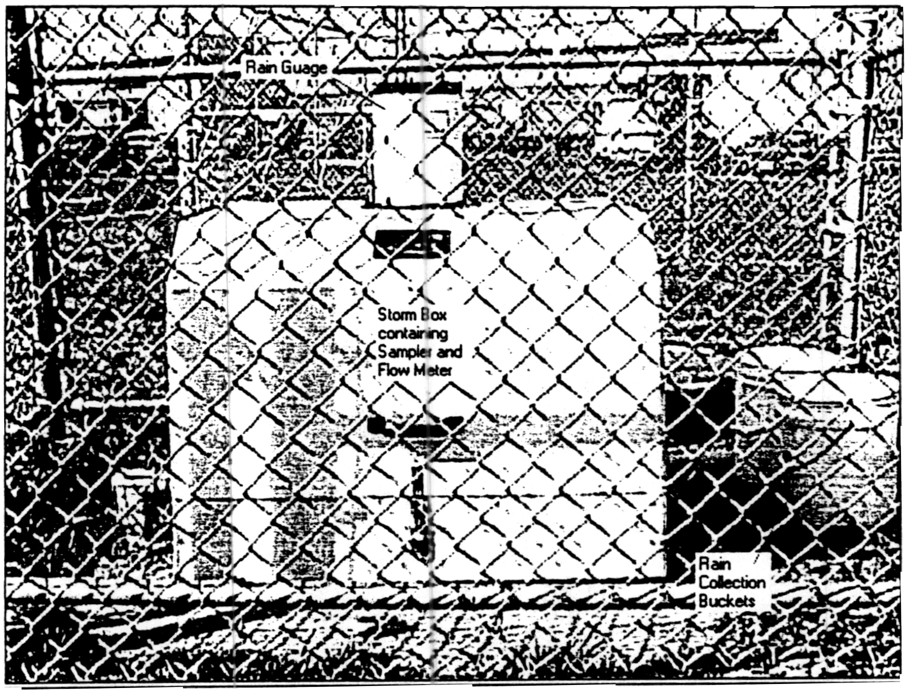

Figure 7-6: Monitoring and Sampling Equipment

Section 8

CONCLUSIONS AND RECOMMENDATIONS

This section presents some of the conclusions associated with the findings presented in Section 5 (the Stockpile Demonstration), Section 6 (the Asphalt Plant Monitoring Demonstration), and Section 7 (the Roadway Demonstration). These conclusions are followed by recommendations concerning the future disposition and management of ash as an aggregate substitute material in asphalt concrete paving mixtures.

Conclusions

Stockpile Demonstration

Bottom ash stockpiles and processing activities can be expected to result in environmental impacts comparable to those of conventional aggregate stockpiling facilities. These impacts include some increase in ambient air particulate levels, but these impacts can readily be contained by conventional dust control measures. The runoff from bottom ash stockpiles can be expected to be rich in salts, and also exhibit some increase in lead concentration. As a result, some measure of runoff control should be practiced. In addition, the relatively high levels of trace metals (particularly lead) in the bottom ash could result in an increase in trace metal concentration of soils adjacent to a stockpile site, if the stockpile is not contained and uncontrolled spreading of the bottom ash is permitted.

Asphalt Production Facility Demonstration

If bottom ash is introduced into an asphalt production facility, extra care must be exercised to ensure that the air pollution control system (baghouse) is performing properly. Fine particulate matter associated with the bottom ash can be expected to carry over from the asphalt plant dryer to the baghouse and be released with the stack gas if the baghouse is not secure.

Roadway Demonstration

With the exception of some surficial defects due to popouts and some glass stripping, the engineering performance of an ash-modified (14% bottom ash) overlay can be expected to be similar to that of a conventional pavement. Runoff and leachate from ash-modified (14% bottom ash) overlay can be expected to be similar to those of a conventional pavement.

Recommendations

Although the production of bottom ash-modified pavements (containing 14% bottom ash) can produce an asphalt pavement that will perform in a satisfactory manner, the findings and conclusions of the demonstration yielded results that suggest that uncontrolled widespread use of bottom ash in all pavements and in all environments is not a viable option at the present time.

Although bottom ash can be processed and stockpiled as a conventional aggregate material, it is recommended that locations for bottom ash processing and stockpiling be selected to control and prevent potential impacts due to high salt runoff or increased levels of trace metal (lead) in the runoff. Such locations should also be controlled to prevent the spreading and mixing of the bottom ash with a clean soil environment. It is recommended that ashfill or solid waste landfill sites be the primary sites for an ash stockpiling operation.

Although bottom ash can be used in the asphalt production process to produce an asphalt concrete mix that is suitable for paving, it recommended that prior to the introduction of municipal waste combustor bottom ash into an asphalt production facility, the facility be subjected to pre-testing to ensure that particulate emission removal efficiencies are satisfactory and excessive trace metal and organics will not be released. It is also recommended that regular monitoring of such facilities (facilities that incorporate municipal waste combustor ash) be undertaken to ensure that high air pollution control efficiencies are being maintained.

From an engineering perspective, the 24-month monitoring program data suggest that an ash-modified pavement containing approximately 14 percent bottom ash, screened to less than ¾ inch in size and with ferrous metal removed, can be expected to perform in a satisfactory manner. However, due to the presence of surficial defects resulting from pop-outs and the presence of foreign matter in the ash-modified pavement, unless sufficient processing of the ash is undertaken to remove almost all of the ferrous metal and to reduce the glassy particles down to a sand-size (where stripping would be less of a concern), it is recommended that bottom ash be considered primarily for use in subsurface asphalt pavement applications (base or binder courses). This would eliminate any concern over the surficial defects observed in this evaluation.

From an environmental perspective, the results of the 24-month demonstration program suggest that as long as the pavement is structurally intact, an ash-modified bottom ash pavement containing less than 14 percent bottom ash will generate runoff that is statistically similar in quality to that of conventional pavements, and will not impact subsurface water or soil quality