DOE/MC/28060-94/C0276

Truck Ramp Construction From Clean Coal Technology Waste Products

Authors:

W.E. Wolfe

J.H. Beeghly

Contractor:

Dravo Lime Company

3600 Neville Road

Pittsburgh, PA 15225

Contract Number:

DE-FC21-91MC28060

Conference Title:

Symposium on Recovery and Effective Reuse of Discarded Materials and By-Products for Construction of Highway Facilities

Conference Location:

Denver, Colorado

Conference Dates:

October 19-22, 1993

Conference Sponsor:

Federal Highway Administration

and

U.S. Environmental Protection Agency

DISCLAIMER

Presented at Symposium: Recovery and Effective Reuse of
Discarded Materials and By-Products for Construction of Highway Facilities
Sponsored by: Federal Highway Administration and Environmental
Protection Agency, Denver, Colorado, October 19-22, 1993

TRUCK RAMP CONSTRUCTION FROM CLEAN COAL TECHNOLOGY WASTE PRODUCTS

Conf-9310272--1

William E. Wolfe
Department of Civil Engineering
The Ohio State University
Columbus, Ohio 43210

Joel H. Beeghly
Dravo Lime Company
Research Center
3600 Neville Road
Pittsburgh, Pennsylvania 15225

ABSTRACT

The construction and performance of a truck ramp made from clean coal technology waste products are described. The specific waste product used in this project was generated at the power plant located on the campus of The Ohio State University in Columbus. The ramp is used by University vehicles depositing hard trash at a central disposal facility on the OSU campus.

Laboratory tests which had been conducted on samples made from the power plant waste product clearly showed that, when the material is properly compacted, strengths could be obtained that were much higher than those of the natural soils the clean coal waste would replace. In addition, the permeability and swelling characteristics of the waste product should make it an attractive alternative to importing select borrow materials.

Based on the results of the laboratory tests, a decision was made to use the power plant waste in the truck ramp rather than the soil that was called for in the original design. Prior to the start of construction, the area on which the ramp was to be located was covered with an impermeable geomembrane. Drain lines were installed on top of the geomembrane so that water that might leach through the ramp could be collected. The waste product from the power plant was placed on the geomembrane in 20 to 30 centimeter lifts by University maintenance personnel without special equipment. A drain line was installed across the toe of the ramp to intercept surface runoff, and a wearing surface of 7 to 15 centimeters of crushed limestone was placed over the compacted ash. The finished ramp structure recycled approximately 180 metric tons of the power plant by-product.

Tests conducted on the ramp material have shown some deviation from the properties measured on laboratory prepared samples, particularly with regard to sample strength. This indicates the properties are sensitive to compacted water content and density. However, after over a year in service there is no indication of erosion or rutting in the ramp surface. Tests performed on the leachate and runoff water have shown the high pH characteristic of these materials, but concentrations of metals fall below the established limits.

The success of the truck ramp should lead to increased acceptance of this class of waste materials in highway and other construction projects. Power generating units that rely on coal, including the Ohio State University which is spending approximately $750,000 annually to dispose of its combustion waste products, should benefit substantially from the alternatives to landfilling that may result from this demonstration project.

INTRODUCTION

The combustion of coal containing sulfur in US power plants is thought to be one of the principal causes of acid rain in North America. Attempts to reduce the environmental threat from sulfur released into the atmosphere resulted in the passage of the Clean Air Act of 1970. This law established emission standards for sulfur dioxide from coal fired power plants. Subsequently, amendments in 1977 and 1990 to the act have considerably strengthened its provisions with respect to allowable levels of atmospheric SO_2, and have resulted in the installation of desulfurization systems at a number of power plants. Typically these desulfurization systems work by injecting a reagent that combines with the sulfur to form a solid compound which can then be collected before the exhaust gas is released to the atmosphere. There are at present two main desulfurization methods; wet scrubbers and dry scrubbers. Currently, the wet processes are the more commonly used procedures for SO_2 removal. In a power plant equipped with a wet scrubber the particulates in the exhaust are first removed and then the gasses are mixed with a slurry of water and the reagent. The reaction of the SO_2 with the reagent creates a paste like waste product which, after it is collected, must be dewatered and then disposed of, usually in a landfill. In the dry scrubber processes, the reagent may be mixed with the coal as the coal enters the furnace, sprayed directly into the furnace, or injected into the exhaust gas stream. The resulting solid waste product is collected and disposed of in a landfill. Current regulations treat the scrubber sludge as a solid waste and require that it be disposed of in a controlled, monitored landfill. At the present time, the direct cost of landfilling may be as low as $12-17 per metric ton in rural areas, but is typically much higher for plants located in or near urban areas (OSU, which has been sending its ash to a sanitary landfill 120 kilometers from campus, is paying $29 per metric ton). The cost of disposal will certainly continue to rise as old landfills are closed and replaced with new facilities.

It is clear that the attempt to clean up the atmospheric pollution that has been associated with the burning of coal has resulted in a new and ever growing solid waste problem. At the present time, the amount of these waste products generated annually in the nation's power plants is estimated to exceed 18.1 million metric tons(1). This volume is projected to increase by an additional 18.1 million metric tons as the provisions in the 1990 amendments take full effect(1). The Department of Energy estimates that the amount of solid waste generated over the life of one 500 MW power plant would fill a 200 hectare disposal pond to a depth of 12.2 meters(2). These volumes of solid waste predicted by the Department of Energy are simply too great to continue to dispose of in what is becoming less and less space for landfills and so a number of groups are looking to identify alternate uses for these flue gas desulfurization (FGD) wastes. Some of the more promising beneficial uses of the FGD by-products include high volume applications such as structural fills for highway embankments, the backfill for retaining walls, and as the select material used in subbases and base courses for roadways.

DESIGN OF AN ENGINEERED EMBANKMENT

The design of an engineered embankment consists of the following components;

1) specifying the design geometry,
2) determining the appropriate engineering properties for the proposed fill material,
3) evaluating the stability of the structure designed in step 1 using the engineering properties obtained for the material in step 2,
4) revising the design as necessary until an adequate degree of safety or minimum acceptable performance is achieved, and 5)during construction, monitoring the activities of the construction crews and, after construction is completed, observing the long term behavior of the embankment.

Table 1 lists in very general terms the requirements to be addressed when designing a highway embankment including the slopes, shoulders and structural backfill placed around a buried culvert.

TABLE 1. SUMMARY OF PROPERTIES AND PERFORMANCE

	Structural Component			
	1	2	3	4
	Embankment	**Slope**	**Shoulder**	**Backfill**
Properties	static stress-strain-strength	same as (1)	static and dynamic stress-strain-strength	same as (1)
Laboratory Tests	Unconfined comp. direct shear, triaxial	same as (1)	same as (1), freeze-thaw	same as
Performance Criterion	settlement	deformation	deformation incl.. rutting	culvert deformation
In-situ Measure-ments	slope indicator tubes plus magnetic collar water quality	same as (1)	dynaflect and/or falling weight deflec-tometer.	same as (1)
Analytical Model	finite element models	finite element plus non-FEM codes	pavement equations	finite element

An evaluation of the engineering characteristics of the candidate material to be used in the embankment must be performed according to accepted procedures. This is particularly important in the case of FGD by-products because the engineer must be able to relate the results obtained in the laboratory for the FGD by-product to the properties of more conventional soils. Laboratory tests conducted in the Civil Engineering Department at The Ohio State University on samples of FGD materials were performed according to the procedures specified in Table 2.

TABLE 2. TEST PROTOCOLS FOR LABORATORY DETERMINATION OF ENGINEERING PROPERTIES OF DRY FGD BY-PRODUCT

Laboratory Procedure	Reference
Optimum Moisture and Density (Standard Proctor Compaction)	ASTM D698-78 [3]
Unconfined Compression	ASTM D2166-85[3]
One-dimensional Swell	ASTM D4546-85[3]
One-dimensional Consolidation	ASTM D2435-80[3]
Falling Head Permeability	4

[3] ***1990 Annual Book of ASTM Standards, Vol. 4.08***

[4] ***Soil Properties Testing, Measurement and Evaluation, 2nd edition***, Cheng Lin and Jack B.Evett, Prentice-Hall Inc., 1990

SOURCE AND PROPERTIES OF THE FGD BY-PRODUCT

The McCracken power plant located on the main campus of The Ohio State University burns coal to generate approximately 62,400 kilograms of steam per hour. The coal used in the OSU facility typically has a sulfur content of 2.5% to 3%. To reduce the SO_2 emissions, slaked lime is used as the reagent in a spray dryer. In fiscal year 1990-91, Ohio State burned a total of 48,740 metric tons of coal and disposed of 26,279 metric tons of ash. The cost to OSU to landfill its ash that year was more than $750,000. Recent local regulations have forced University officials to plan for substantial increases in this cost in the near future. Clearly, the University needs to find alternate uses for the ash from the campus power plant.

Samples of the FGD waste product were collected at different times from the silos as the ash was being loaded onto trucks for disposal. The samples, which were then taken to the laboratory for testing, varied in composition as a function of several parameters, but most importantly in the coal used, the amount of lime injected, and the temperature of the exhaust gasses. The crystalline phases of the OSU FGD by-product as detected by x-ray diffraction are listed in Table 3. The range of measured engineering properties is illustrated by the results shown in Table 4 for four different samples. The FGD waste averaged about 70% flyash and 30% bottom ash. The fly ash fraction contained between 15 and 25% available lime. All laboratory tests were performed on samples made from the FGD ash compacted according to ASTM Standard D698 (Standard Proctor). Athough the results of the laboratory tests vary with the different samples, the data presented in Table 4 clearly show that, in comparison with typical soil properties (shown in Table 5), the compacted FGD by-product is a high strength, low weight material, and that the FGD ash should be an excellent replacement for most natural soils now being used in highway construction. Also, the permeability and swelling properties indicate that the FGD by-product could be a satisfactory alternative to select borrow.

TABLE 3. MINERALOGY OF THE OSU FGD BY-PRODUCT

Sample ID	Major Constituents		Minor Constituents	
OSU-01	$CaCO_3$	Calcite	Fe_2O_3	Hematite
	$Ca(OH)_2$	Portlandite Fe_3O_4	Magnetite	
	$CaSO_3 \cdot 0.5H_2O$	Hemihydrate	SiO_2	Quartz
			$Al_6Si_2O_{13}$	Mullite
OSU-02	$Ca(OH)_2$	Portlandite $CaCO_3$	Calcite	
	$CaSO_3 \cdot 0.5H_2O$	Hemihydrate	Fe_2O_3	Hematite
			SiO_2	Quartz
			$Al_6Si_2O_{13}$	Mullite
OSU-03	$Ca(OH)_2$	Portlandite $CaCO_3$	Calcite	
	$CaSO_3 \cdot 0.5H_2O$	Hemihydrate	Fe_2O_3	Hematite
			SiO_2	Quartz
			$Al_6Si_2O_{13}$	Mullite

Even though the physical properties of the FGD compare very favorably with natural soil, a decision as to whether or not the material can be used in a construction project or must be disposed of in a monitored landfill, is likely to be dependent upon the character of the materials that leach out of the ash. Of particular concern are the eight RCRA metals. Water quality determinations made of leachate obtained from laboratory samples are presented in Table 6.

TABLE 4. ENGINEERING PROPERTIES OF THE OSU FGD BY-PRODUCT

Sample ID	Optimum Density g/cm^3	Optimum Moisture Content %	Compressive Strength kPa, Curing Time (days) 0	7	28	Permeability Coefficient cm/sec ($x10^{-5}$), Curing Time (days) 0	7	28
OSU-01	0.909	50	170.	152.	360.	3.6	1.6	0.76
OSU-02	0.833	68	292.	258.	491.	0.17	***	***
OSU-03	0.845	63	300.	262.	352.	0.74	0.77	0.15
OSU-11	1.056	40	460.	399.	605.	0.42	0.39	0.27

Sample ID	Duration of Swell Test (days)	Swell %
OSU-03A	423	1.97
OSU-03B	272	2.56
OSU-03C	82	1.60

*** not enough of this material remained to perform the test

TABLE 5. TYPICAL ENGINEERING PROPERTIES FOR SOILS [5-9]

Sample ID	Optimum Density g/cm^3	Optimum Moisture Content %	Compressive Strength kPa	Permeability Coefficient cm/sec ($x10^{-5}$)
Silty Clay	2.04	10	117	20
Clay Shale	1.88	10	360	.5
Kaolin Clay	1.66	27	172	.1

Along with the concentrations of the RCRA metals detected in the by-product, Table 6 lists the levels of these metals that can be found in fly ash which qualifies for an exemption from the solid waste regulations. Also listed are the drinking water standards established by the state of Ohio for the same RCRA metals. The concentration of heavy metals in the FGD leachate is seen to be well below the limits allowed by EPA and therefore should not pose a threat to the environment.

However, as thorough as a laboratory program might be, before FGD by-products will be accepted as replacement for the fill soils presently specified in construction plans, their behavior in field demonstration projects must be established. In this paper, one such demonstration of the performance of an FGD by-product in a field application is discussed.

TABLE 6. TOTAL METALS ANALYSIS - LABORATORY SAMPLES[9]

Parameter	Measured Amounts mg/l	Ohio Drinking Water Standard mg/l	Flyash Standard mg/l	Federal/State HW Criteria mg/l
Arsenic (As)	0.	0.05	1.5	5.
Barium (Ba)	0.08	1.00	30.	100.
Cadmium (Cd)	<0.01	0.01	0.3	1.
Chromium(Cr)	<0.02	0.05	1.5	5.
Lead (Pb)	0.05	0.05	1.5	5.
Mercury (Hg)	<0.0002	.002	0.06	0.2
Selenium(Se)	<0.2	0.01	0.3	1.
Silver (Ag)	<0.01	0.05	1.5	5.

FIELD DEMONSTRATION - TRUCK RAMP

A small truck ramp was designed by engineers in OSU's Department of Physical Facilities to provide a location for University vehicles unload hard trash. The ramp was designed to be 17 meters long by 7.5 meters wide by 1.2 meters high at its highest point (Figure 1).

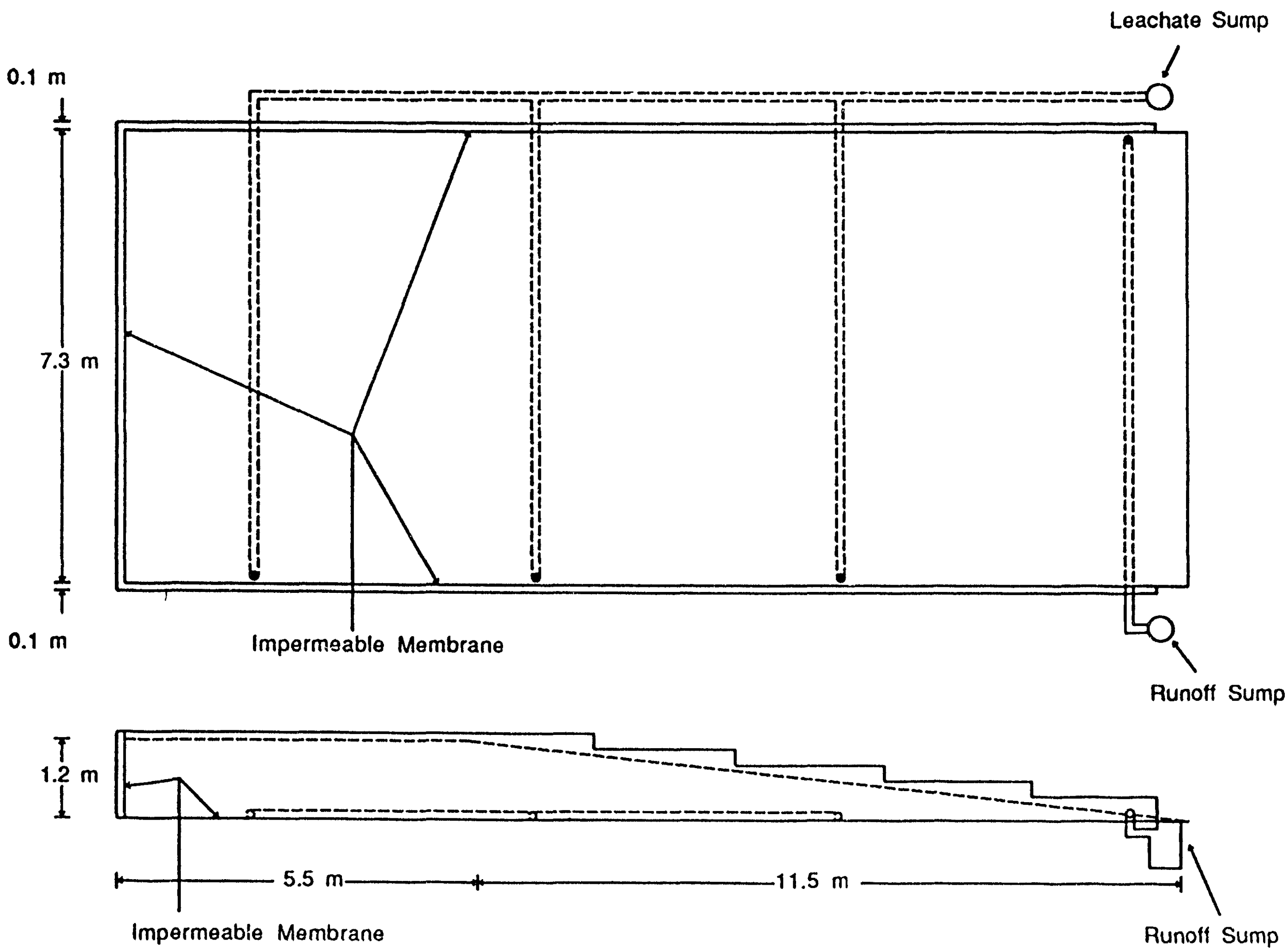

Figure 1. Plan and Elevation Views of Truck Ramp

The by-product was delivered to the construction site by the contract haulers and dumped next to the ramp. The ramp was constructed during July and August, 1992 whenever there was a break in the work schedule of the University maintenance people. Construction of the ramp was performed by University maintenance personnel using only University owned equipment. Figure 2 is a photograph of the ramp's frame, which was constructed from 10cm x 10cm treated lumber covered with a geotextile, before placement of the

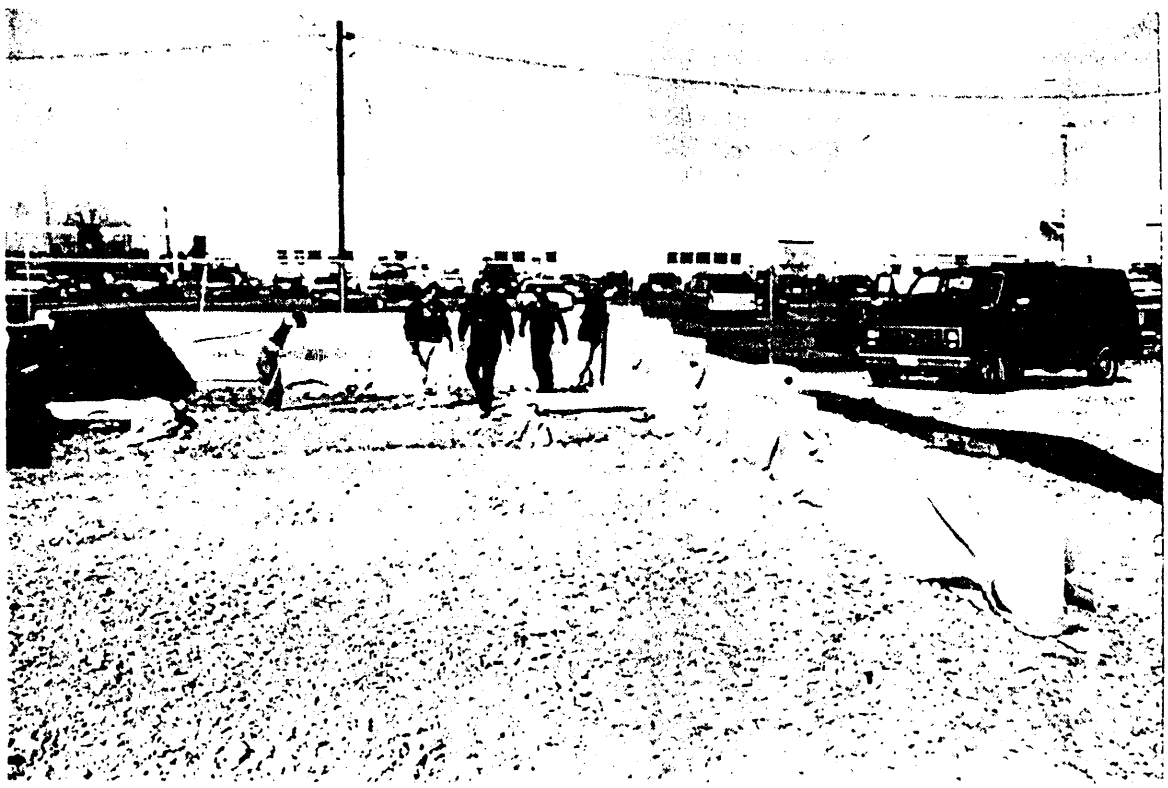

Figure 2. Ramp Framework Prior to any Construction

impermeable geomembrane. In Figure 3, the geomembrane is being placed on the bottom and up the walls of the ramp. Figure 4 shows the ramp's frame work with the geomembrane in place and the drain lines for collecting leachate installed. Also shown in this Figure is some of the stockpiled by-product. Figure 5 shows the ramp after the first day of placing the FGD ash. Compaction was attained primarily by the equipment used to place the material, although a hand tamper was used along the side and back walls. Measurements made in the fill as it was being placed indicated that the average in-place density was only about 90% of Standard Proctor density. Since an increase in density did not appear to be possible with the equipment the crew had available, density measurements were recorded, but no material was removed. In addition, an overnight rain in excess of 2.5 centimeters meant that optimum moisture conditions could not be maintained for the remainder of the construction. Figure 6 shows the next day construction. It is apparent that at the time this photograph was taken, the ash was considerably wetter than optimum. The material was still fairly easy to work with however, and the construction of the ramp was allowed to continue. After the ramp was brought up to within 15 centimeters of the final grade, a wearing surface of crushed limestone was placed. Figure 7 shows the truck ramp as it looked shortly after completion. Approximately 181 metric tons of ash were placed in the ramp.

Figure 3. Placing the Geomembrane

Figure 4. Truck Ramp After Geomembrane and Drainage Lines Had Been Installed.

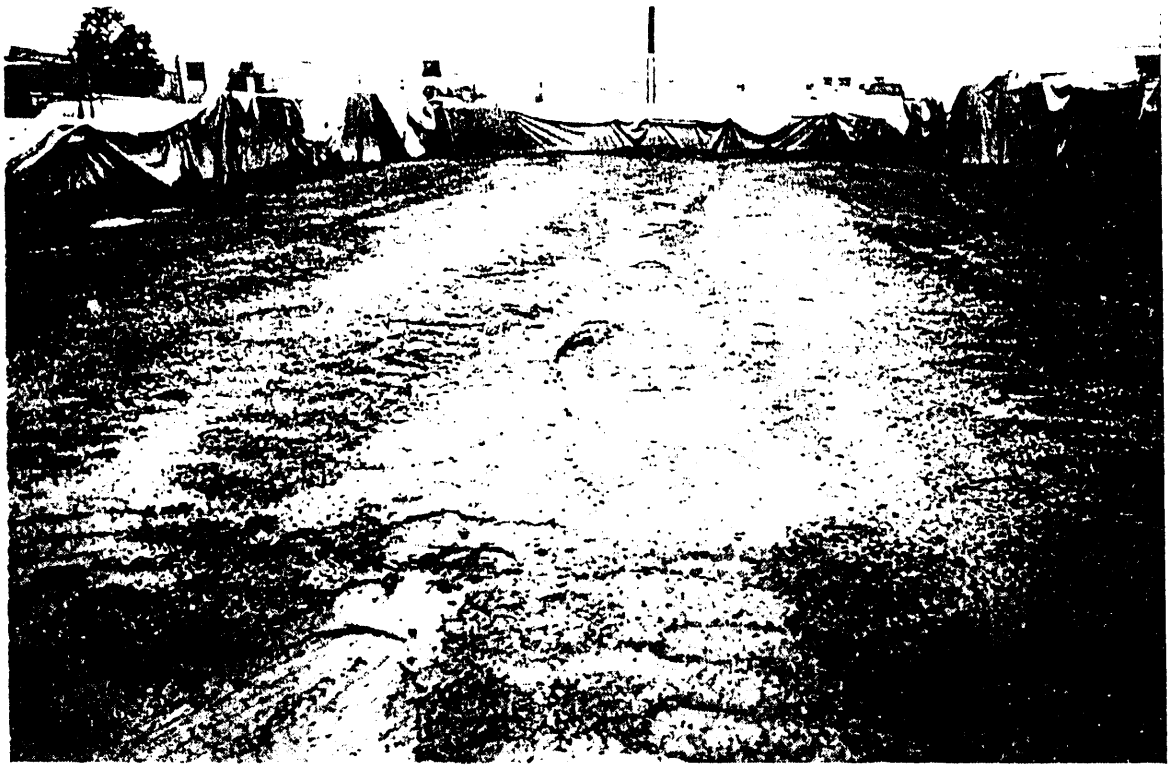

Figure 5. Truck Ramp During Construction

Tests performed on samples cored from the ramp over the first ten months after its completion show that although not saturated, the water content was considerably higher than the optimum water content. The inplace density was found to be approximately 10% lower than the standard Proctor density. Compression tests performed on core samples typically yielded field strengths lower than those obtained in the laboratory but the results were widely scattered (76 to 840 kPa), thus indicating the importance of maintaining proper control over moisture during placement and compaction. However, at this point in time, over one year after the completion of the truck ramp, there is no evidence of distress nor have any problems with the performance of the ramp been reported.

Samples of the water from both the underdrains and the surface of the ramp have been collected periodically since the completion of construction. The samples are analyzed for pH and metals content. The pH has remained in the region of 9 to 10 throughout the past year. The results of a typical metals analysis are presented in Table 7. Also presented for comparison are the Federal and State hazardous waste criteria and the flyash leachate requirement.

TABLE 7. TOTAL METALS ANALYSIS - FIELD SAMPLES

Parameter	Surface Runoff mg/l	Leachate mg/l	Flyash Standard mg/l [9]	Federal/State HW Criteria mg/l [9]
Arsenic (As)	0.073	0.044	1.5	5
Barium (Ba)	<0.20	<0.20	30.0	100
Cadmium (Cd)	0.04	0.04	0.3	1
Chromium(Cr)	<0.06	<0.06	1.5	5
Lead (Pb)	0.31	0.49	1.5	5
Mercury (Hg)	<0.001	0.004	0.06	0.2
Selenium(Se)	0.014	0.014	0.3	1
Silver (Ag)	<0.03	<0.03	1.5	5

Figure 6. The Truck Ramp in the Latter Stages of Construction.

SUMMARY and CONCLUSIONS

A truck ramp was constructed on the OSU campus using a dry flue gas desulfurization waste generated by the University's coal burning power plant. The purpose of the construction project was to demonstrate the potential for using this type of material as a substitute for select borrow in a structural fill. The ramp was designed and constructed by the University's Department of Physical Facilities. No special measures were taken either in the design or in the construction of the truck ramp. Laboratory tests performed on samples of the waste material which had been compacted to 100% of Standard Proctor density indicated that the FGD by-product possessed the necessary strength, and had acceptable permeability and swelling characteristics to be a satisfactory replacement for the select borrow material that was originally specified. In spite of the fact that the light duty equipment used to place the by-product was not capable of achieving the densities used in the laboratory study, the ramp is performing as designed and, one year after construction, there is no evidence of any physical deterioration that could be attributed to the fill. Water quality determinations made for both the runoff water and the leachate indicate a continuing alkaline environment. Measured levels of metals in both leachate and runoff have always been significantly below the concentration levels accepted by the EPA. Monitoring of the water quality as well as the engineering properties is scheduled to continue for at least the next twelve months.

Three to four days of ash production was used in the truck ramp saving the University approximately $5600 in direct disposal costs. Additional savings were realized by not purchasing the select borrow which was to be used to construct the ramp. More importantly, the construction and subsequent satisfactory performance of the ramp have demonstrated that these FGD by-products can be used in construction and should be seen as a resource rather than as a solid waste.

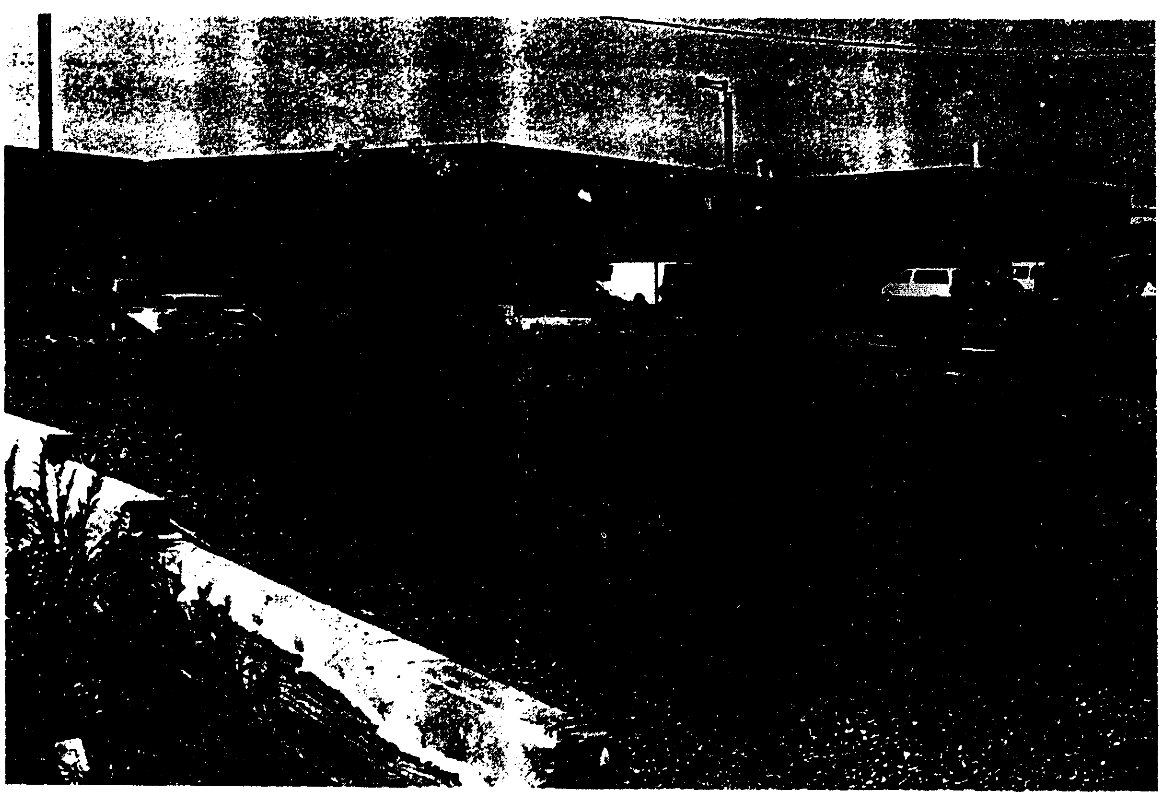

Figure 7. The Truck Ramp after Construction is Completed

ACKNOWLEDGEMENTS

The work described in this paper forms part of a project titled "Land Application Uses of Dry FGD By-Product," being performed in the Civil Engineering Department at The Ohio State University. The contract sponsor is Dravo Lime Company. Principal funding has been provided by the Ohio Coal Development Office and the U.S. Department of Energy, Morgantown Energy Technology Center. Additional funding has been provided by Dravo Lime Co., American Electric Power and Ohio Edison. The authors are grateful for their support. OSU provided the samples of the FGD for testing. Dr. Jerry Bigham of the OSU Agronomy Department supervised the X-ray diffraction analyses.

REFERENCES

1. Taha, R., "Environmental and Engineering Properties of Flue Gas Desulfurization Gypsum," Preprint, 72nd Annual Meeting, Transportation Research Board, Washington, D.C., January 10-14, 1993.
2. U.S. Department of Energy, ***Clean Coal Technology, The New Coal Era***, DOE/FE-0217P, Washington, D.C., March, 1992.
3. American Society for Testing and Materials (ASTM) ***1990 Annual Book of ASTM Standards, Vol. 4.08.***
4. Lin. C. and J.B. Evett, ***Soil Properties Testing, Measurement and Evaluation, 2nd edition***, Prentice-Hall Inc., 1990.
5. Adams, D.A., W.E. Wolfe and T.H. Wu, "Strength Development in FGD-Soil Mixtures," ***Proceedings of the Ninth Annual International Pittsburgh Coal Conference***, Pittsburgh, PA, October, 1992.
6. Kim, S.H., W.E. Wolfe and T.H. Wu, "Permeability of FGD By-Products," ***Proceedings of the Ninth Annual International Pittsburgh Coal Conference***, Pittsburgh, PA, October, 1992.
7. Duarte, R.J. and W.E. Wolfe, "Permeability Measurements in FGD-Soil Mixtures," ***Tenth American Coal Ash Association Symposium,*** Orlando, FL, January, 1993.
8. Adams,D.A. and W.E. Wolfe, "The Potential for Swelling in Samples of Compacted Flue Gas Desulfurized By-Product," ***Tenth American Coal Ash Association Symposium,*** Orlando, FL, January, 1993.
9. Wolfe, W.E., T.H. Wu and J.H. Beeghly, "Laboratory Determination of Engineering Properties of Dry FGD By-Products," ***Proceedings of the Ninth Annual International Pittsburgh Coal Conference,*** Pittsburgh, PA, October, 1992.

END

DATE FILMED

3/21/94