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DEVELOPMENT OF ECONOMICALLY STABILIZED PHOSPHOGYPSUM COMPOSITES FOR SALTWATER APPLICATION

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DEVELOPMENT OF ECONOMICALLY STABILIZED PHOSPHOGYPSUM COMPOSITES FOR SALTWATER APPLICATION

FINAL REPORT

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PERSPECTIVE

The phosphate industry in Florida produces approximately 30 million tons of phosphogypsum each year and to date most of that phosphogypsum has been stored in stacks. Since 1989 the EPA has prohibited the use of phosphogypsum for any purpose unless the proposed use would be as protective of human health as leaving it in the stack. Using it in a marine environment would seem to be an ideal solution to the problem of how to utilize this material to the benefit of society. Research at LSU has demonstrated that it is possible to prepare phosphogypsum-fly ash-cement briquettes that have limited metals leaching characteristics and that have proven to be non-toxic to the marine food chain.

Of secondary importance to demonstrating that environmental acceptable briquettes can be fabricated is the question of economics. While there are good reasons why the briquettes should be used in marine applications in preference to traditional materials, the cost to manufacture the briquettes will dictate how likely it is that they will be selected for the recommended marine applications. The projected manufacturing cost for the phosphogypsum-fly ash-cement briquettes that were demonstrated to be stable in sea water is low enough to offer a substantial economic incentive for their use and the potential market is large enough to make their manufacture worthwhile.

G. Michael Lloyd, Jr.
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ABSTRACT

Phosphogypsum (PG, $CaSO_4 \cdot 2H_2O$) is a waste by-product produced during the wet-process manufacturing of phosphoric acid. The USEPA mandates that PG be disposed of in stacks due to the potential release of Rn^{222} (from Ra^{226} decay), which may pose a potential threat to public health and the environment.

This research focused on stabilizing PG with Portland Type II cement and Class C fly ash for use in marine environments. The 73%:25%:02%, 67%:30%:03%, 63%:35%:02% and 62%:35%:03% PG:Class C fly ash:Portland Type II cement composites demonstrated promising results with no signs of degradation after 12 months of natural saltwater submergence. The Ra^{226} concentrations in the TCLP leachate were well below the current EPA regulatory value for drinking water (5 $pCi \cdot L^{-1}$). The metal concentrations in the leachate were also well below the USEPA toxicity characteristics limits. A one-dimensional diffusion model based on Fick's second law with a non-zero surface concentration at the solid-solution interface was developed to calculate effective calcium and sulfate diffusion coefficients of composites placed in saltwater. This model determined that the range of effective calcium, sulfate and Ra^{226} diffusion coefficients were $1.36\text{-}8.04 \times 10^{-13}$ $m^2 \cdot s^{-1}$, $2.96\text{-}7.20 \times 10^{-13}$ $m^2 \cdot s^{-1}$ and $1.46\text{-}2.90 \times 10^{-17}$ $m^2 \cdot s^{-1}$, respectively. This model also predicted that calcium, sulfate and Ra^{226} will stop leaching at a critical time (t_c) of 64-78, 122-137, and 150-470 days, respectively, when the leaching processes are balanced by precipitation reactions. The effective diffusion coefficients of Cu, Cr, and Zn ranged from 6.46×10^{-12} to 1.21×10^{-11} $m^2 \cdot s^{-1}$, 5.83×10^{-13} to 1.69×10^{-12} $m^2 \cdot s^{-1}$, and 3.97×10^{-14} to 9.10×10^{-14} $m^2 \cdot s^{-1}$, respectively. The t_c for Cu, Cr, and Zn to stop leaching were 78-254 days, 61-168 days and 89-145 days, respectively.

The engineering properties test results indicated that the composite material could be classified as well-graded gravel or well-graded sand with little or no fines. The direct shear test determined the angle of internal friction as 49-50°. The USCS classification would also qualify the PG briquettes as a potential fill material in embankment construction projects because of the excellent workability characteristics. The economic analysis indicated that the commercial cost for the selected four stabilized PG briquettes ranged from \$11.94 to \$15.45 per ton^{-1} (2003 value) in Tampa, Florida**.** This result indicates that the briquettes (42.5mm x 23.5mm x 14.5mm) can potentially replace the larger (15-30.5 cm) and more expensive (\$35 per ton^{-1}**;** average delivered cost for 2003) granite backfill currently used in the state of Florida.

It is recognized that granite would still be needed as an armoring to protect the stabilized PG from wave-derived energy.

ACKNOWLEDGMENTS

Foremost, our sincere appreciation goes to the Florida Institute of Phosphate Research for its financial support and assistance.

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EXECUTIVE SUMMARY

Phosphogypsum (PG, $CaSO_4{\cdot}2H_2O$), a waste byproduct of the wet-process manufacturing of phosphate fertilizer from phosphate rock, contains Ra^{226}, which decays to radon gas. Due to the potential for the release of the radon gas, PG is regulated under the National Emission Standards for Hazardous Air Pollutants (Federal Register, 40 CFR Part 61 Subpart 61, February 3, 1999) and must be disposed of in stacks. Unfortunately, continued placement of PG in stacks, combined with an annual PG production rate of 45 million metric tons, has resulted in PG occupying more than 34 km^2 of land. The development of technologically feasible and economically acceptable solutions that result in large applications are required to address this growing solid waste issue.

The researchers at Louisiana State University have demonstrated that a stabilized PG composite mixture is capable of maintaining physical integrity following seawater submergence for more than two years. The original research focused on utilizing stabilized PG as oyster culch material as a replacement for limestone barged from Mexico at $13.50 per ton^{-1}. However, the application of stabilized PG as a fill material in coastal protection devices provides for a much larger market, and is the current focus of the LSU research.

Coastal erosion is a serious problem in the United States, particularly along the Gulf of Mexico coast. Wetlands along the gulf coast are disappearing at a rate of more than 78 km^2 per year. About one-third of Florida's sandy beaches are suffering serious erosion that threatens substantial development, recreational, cultural, and environmental interests for coastal communities. Currently, granite riprap (15-30.5 cm) used for erosion control is transported in by railcar at a cost of $35 per ton^{-1}. The use of granite not only depletes a natural resource but also is very costly. There is an opportunity to develop low profile coastal protection devices using stabilized PG as the fill material and granite as an armoring.

The researchers at Louisiana State University have also demonstrated that stabilized PG composites are capable of maintaining physical integrity following more than two years of saltwater submergence. The application of stabilized PG as a fill material in coastal protection devices can provide a kind of low profile coastal protection material, and reduce PG inventories that pose significant economic and legal environmental liability. The eventual use of stabilized PG as a fill material requires a fundamental understanding of various chemical, physical and engineering properties. First, evidence of long-term physical integrity of specified composite combinations must be provided to show that the composites will not degrade in the natural environment. Second, it must be shown that the potential for the leaching of radium from the composites is minimal. Third, the composites must be characterized to ensure their engineering properties are in the same range of currently used materials. Last, the cost of production of these composites must be competitive with currently used materials. Subsequently, the overall goal of this project was to develop a PG:fly ash:cement composite that is economical, usable in saltwater and eliminates all airborne vectors of transmission of radon. Specific objectives were to: (1) determine the optimum ingredient combination for PG:Class C fly ash:Portland type II cement composites to further reduce the binding agent contents. The binding agent content range should be cement: 1-3% and fly ash: 20-35%; (2) determine the diffusion coefficients of the radionuclides, calcium and sulfate of PG:fly ash:cement composites for incorporation into a leaching model; (3) investigate the geotechnical characteristics of the composites; and (4) conduct an economic analysis to investigate the possible use of the PG in coastal protection devices in the future. The data obtained during this research provided a better understanding of the potential for using stabilized PG as a fill material in marine environments to replace that portion of granite that is currently being used. This research also provided the baseline data necessary to move forward with the development and evaluation of a "test protection device" comprised of stabilized PG as the fill material and limestone/granite as the armor.

The results indicated that the selected 73%:25%:02%, 67%:30%:03%, 63%:35%:02% and 62%:35%:03% PG:Class C fly ash:Portland Type II cement composites could survive 16 months of natural saltwater submergence. The metal concentrations in the leachate were also well below the USEPA toxicity characteristics limits. A one-dimensional diffusion model based on Fick's second law with a non-zero surface concentration at the solid-solution interface was developed to calculate effective calcium and sulfate diffusion coefficients of composites submerged in saltwater. This model determined the ranges of effective calcium, sulfate and Ra^{226} diffusion coefficients to be in the ranges of $1.36\text{-}8.04 \times 10^{-13}$ $m^2 \cdot s^{-1}$, $2.96\text{-}7.20 \times 10^{-13}$ $m^2 \cdot s^{-1}$, and $1.46\text{-}2.90 \times 10^{-17}$ $m^2 \cdot s^{-1}$, respectively. This model predicted that calcium, sulfate and Ra^{226} would stop leaching at critical time (t_c) of 64-78, 122-137 and 150-470 days, when the leaching processes are balanced by precipitation reactions. The effective diffusion coefficients of Cu, Cr, and Zn were in the ranges of 6.46×10^{-12} to 1.21×10^{-11} $m^2 \cdot s^{-1}$, 5.83×10^{-13} to 1.69×10^{-12} $m^2 \cdot s^{-1}$, and 3.97×10^{-14} to 9.10×10^{-14} $m^2 \cdot s^{-1}$, respectively. The t_c for Cu, Cr, and Zn to stop leaching were 78-254 days, 61-168 days, and 89-145 days, respectively.

The results from the engineering properties tests indicated that the composite material could be classified as well-graded gravel or well-graded sand with little or no fines. The direct shear test determined the angle of internal friction as 49-50°. The USCS classification would also qualify the PG briquettes as a potential fill material in embankment construction because of the excellent workability characteristics.

INTRODUCTION

BACKGROUND

The United States is the world's leading producer and consumer of phosphate rock and phosphate fertilizers (USGS 2002). The U.S. phosphate industry uses the wet process, which treats phosphate rock with sulfuric acid to produce phosphoric acid (USGS 2002). The phosphoric acid is then used to make fertilizer. While this process is economical, it results in the byproduct phosphogypsum (PG, $CaSO_4 \cdot 2H_2O$) at a phosphoric acid:PG ratio of 1:4.5-5.5 (USEPA 2004). Approximately 80% of the radium (Ra^{226}) from the phosphate ore is found in the phosphogypsum (USEPA 1993).

Ra^{226} decays to radon gas (Rn^{222}), which has ? radiation capacity and a short half-life (3.8 days). Radon has been classified as a cancer-causing, radioactive gas (USEPA 2004). The concern over radon emissions from PG resulted in the promulgation of disposal/usage guidelines under the National Emission Standards for Hazardous Air Pollutants (NESHAP) and the National Emissions Standards for Radon Emission from PG Stacks (Federal Register, 40 CFR Part 61 Subpart 61, February 3, 1999). In 1992, USEPA ruled that PG intended for most applications, including agricultural and other usages, must have a certified average Ra^{226} concentration of not more than 10 $pCi \cdot g^{-1}$. Typical radium concentrations in PG stacks in the U.S. fall within a range of 11 to 35 $pCi \cdot g^{-1}$ (Cohen and Associates 1993). Consequently, USEPA (1992) has banned the use of most of the PG in the U.S. and ruled that PG must be stacked. In 1999, USEPA modified the rule stating that 318 to 3,182 kg of PG may be used for indoor research and development, thereby allowing researchers to efficiently develop more practical applications of this waste material (Lloyd 2002).

The phosphate industry has produced 44-51 million metric tons of PG annually. The total PG produced in the United States from 1910 to 1981 was about 8.5 billion metric tons (USEPA 2004). Central Florida is one of the major phosphoric acid producing areas, generating about 32 million metric tons of PG each year and contributing to the nearly one billion metric tons of PG already in stacks (USEPA 2004). Various beneficial uses of PG are presently being investigated to seek a long-term solution for PG disposal. The beneficial and commercial usage of PG will eliminate the potential risks of PG stacks to humans and the environment.

PG can be potentially used as a soil amendment in agriculture, road base construction, wallboard, and landfill cover (Birky 2002). However, only PG from North Florida has radiation levels low enough (<10 $pCi \cdot g^{-1}$) to qualify for agricultural uses (FIPR 1996). Unfortunately, the PG from central Florida has an average Ra^{226} concentration of 26 $pCi \cdot g^{-1}$ (Lloyd 2002) and cannot be used under current regulations. A more economical and environmentally sound alternative is to use PG briquettes as mechanically stabilized fill material in coastal protection devices (Guo and others 2001; Deshpande 2003). This application provides one of the best means to minimize human radon gas exposure, leaving bioaccumulation as the only potential transfer pathway. This proposed use of PG briquettes would provide an attractive alternative to current coastal restoration construction materials.

POTENTIAL FOR USING STABILIZED PG BRIQUETTES AS FILL MATERIAL IN COASTAL PROTECTION DEVICES

Our nation's beaches and coastal wetlands are highly valued as economic and recreational resources. However, coastal erosion threatens their existence, particularly along the Gulf Coast. Our nation's wetlands are disappearing at a rate of more than 78 km^2 per year (LADNR 2004). About one third of Florida's sandy beaches are suffering serious erosion that threatens substantial developmental, recreational, cultural, and environmental interests for these coastal communities (Florida Beach Control Program, 2003). Currently, granite riprap and back fill used for erosion control in Tampa, Florida is carried in by railcar at a cost of \$35 per ton^{-1} (Lowish 2004). Annual granite requirements for coastal erosion agencies average in the tens of thousands of tons (Lowish 2004). In Louisiana, the majority of material used as riprap and for dike construction is limestone mined in Arkansas and barged to the state at a cost of \$36-\$52 per ton^{-1}, with needed quantities in the tens of thousands of tons per project.

In addition to cost, the coastal protection materials currently used have a high "sinkage" coefficient, resulting in a portion of the material being lost to the sediments. The end result is the need for additional material. Consequently, low mass, low profile, and durable materials are needed for use in coastal protection programs. Researchers at Louisiana State University are currently investigating methods for stabilizing PG (Guo and others 1999a, 1999b, 2001; Deshpande 2003; Rusch and Guo 2003) for use as fill materials in coastal protection devices.

The proper design and implementation of marine structures (dikes, embankments, revetments, riprap, etc.) must consider overall strength and stability. Geogrid and geotextile materials are designed to be integrated with available fill materials. They provide tensile strength to the structure, similar to reinforcing steel in concrete, and they allow the construction of embankments and retaining walls at slopes and heights higher than allowed with the original granular materials (Koerner 1998; Abramson and others 2002). Geogrid-reinforced structures can be used in the harsh conditions associated with coastal erosion and submerged foundation projects. Stabilized PG may be used in conjunction with geotextile fabric to produce a mechanically stabilized fill material for coastal protection devices (Figure 1). The effectiveness of this coastal protection strategy results from several key features, including: monolithic high mass and porosity, flexibility and hydraulic stability; durability and long-term tensile capacity of the geogrid; and energy dissipation characteristics. The geogrid reinforced structure using stabilized PG:Class C fly ash:Portland type II cement briquette as a fill material may be used in the coastal applications as core material topped with a limestone/granite armor to adsorb most of the kinetic energy exerted on the structures and protect the stabilized PG fill material, thus reducing the cost of building and maintaining the structure. The replacement of the granite back fill with the stabilized PG fill material would not only reduce costs, but also the overall weight burden of the protection device.

Researchers at Louisiana State University have been investigating methods for stabilizing PG (Guo and others 1998, 2001; Rusch and Guo 2003) for use in coastal areas. The original concept was to use PG as oyster culch material as a replacement for limestone barged in from Mexico at \$13.50 per ton^{-1} (1996 cost, Wilson and others 1998). However, the difference between the production cost of stabilized PG briquettes (\$13.62·ton^{-1}, 1996 cost) and the limestone was not big enough to promote a switch to the stabilized material. The use of stabilized PG as a fill material in coastal protection devices, on the other hand, would result in a large potential savings. It is proposed to replace the currently used granite backfill (size: 15-30.5 cm; \$35·ton^{-1} average delivered cost for 2003 in Tampa, FL) with the smaller stabilized PG briquettes (42.5 mm x 23.5 mm x 14.5 mm).

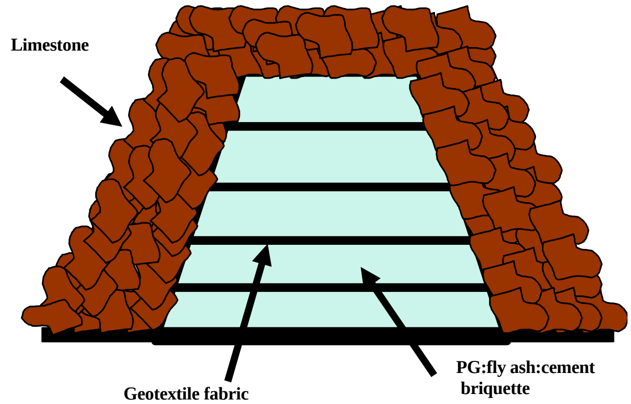

Figure 1. The Stabilized Composites Can Be Used as Fill Materials in the Coastal Protection Devices.

Several experiments have been conducted on the stabilized phosphogypsum composite specimens to understand their leaching behavior and to determine the diffusivities of calcium (Guo 1998; Guo and others 2001), trace metals such as As, Pb, Ba, Cr, Fe, Al and Mn and radionuclides such as Ra^{226} and Rn^{222} (Gokmen 1995; Fan 1997). Stabilizing PG with Class C fly ash and Portland Type II cement will minimize the migration of radon gas from the PG composite into the surrounding environment (Guo and others 2001; Deshpande 2003). By submerging the PG composites in an aquatic environment this would provide double protection against the escape of radon gas. The stabilized PG matrix will minimize the diffusion of the radium. The most recent research demonstrated that the 73%:25%:2% PG:Class C fly ash:Portland Type II cement composite can survive in seawater for more than one year (Deshpande 2003). While this composition meets the less than 5% cement criterion based on cost constraints (Rusch and others 2001), the admixture composition has not been tested for all geotechnical properties. In addition, the optimized combination must also be evaluated for the long-term release of trace metals and radium and the potential for bioaccumulation.

The long-term goal of this research seeks to provide an alternative commercial application of PG that will be as safe as or safer than presently placing PG in stacks. Optimizing PG:fly ash:cement composites for use as a fill material in coastal protection devices can provide long-term economic benefits to the States of Florida, Louisiana and coastal communities by establishing a new industry and protecting the coastal region from erosion. This beneficial utilization of PG will also reduce PG inventories that pose significant economic and legal environmental liability. This research would lay the foundation for testing whether the PG briquettes can be used as a fill material. The research objectives were to: (1) determine the optimum ingredient combination for PG:fly ash:cement composites and further reduce the binding agent contents, (2) determine the diffusion coefficients of the radionuclides, toxic metals, calcium and sulfate of PG:fly ash:cement composites for incorporation into a newly developed leaching model, (3) perform a preliminary evaluation of basic geotechnical characteristics of the composites, and (4) perform economic analysis for commercial production of PG briquettes.

METHODOLOGY

This research was performed in two phases. The first phase was a screening process implemented to reduce nine PG composite combinations to four based on preliminary tests (28-day dynamic leaching, field submergence, cost analysis, surface hardness, porosity, compaction, and specific gravity). In the second phase, the selected four composite combinations were subjected to 77-day dynamic leaching, field submergence and direct shear tests in addition to the tests carried out in the Phase I study to evaluate their chemical and engineering characteristics.

RAW MATERIALS AND CHARACTERIZATION

Raw PG was obtained from IMC-Agrico Co., Uncle Sam Operations, Louisiana. The River Cement Co., St. Louis, Missouri, donated the Portland Type II cement, and Bayou Ash Inc., Erwinville, Louisiana, donated the Class C fly ash. The raw PG was oven-dried at 45^{o}C for 12 hours and ground to pass through a US Standard sieve No.10. Precautions were taken to verify and maintain the temperature in the oven so that only free water was removed.

COMPOSITE COMBINATION IDENTIFICATION AND FABRICATION

Composites can be fabricated in house using a static press or commercially via briquette fabrication technique. The static compaction technique has the advantages of complete control over the process and flexibility over the fabrication schedule. All experiments to date utilized this fabrication procedure. The researchers recognized however, the need to move to a commercially viable fabrication technique. Subsequently, the first year's studies utilized both blocks (static press at LSU) and briquettes fabricated at a commercial facility to initiate the eventual movement from research protocols to commercial protocols. There are several differences between the two fabrication techniques, including compaction pressure, surface area to volume ratio and compaction method (the blocks are a monolith with no seams; whereas, the briquettes contain a seam at the point where the two parts of the mold come together). Submergence results were utilized as the key parameter to compare the blocks and briquettes.

Fabrication of Composites for Phase I Testing

The incomplete factorial experimental design was applied to select ingredient combinations for the screening process (Tables 1-2). The lower bounds were 1, 20 and 63 percent for the Portland Type II cement, Class C fly ash and PG ingredients, respectively. The 62%:35%:03% PG:Class C fly ash:Portland Type II cement composition was used as the control. This control combination was selected based on previous research (Guo and others 2001). Four combinations were selected for fabrication using the static press, while nine combinations were fabricated using the briquetting process. The four static press fabricated blocks were a subset of the combinations selected for briquetting.

Table 1. Four Combinations of PG:Class C Fly Ash:Portland Type II Cement Blocks Were Selected and Fabricated Using a Static Press.

Phosphogypsum (%)	Class C Fly Ash (%)	Portland Type II Cement (%)
77	20	3
72	25	3
67	30	3
63	35	2

The blocks were subjected to submergence tests.

Table 2. Nine Combinations (Dry Mass) of PG:Class C Fly Ash:Portland Type II Cement Briquettes Were Fabricated by K. R. Komarek Briquetting Research, Inc.

Phosphogypsum (%)	Class C Fly Ash (%)	Portland Type II Cement (%)
77	20	3
73	25	2
72	25	3
69	30	1
68	30	2
67	30	3
64	35	1
63	35	2
62	35	3

Static Press

Portland Type II cement, Class C fly ash, and dried/crushed PG were combined (according to Table 1) and homogenized. Water equivalent to eight percent of the combined ingredients' solid mass was added to attain the desired moisture content. Ninety grams of the mixture were weighed and compressed into a 3.81cm diameter and 3.81cm long steel mold under 9.8×10^{7} $N\cdot m^{-2}$. The composites had an average surface area of 68.4 cm^2 and a dry density of 2.0 $g\cdot cm^{-3}$. The composites were allowed to cure at 100 % humidity and room temperature for one month before testing. The average dry weight was 87 grams.

Commercial Briquetting

The briquettes were fabricated at K.R. Komarek Briquetting Research, Inc., Anniston, Alabama, according to the combinations listed in Table 2. Portland Type II cement was combined with Class C fly ash and dried/crushed/sieved PG. Water at 8% of solid mass of the combined ingredients was added to attain the desired moisture content. The appropriate raw materials were combined in a mechanically operated mixer for seven minutes, and then compacted between two rollers cantilevered on the ends of shafts outside the bearing blocks. The force holding the two rollers together was provided by a fully adjustable hydraulic system, and the average pressure maintained to compact the briquette between the rollers was 37.3×10^6 $N \cdot m^{-2}$. The fabricated briquettes had a mean weight of 15.07 g, a mean volume of 8 cm^3 and a solid density of 1.98 $g \cdot cm^{-3}$. The composites were allowed to cure at room temperature and 100% humidity for one month before testing.

Fabrication of Composites for Phase II Testing

The four PG composite combinations selected from the initial screening process were fabricated at K.R. Komarek Briquetting Research, Inc., AL. On average, 120 pounds of briquettes for each combination were fabricated. The water content was reduced to 4% and the pressure between the rollers was increased to 143.1×10^6 $N \cdot m^{-2}$ to attain a better solid density of the PG composite briquettes. The composites were allowed to cure at room temperature and 100% humidity for one month before testing. The briquette parameters are listed in Table 3.

Table 3. Fabrication Parameters Used for the Best Four PG Combinations.

Briquette Parameter	Final Four Combinations
Water Content, %	4
Mean Pressure, $N \cdot m^{-2}$	143.1×10^6
Mean Solid Density, $g \cdot cm^{-3}$	2.15
Mean Mass, g	19.5
Mean Volume, cm^3	9.0
Dimensions, (L × B × H) mm	42.5 × 23.5 × 14.5
Approx. Surface Area, cm^2	28.75

As provided by K.R. Komarek Briquetting Research, Inc., AL.

DEVELOPMENT OF EVALUATION MATRIX

Evaluation Criteria

An evaluation matrix (Table 4) was established to aid in determining the best four composite combinations from the original nine combinations for future complete testing and analysis. The parameters of the evaluation matrix included calcium and sulfate results from the dynamic leaching study, observations and measurement results from the submergence studies. Results from the economic analysis were superimposed on this matrix. Based on saltwater submergence experiments from previous research, it was determined that the control (PG:Class C fly ash:Portland Type II cement 62%:35%:03%) PG:Class C fly ash:Portland Type II cement composites survived for more than two years (Guo and others 2001) and has been selected as the basis for comparison. The effective diffusion coefficients obtained for Ca^{2+} and SO_4^{2-} were $1.21x10^{-12}$ and $0.95x10^{-12}$ $m^2{\cdot}s^{-1}$, respectively, for the 62%: 35%: 03% PG Class C fly ash: Portland Type II cement composite. Considering the results from previous research, the maximum allowable values of Ca^{2+} and SO_4^{2-} for selection of composites to be further tested were rounded to 1.25×10^{-12} and 1.0×10^{-12} $m^2{\cdot}s^{-1}$, respectively.

The estimated commercial production cost of the composites was another important criterion summarized in the evaluation matrix (Table 4) for choosing the best four combinations. To maintain the structural integrity, an adequate amount of the binding agent is needed. For this reason, the composite combinations having cement proportions greater than or equal to 1% were considered suitable in the screening process.

Table 4. An Evaluation Matrix Stating the Selection Criteria for Choosing the Best Four PG Briquette Combinations for Complete Analysis.

Test Parameter	Natural Saltwater Submergence	Calcium D_e $m^2{\cdot}s^{-1}$	Sulfate D_e $m^2{\cdot}s^{-1}$	Production Cost [(a)]	Cement Proportion
Criteria	Survivability for nine months	$= 1.25 \times 10^{-13}$	$= 1.00 \times 10^{-13}$	$\leq$ \$13.62·ton^{-1}	> 1%

(a) Based on the cost ($13.62 per ton) of 62%:35%:02% PG composite that survived in natural saltwater conditions for more than two and half years (Guo and others 2001)

LEACHING ANALYSIS AND MODELING

Dynamic Leach Test

A dynamic leach test (ANSI 16.1 1986) was performed to determine calcium and sulfate release rates from the PG composite briquettes as an indicator of potential PG dissolution and eventual composite failure. The dynamic leach test was run in triplicate on each composite combination. The briquettes were rinsed before being placed in the leaching solution. To generate enough leachate, three briquettes of each composite combination were placed in each container with 690 ml 20‰ artificial saltwater (Instant Ocean™). Artificial saltwater was used as a leaching medium to simulate the natural saltwater environment. The leachate volume to composite surface area ratio used was 8:1. The leachate in the test bottles was not subjected to any agitation and was completely exchanged at a standard medium renewal frequency/intervals of 0.08, 0.29, 1, 2, 3, 4, 5, 8, 11, 14, 21, and 28 days for the screening process. The dynamic leaching process for the final four composites was similar, with the addition of 42-, 56-, and 77-day renewal time. Leachate samples were analyzed for pH, alkalinity, calcium, sulfate and magnesium concentrations. Saltwater blanks were also analyzed for pH, alkalinity, calcium, sulfate and magnesium concentrations. The mean concentrations in the blanks were subtracted from the leachate samples to determine the contaminant amount leached from the PG composite. Alkalinity and pH were measured in accordance with *Standard Methods* (APHA 1998). Calcium, sulfate and magnesium were analyzed by ion chromatography (IC). All analyses were performed at room temperature (23^oC). The data obtained from these tests were used as a basis for the calculation of the effective calcium and sulfate diffusion coefficients via the new diffusion model (Guo and others 2004). These data were also used to determine the mechanisms of the leaching process.

The leachate samples from the dynamic leaching study performed on the final four combinations were analyzed for radium and metal concentrations in addition to calcium, sulfate, magnesium, pH and alkalinity. Approximately 500 ml of each of the leachate samples from the dynamic leaching test were preserved with 0.1% hydrochloric acid. USEPA Standard Method 903.1 was used to measure the radium concentration ($pCi \cdot L^{-1}$). In this method, barium nitrate was added into the leachate to co-precipitate radium with the barium sulfate precipitate. The precipitate was then washed and sealed for four weeks until enough radon had accumulated to be measured by alpha (α) emissions. The radium analyses were carried out in duplicate. The metals analyses were carried out in triplicate. For analysis of metals, the samples were preserved with nitric acid and analyzed for Cr^{3+}, Cu^{2+}, Zn^{2+}, Fe^{2+}, Pb^{2+} and Cd^{2+} using inductively coupled argon plasma spectroscopy (ICAP). The total constituent analysis for metals (C_o, $mg \cdot cm^{-3}$) in the briquette samples was performed after acid digestion (USEPA Method: 3050A).

Diffusion Model

The simple diffusion model developed by Duedall and others (1983) was used in the Phase I study, and the newly developed diffusion model based on non-zero surface concentration was used in Phase II study. The diffusion models currently used do not include the boundary condition of non-zero surface concentrations of the leaching ions. The zero surface concentration is a good assumption for the leaching of toxic metals and radionuclide in fresh/saltwater. However, both calcium and sulfate ions are present in saltwater at about 6 and 10 m $mol \cdot l^{-1}$, respectively. To predict the long-term integrity of stabilized PG composites under saltwater conditions, a non-zero surface concentration at the solid-solution interface must be considered in the diffusion model.

Diffusion Model for Daily Flux

Assumptions for use in the simple diffusion model include: (1) the waste form has rectangular geometry; (2) the concentration of contaminant at the interface of the solid-leaching solution is zero; (3) the contaminant is uniformly distributed within the solid; (4) the contaminant content at the center of the solid does not change during the leaching period (Duedall and others 1983), and (5) continuous renewal of the saltwater; the leaching ion concentration does not increase in the saltwater, and therefore, the daily flux of the leached ion does not change. The leaching model developed by Duedall and others (1983) was used to calculate effective diffusion coefficients during Phase I research. The one-dimensional flux of the diffusing ion is thus assumed to follow Fick's second law:

$$\frac{\partial S}{\partial t} = D_e\left(\frac{\partial^2 S}{\partial x^2}\right) \qquad 0 \le x \le \infty, 0 \le t \tag{1}$$

where:

C is the ion concentration, D_e is the effective diffusion coefficient, x is the one-dimensional coordinate system for the composite extended from the water interface at x = 0 to the composite center at x = + 8 , and t is time in days.

This model is one dimensional for ions in solidified composites and in well-stirred aqueous systems. It assumes a uniform distribution of the diffused ions in the composites and the solid-solution interface that is proportional to the concentration at the interface. The initial boundary conditions for one-dimensional diffusion are:

Initial Condition: C (x, 0) = C_o (2)

Boundary Condition 1 for a transfer coefficient h:

$$D_e\left(\frac{\partial C}{\partial x}\right) = hC \qquad \text{for } x = 0 \text{ or } \lim_{x \to 0} \frac{1}{C}\frac{\partial C}{\partial x} \to \frac{h}{D_e} \tag{3}$$

Boundary Condition 2:

$$\lim_{x \to \infty} C(x,t) \to C_o \tag{4}$$

The solution for the Equation (1), where calcium, sulfate, Ra^{226} and toxic metal release is controlled by diffusion in the PG composites, $h \to \infty$, is:

$$C(x,t) = C_o \, erf\left(\frac{x}{2\sqrt{D_e t}}\right) \tag{5}$$

$$J = C_o\sqrt{\frac{D_e}{tp}} \tag{6}$$

where:

J is daily flux of ions such as calcium, sulfate, Ra^{226} and toxic metals, and C_o is the initial concentration of ions in the PG composite.

Equation (6) can be rewritten in its log form as:

$$\log(J) = -0.5\log(t) + \log(C_o) + 0.5\log(D_e) - 0.5\log(\pi) \tag{7}$$

The effective diffusion depth, X_c (cm), is defined as the depth at which Ca^{2+} and SO_4^{2-} concentration decreases due to diffusion (Duedall and others 1983). The effective diffusion depth is used as an indicator of the diffusion degradation process:

$$X_c = (2D_e t)^{0.5} \tag{8}$$

The simplicity and self-verification capability of this model makes it popular, hence it is widely used for diffusion coefficient calculations (Edwards and Duedall 1985; Rusch and others 2001). This model predicts a slope of -0.5 for a plot of log (J) vs. log (t), which can be used to verify the assumption of the model (Guo and others 2001). However, this model assumes no initial concentration present at the specimen boundary. Hence, a more in-depth and complete diffusion model was developed that includes the initial calcium and sulfate in the saltwater.

Development of Diffusion Model with Non-Zero Surface Concentration

The development of the new diffusion model adapted all of the assumptions listed for the simple diffusion in the previous section with the exception of the zero contaminant concentration at the briquette-water interface. This boundary condition has been replaced with a non-zero surface concentration at the solid-solution interface. The one-dimensional flux of the diffusing ion is thus assumed to follow Fick's second law, Equation (1).

The initial condition for this case is given as:

at $t = 0$, $C = C_o$ (initial content in the stabilized solid, mol·cm^{-3}) (9)

For stabilized PG briquettes, C_o is assumed to be in equilibrium. Thus, the boundary condition is given as:

at $x = 0$, $C = C_1$ (ion concentration at the briquette-water interface, mol·cm^{-3}) (10)

Given the initial and boundary conditions, the solution for Equation (1) is (Crank 1975):

$$\frac{C - C_1}{C_o - C_1} = erf\left(\frac{x}{2 \cdot \sqrt{D_e t}}\right) \tag{11}$$

$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-u^2} du \tag{12}$$

$$= \frac{2}{\sqrt{p}} (x - \frac{x^3}{3 \cdot 1!} + \frac{x^5}{5 \cdot 2!} - \frac{x^7}{7 \cdot 3!} + \cdots) \tag{13}$$

Under the condition of x? 0, Equation (13) becomes:

$$erf(x) = \frac{2\,x}{\sqrt{p}} \tag{14}$$

Under the condition of x? 0, Equation (11) then becomes:

$$\frac{C - C_1}{C_o - C_1} = \frac{x}{\sqrt{pD_e t}} \tag{15}$$

which can be differentiated and substituted into Equation (1) to yield:

$$\left(\frac{dC}{dt} \right)_{x \to 0} = (C_o - C_1) \frac{1}{\sqrt{pD_e t}} \tag{16}$$

The flux, J(t), of diffusing substances at a unit time and unit area through the solid-solution interface is therefore:

$$J(t)_{x \to 0} = (C_o - C_1) \sqrt{\frac{D_e}{pt}} \tag{17}$$

where:

J (mol·cm^{-2}·d^{-1}) is the flux of diffusing ions. The cumulative flux, f(t), of diffusing ions at a unit area through the solid-solution interface is obtained by integrating Equation (17) over time (t):

$$f(t)_{x \to 0} = 2(C_o - C_1) \sqrt{\frac{D_e t}{p}} = K_2 (C_o - C_1) \sqrt{t} \tag{18}$$

where:

K_2 is the rate constant of the diffusion process given by:

$$K_2 = 2 \sqrt{\frac{D_e}{p}} \tag{19}$$

Generally in a diffusion process, the leaching ions take part in some sort of chemical reaction. Considering a pure diffusion process that is part of the leaching mechanism with no reaction, a constant cumulative flux can be calculated with respect to any value of x:

$$f(t)_{x \to 0} = f(t)_x = f(t) \quad (20)$$

Determination of Leaching Kinetics Mechanisms – Regression Method

Plotting the cumulative release rate of the waste component versus time facilitates the identification of kinetic -leaching processes. In theory, the dissolution, diffusion and surface wash-off processes correspond to associated slopes of 1, 0.5 and 0 in the cumulative release rate versus time plots (de Groot and van der Sloot 1992). In practice, obtaining exact values of 1, 0.5 or 0 is rare since leaching is usually a combination of the dissolution, diffusion and surface wash-off. To address this issue, a statistical model was developed to decompose the measured cumulative waste component release rates into rates of the individual dissolution, diffusion and surface wash-off processes involved in the dynamic leaching process:

$$F(t)_{sw} = K_1 (C_0 - C_1) + e_i \quad (21)$$

$$F(t)_d = K_2 (C_0 - C_1)\sqrt{t} + e_i \quad (22)$$

$$F(t)_{ds} = K_3 (C_0 - C_1)\, t + e_i \quad (23)$$

where:

$F(t)_{sw}$, $F(t)_d$ and $F(t)_{ds}$ are the cumulative flux for surface wash-off, diffusion, and dissolution conditions, respectively; K_1 is the rate constant of surface wash-off (immediate dissolution); K_2 is the rate constant of the diffusion process; K_3 is the rate constant of the long-term kinetically controlled dissolution process; e_i is the random error term assumed to be normally distributed with a mean equal to zero and a common variance.

Combining Equations (21) and (22) results in:

$$F(t)_1 = K_1 (C_o - C_1) + K_2 (C_o - C_1)\sqrt{t} + e_i \quad (24)$$

Combining Equations (22) and (23) results in:

$$F(t)_2 = K_2 (C_o - C_1)\sqrt{t} + K_3 (C_o - C_1)\, t + e_i \quad (25)$$

A complete model reaction can then be summarized as:

$$F(t) = K_1 (C_o - C_1) + K_2 (C_o - C_1)\sqrt{t} + K_3 (C_o - C_1)\, t + e_i \quad (26)$$

Equations (24), (25) and (26) represent combinations of the diffusion, dissolution and surface wash-off processes. Equation (26) is the complete model, including all terms representing the complete reaction mechanisms. All other equations are reduced models of Equation (26). The dynamic leaching data from the selected four PG:Class C fly ash:Portland Type II cement composite combinations were used as the input for a SAS program to select the simplest, best-fit model among the models [Equations (21) to (26)]. All models were tested for lack of fit. The best model was selected based on the p-value.

Residual error, e_i, is the random error term assumed to be normally distributed with a mean equal to zero and a common variance (σ^2). The Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises and Anderson-Darling test methods were used to test the normality assumption of the error term. Levene’s test was used to test the variance homogeneity of the residual error (e_i). The error term was considered a standard normal distribution with uniform variance if the tested p-values were $\geq$ 0.05. If the p-value from Levene’s test ranged between 0.03-0.05, the error term was considered to have an approximately homogeneous variance. The error term was considered to be normally distributed if the p-values of at least one of four normality tests (Shapiro-Wilk, Kolmogorov-Smirnov, Cramervon Mises and Anderson Darling) $\geq$ 0.05. If the p-values < 0.05 for all tests, the error term was not considered to be normally distributed. If the p-value of at least one test was between 0.01-0.04, the error term was considered to be approximate normally distributed. The r-square value, which is used to assess the fit of the model, indicates the percentage that independent variables account for the dependent variable. An r-square value close to unity indicated a better fit of the model. SAS 8.2 was used for regression data analyses.

Equation (26) forms the theoretical framework for identifying leaching mechanisms and was also used to calculate effective diffusion coefficients. The validity of this approach was investigated by comparison of the diffusion coefficients with those calculated by the daily flux (Duedall and others 1983) and cumulative flux methods (El-Kamash and others 2002) derived from the simple diffusion model with zero surface concentration.

The use of stabilized composites in the marine environment requires an estimation of the potential for long-term survival that is controlled by both diffusion and surface precipitation. Therefore, the critical time, t_c, needed for the precipitation processes to equal the diffusion processes can be found by differentiating Equation (26) to find the daily flux:

$$f(t) = \frac{K_2(C_o - C_1)}{2\sqrt{t}} + K_3(C_o - C_1) \qquad (27)$$

At daily flux f(t) = 0,

$$t = t_c = \left(\frac{K_2}{2K_3}\right)^2 \qquad (28)$$

where:

t_c is the time when the rate of diffusion equals that of precipitation.

Equation (27) was used to generate the daily flux plot and Equation (28) was used to calculate the critical time (t_c). Lower values of K_3 and/or the higher values of K_2 result in higher t_c values. In the initial phase ($t < t_c$), the diffusion process dominates the leaching process, and the net daily flux is outward leaching of calcium/sulfate ions. When $t > t_c$, precipitation dominates the leaching process, the net daily flux is precipitation of calcium/sulfate ions.

FIELD SUBMERGENCE

The PG briquettes were submerged in a bay at the Louisiana Marine Consortium (LUMCON) satellite camp, Port Fourchon, Louisiana, for both screening and final testing purposes. Five briquettes were randomly selected, tied with colored tags and placed in polyethylene autoclaving baskets (23cm × 23cm × 24 cm, Nalgene™). Some baskets were suspended in the water column, thus subjecting the samples to natural currents and tides and maximizing interaction potential with various aquatic organisms. Physical observations such as size change and organism growth on the PG briquettes were recorded for the water-suspended samples every three months. PG blocks were also subjected to the same submergence test and field observation.

PRELIMINARY GEOTECHNICAL CHARACTERISTICS

The basic objective of the geotechnical work was to perform a preliminary evaluation of the physical and engineering properties of the PG composites for possible use as fill materials in coastal protection devices. The critical geotechnical properties for these applications include compaction characteristics and shear strength. Further, in order to relate the various gravimetric and volumetric properties of the composite in the actual installation, the specific gravity of the composites must be determined. Physical integrity studies were conducted subsequent to compaction and direct shear testing. Specifically, sieve analyses tests were conducted to determine the magnitude of physical degradation as a result of the compacted and shear energy imparted to the material during the respective tests. The basic purpose of each test conducted, along with the procedure and number of tests, is discussed below.

Specific Gravity and Standard Proctor Compaction Tests

The specific gravity (G_s) of a substance is a comparison of its density to that of water (ASTM: C127-88). It was determined by weighing a set of briquettes in air (W_a, gm) and in water (W_w, gm). The ratio $W_a/(W_a-W_w)$ was termed as the specific gravity (G_s) of the composites. Three sets of PG composite briquettes were analyzed for better statistical reliability of the data. The specific gravity value of the composites was used as a physical parameter and it does not really help in understanding the behavior of the composite structure as a fill material. However, the specific gravity of the composites was compared to that of coarse aggregates generally used as a fill material in coastal embankments.

Depending on the type of material and its moisture content, the fill materials may vary widely in range for dry unit weight (Das 1997). Generally there are no specified requirements for a minimum or maximum dry unit weight (either before or after compaction). Fill materials exhibiting relatively low unit weights may offer the advantage of transmitting less stress to the underlying soil that supports an embankment.

Standard Proctor compaction tests (ASTM: D698) were performed in triplicate, without added moisture. This test was used to assess the physical stability of the briquette as a function of dynamic compaction. No compaction curves were generated and the moisture content of the composite was used while calculating the dry unit weight of the compacted material. The results of these tests established the range of dry unit weights for use with the engineering properties tests. A standard compaction mold of volume 942.95 cm^3 was used to perform the test. The dry unit weight of the compacted material (?$_d$, g·cm^{-3}) was determined using the equation:

$$g_d = \frac{g}{1 + \frac{w(\%)}{100}} \tag{29}$$

where:

? is moist unit weight of the compacted material (g·cm^{-3}) and w is moisture content of the composite (%).

Particle Size Distribution (Sieve Analysis)

The sieve analysis tests (ASTM: D422) conducted in conjunction with the compaction tests provided a quantitative measure of the physical integrity of the composite briquette under typical construction conditions. Specifically, sieve analysis tests were conducted to determine the particle size distribution and the magnitude of physical degradation as a result of the compacted energy imparted to the material during the Standard Proctor compaction test.

The uniformity coefficient (C_u) and the coefficient of curvature (C_c) were determined and used to characterize the particle size distribution by using the following equations:

$$C_u = \frac{D_{60}}{D_{10}} \tag{30}$$

$$C_c = \frac{D_{30}^2}{D_{60} \times D_{10}} \tag{31}$$

where:

D_{10} is the particle diameter corresponding to 10% finer, D_{30} is the particle diameter corresponding to 30% finer, and D_{60} is the particle diameter corresponding to 60% finer.

The Unified Soil Classification System (USCS) as defined in ASTM D2487 was used to classify the post-compaction material.

Surface Hardness

Surface hardness tests were performed according to BS:1377 (1975) British Standards, Methods of Testing Soils for Engineering Purposes (BS1377:1975). Surface hardness provides a measure of the resistance of the composite surface to penetration. The surface hardness is judged to be an indicator of the quality and strength of the composites. Certain hardness levels may be established that are required for the PG composites to withstand destruction in an aquatic environment.

Surface hardness tests were performed in triplicate on the 'control' PG composites (i.e., the PG briquettes subjected to 28 day). To determine the extent the composites were affected by submergence, the samples used in the dynamic leaching study (i.e., 'leached' PG briquettes) were also tested in triplicate. The tests were conducted using a WF21510 Cone Penetrometer (Humboldt Mfg., Inc.). Six points were measured on each of the control and leached PG composites. The surface hardness in this study is defined as the inverse of the depth (in mm) penetrated. The higher the depth penetrated, the lower the surface hardness of the composite. The mean depths penetrated (mm^{-1}) were compared with one-way analysis of variance (ANOVA) to determine whether the mean differences were significant at a 0.05 level.

Pore Volume

The volume occupied by the water molecules in the pore spaces of the composites was estimated by determining the weight loss of the composites under submerged conditions. The PG composites were immersed in tap water for 24 hours at room temperature (23ºC) and then weighed (W_1, g). The composites were then oven-dried at 50ºC for 24 hours and re-weighed (W_2, g). The difference in the weights W_1 and W_2 is the weight of water filled by the pore spaces. The weight of water in the pores can be converted into pore volume by dividing by the density of water (1.0 $g\cdot cm^{-3}$). The porosities (n, %) were calculated as pore water volume divided by composite volume.

ANOVA was used to compare the means of the pore volume increased after water submergence.

Direct Shear Test

Direct shear was measured using a strain-controlled test. A normal load was applied to the specimen and sheared at a constant rate ($0.07 mm?min^{-1}$). The shear box (30.5cm × 30.5cm × 10.3cm) is made of two separate halves. After the application of the normal load, the lower box is moved relative to the upper box, shearing the sample (the box is filled with briquettes) on the plane that is separating the two halves. A dial gauge fixed to the lower half recorded the displacement of the lower half against the stationary upper half.

The direct shear test imposes stress conditions on the sample that forces the failure plane to occur on the plane that separates the two halves of the box. The two forces acting on this plane are normal stress, σ_n. For a specimen of surface area A (cm^2), the normal stress (σ_n, $kg \cdot cm^{-2}$) and shear stress (τ, $kg \cdot cm^{-2}$) resulting from the applied vertical load (P_v, kg) respectively can be calculated as:

$$s_n = \frac{P_v}{A} \quad (32)$$

$$t = \frac{P_h}{A} \quad (33)$$

Shear deformation was recorded for three different normal loads applied, i.e., 227 kg (500 lb), 454 kg (1000 lb) and 635 kg (1400 lb). Under each applied load and constant shearing rate, shear stress versus horizontal displacement was plotted to obtain the maximum shear stress value. With normal stress on the abscissa and shear stress on the ordinate, the maximum shear stress for each applied normal load was plotted; a line was forced through the origin and passed through the points plotted. The angle between the straight line and horizontal line (ϕ) defined the angle of internal friction.

ECONOMIC ANALYSIS OF THE PG:FLY ASH:CEMENT COMPOSITES

The commercial production costs of stabilized PG briquettes for year 2001 used for screening purposes during Phase I testing was based on the economic analysis developed by Rusch and others 2001. To provide the most up-to-date analysis and to understand the effects of market conditions (inflation), an economic analysis was updated using the raw material costs (Portland Type II cement and Class C fly ash) in Florida and Louisiana for the year 2003 (Phase II research).

RESULTS

PHASE I. SCREENING OF THE NINE PG COMPOSITE COMBINATIONS

The physical and chemical tests performed on the initial nine briquette combinations during Phase I research included dynamic leaching studies to determine dissolution potential, surface hardness, submergence tests to evaluate survivability, compaction/sieve analysis and economic analysis. The results of dynamic leaching, field submergence tests and economic analysis were used to select the four best combinations for complete physical, chemical and geotechnical testing during Phase II research. The initial concentrations (C_o) of calcium and sulfate were calculated using the chemical formula ($CaSO_4$) of PG and assuming calcium and sulfate associated with Class C fly ash and Portland Type II cement are not soluble.

Effective Calcium Diffusion Coefficients and Effective Diffusion Depths

The effective calcium diffusion coefficients for each composite, determined using the plots of log J ($mol \cdot cm^{-2} \cdot day^{-1}$) versus log T (day), ranged from 1.02×10^{-12} $m^2 \cdot s^{-1}$ to 1.59×10^{-12} $m^2 \cdot s^{-1}$ (Figure 2), while effective diffusion depths (X_c) ranged from 44.02 mm to 54.93 mm for 30 years submergence (Table 5). All data are centered along the best-fit line with a slope in the range of -0.5 to -0.65. These values are one to two orders of magnitude larger than the results from previous research (10^{-13} to 10^{-14} $m^2 \cdot s^{-1}$) for PG: Class C fly ash: Portland Type II cement composites (Guo and others 2001) that survived in the saltwater for more than two years. These results are one order of magnitude larger than the results (10^{-13} $m^2 \cdot s^{-1}$) from Edwards and Duedall (1983) for stabilized FGD:Class C fly ash:lime blocks that survived in the saltwater submergence for more than eight years (Hockley and van der Sloot 1991) and the same order of magnitude as the results (10^{-12} $m^2 \cdot s^{-1}$) from Breslin and Roethel (1995) for stabilized municipal solid waste that survived in saltwater for more than 4.5 years.

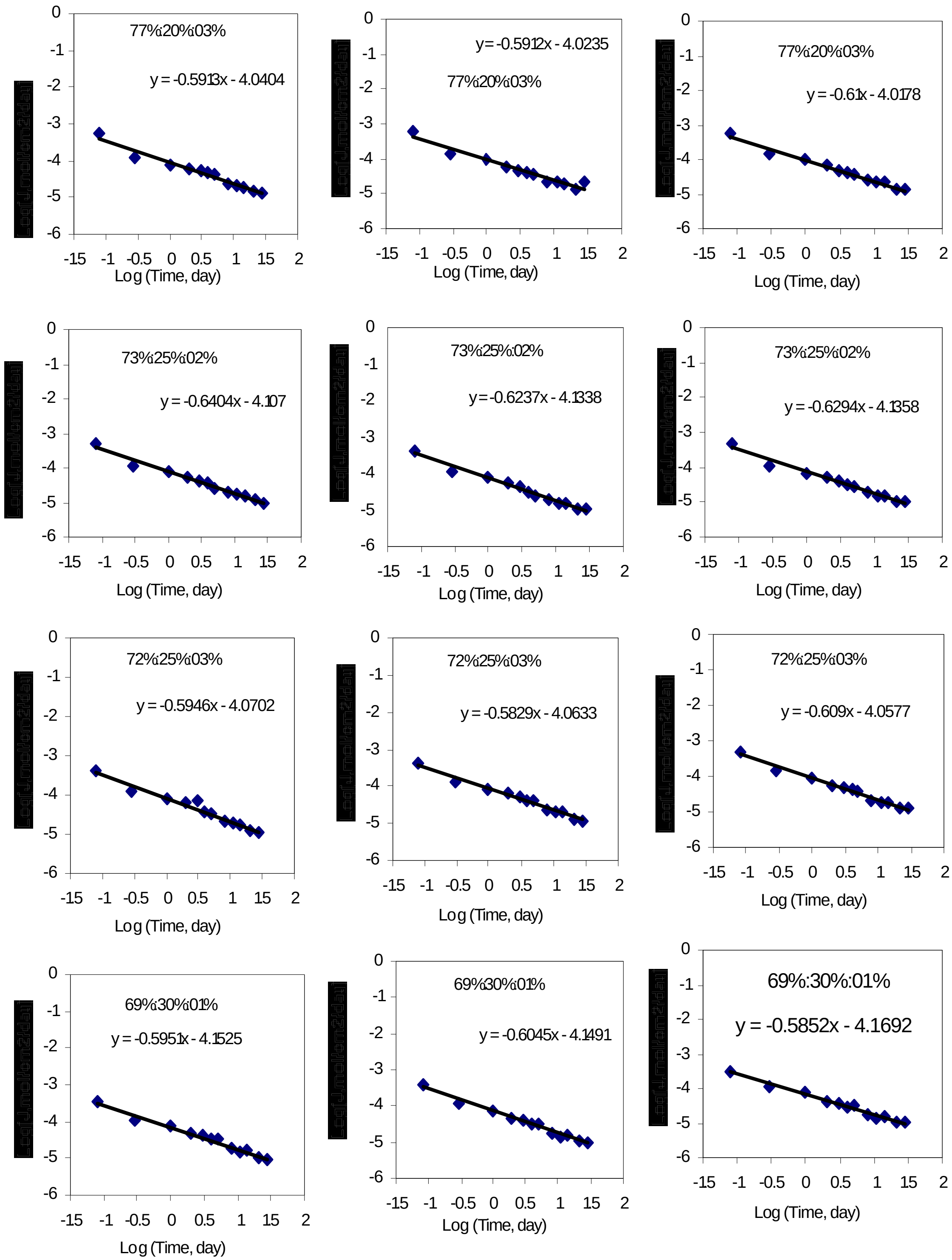

Figure 2. Plots for Log (J) Versus Log (T) Used to Estimate the Calcium Effective Diffusion Coefficients for the PG: Class C Fly Ash: Portland Type II Cement Composites.

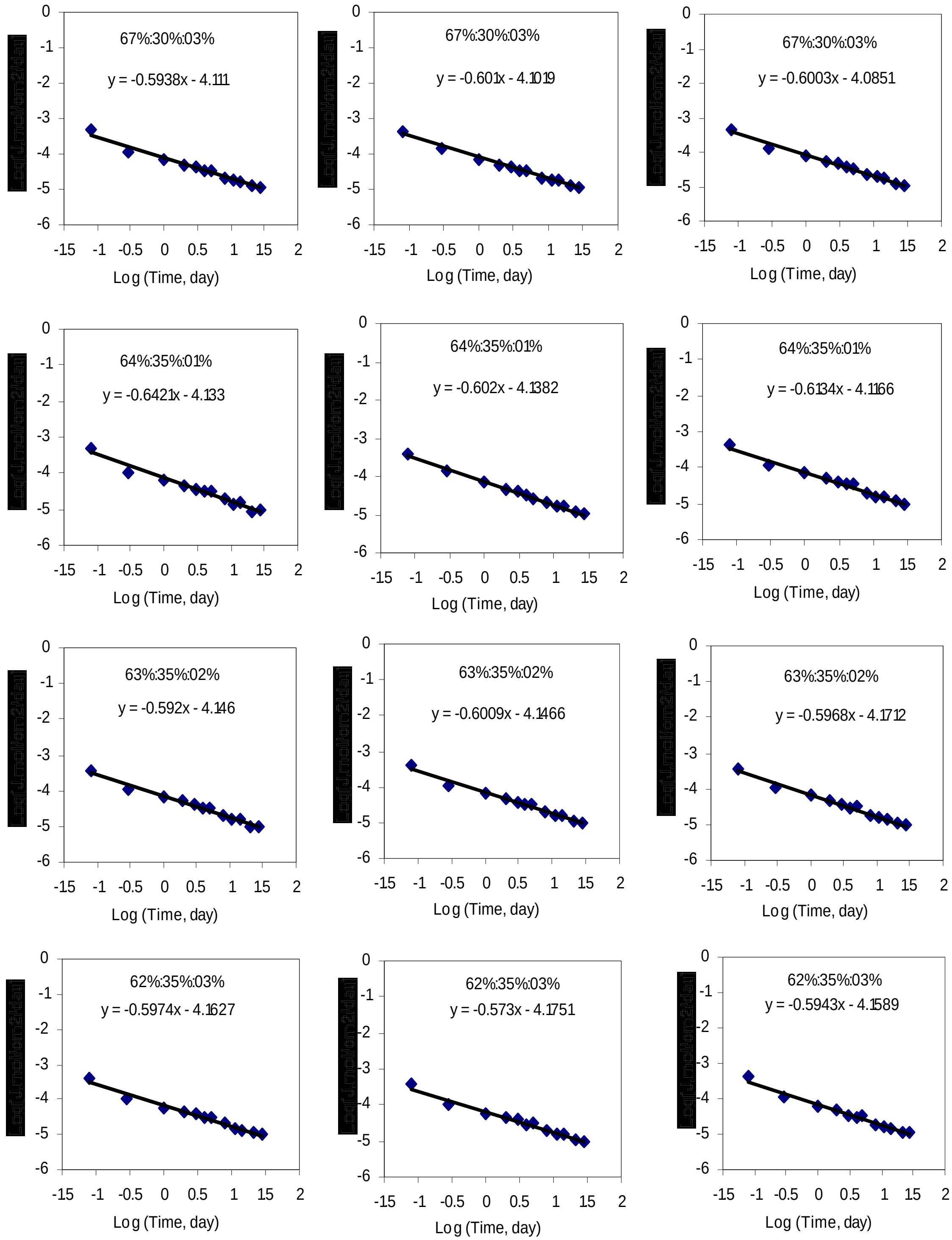

Figure 2 (Cont.). Plots for Log (J) Versus Log (T) Used to Estimate the Calcium Effective Diffusion Coefficients for the PG: Class C Fly Ash: Portland Type II Cement Composites.

The increase in effective diffusion coefficients from previous research may be attributed to the percent reduction of the binding agents in the composite. The 77%:20%:03% PG:Class C fly ash:Portland Type II cement composite and the 72%:25%:03% PG:Class C fly ash:Portland Type II cement composite produced the highest calcium effective diffusion coefficients; therefore, these combinations are likely to be excluded from the selection criteria of the best four combinations. The maximum allowable effective diffusion coefficient for Ca^{2+} in selecting the optimum PG composite combinations is 1.25×10^{-12} $m^2 \cdot s^{-1}$. The PG briquette combinations meeting this criterion for Ca^{2+} are highlighted in bold in Table 5.

Table 5. Calcium Effective Diffusion Coefficients (D_e) Expressed as Mean ± SD (n=3) and Effective Diffusion Depths (X_c) Calculated Using Data Obtained from the 28-Day Dynamic Leaching Study for the Nine PG Composite Briquettes.

PG:Class C Fly Ash:Portland Type II Cement	D_e ($m^2 \cdot s^{-1} \times 10^{-12}$)	X_c (mm)[a]	X_c (mm)[b]
77%:20%:03%	1.48 ± 0.08	9.69	53.07
73%:25%:02%	**1.05 ± 0.08**	**8.15**	**44.65**
72%:25%:03%	1.59 ± 0.23	10.03	54.93
69%:30%:01%	**1.02 ± 0.05**	**8.04**	**44.02**
68%:30%:02%	1.29 ± 0.13	9.04	49.50
67%:30%:03%	1.41 ± 0.08	9.43	51.66
64%:35%:01%	1.35 ± 0.07	9.21	50.47
63%:35%:02%	**1.24 ± 0.08**	**8.83**	**48.38**
62%:35%:03%	**1.21 ± 0.05**	**8.75**	**47.90**

(a) time = 1 years, (b) time = 30 years.

Effective Sulfate Diffusion Coefficients and Effective Diffusion Depths

Magnesium ion was found not to participate in the sulfate leaching reaction (Appendix L). The effective sulfate diffusion coefficients for each composite were determined from the plots of log J ($mol \cdot cm^{-2} \cdot day^{-1}$) versus log T (day) (Figure 3). The effective diffusion coefficients ranged from 8.9×10^{-13} $m^2 \cdot s^{-1}$ to 1.43×10^{-12} $m^2 \cdot s^{-1}$, while effective diffusion depths (X_c) ranged from 41.22 mm to 51.96 mm for 30 years submergence (Table B-6). The slopes of the regression equations were within the range of -0.6 to -0.7.

The 77%:20%:03% PG:Class C fly ash:Portland Type II cement composite and 72%:25%:03% PG:Class C fly ash:Portland Type II cement composites produced the highest sulfate effective diffusion coefficients and would likely be excluded from the selection of the final four. The maximum allowable effective diffusion coefficient for SO_4^{2-} in selecting the optimum PG composite combinations is 1.0×10^{-12} $m^2 \cdot s^{-1}$. The PG briquette combinations meeting this criterion are highlighted in bold in Table 6.

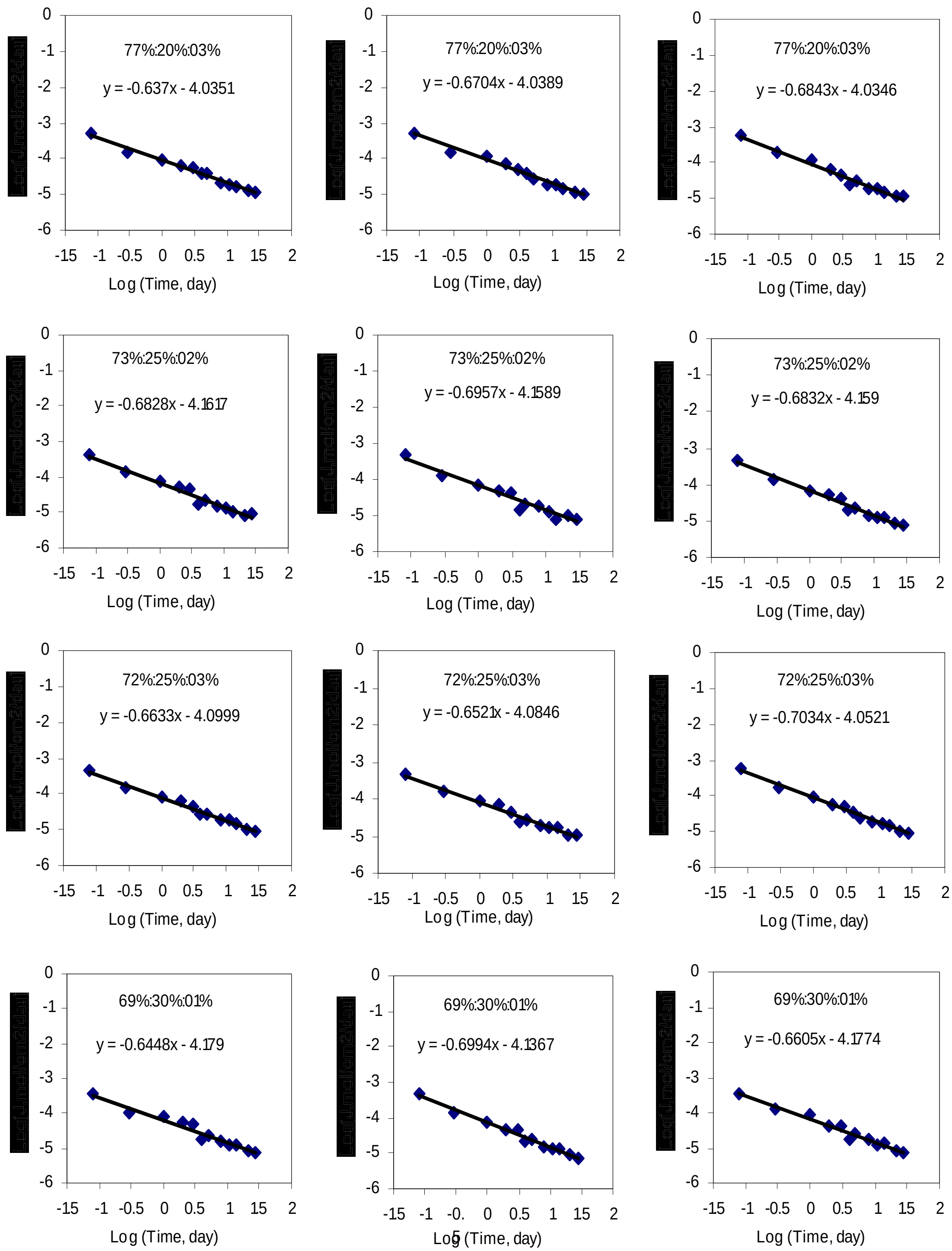

Figure 3. Plots for Log (J) Versus Log (T) Used to Estimate the Sulfate Effective Diffusion Coefficients for the PG: Class C Fly Ash: Portland Type II Cement Composites.

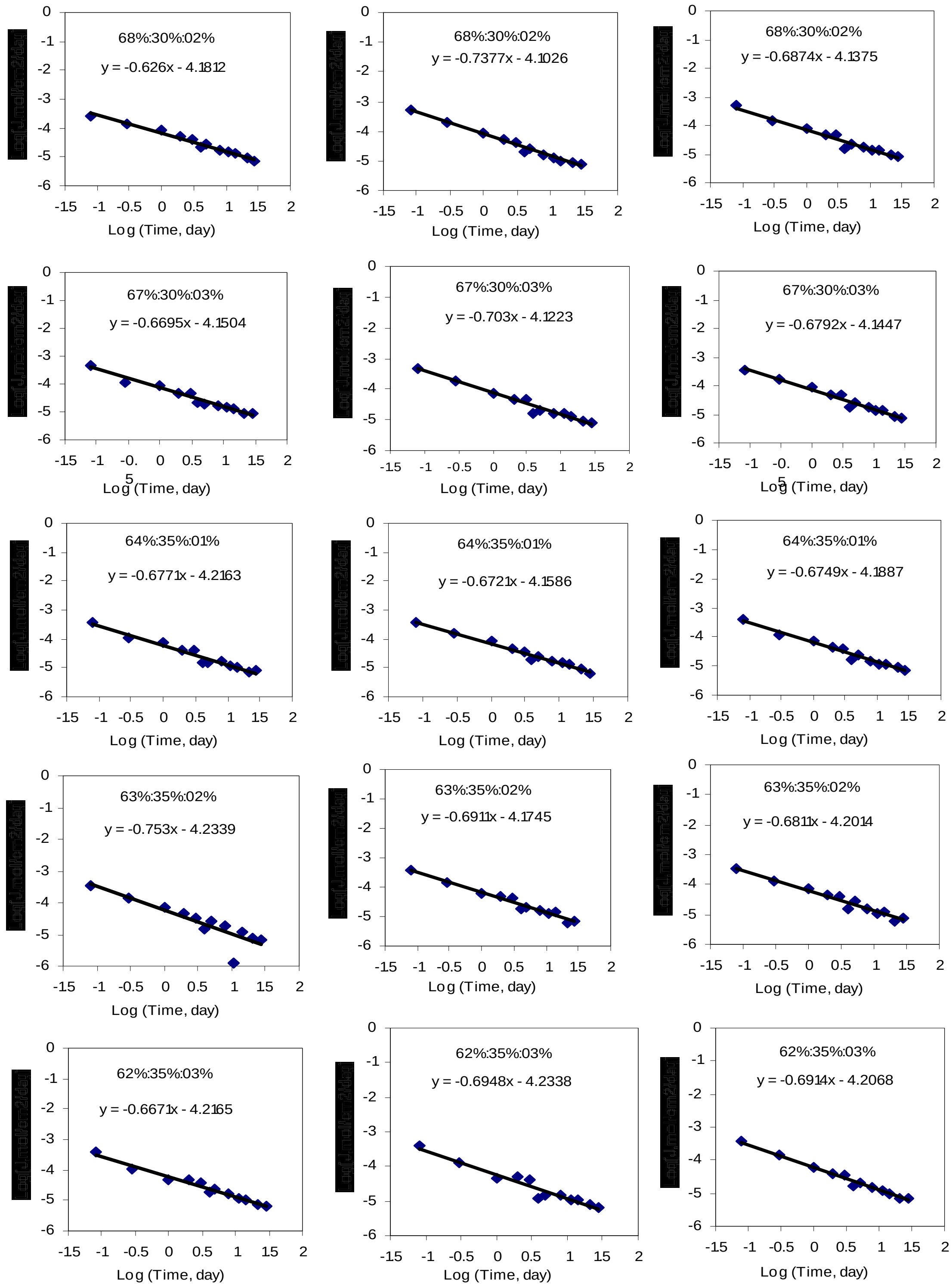

Figure 3 (Cont.). Plots for Log (J) Versus Log (T) Used to Estimate the Sulfate Effective Diffusion Coefficients for the PG:Class C Fly Ash: Portland Type II Cement Composites.

Table 6. Sulfate Effective Diffusion Coefficients (D_e) Expressed as Mean ± SD (n=3) and Effective Diffusion Depths (X_c) Calculated Using Data Obtained from the 28-Day Dynamic Leaching Study on the PG Composite Briquettes.

PG:Class C Fly Ash:Type II Portland Cement	D_e (m^2 s^{-1} × 10^{-12})	X_c (mm)[a]	X_c (mm)[b]
77%:20%:03%	1.43 ± 0.02	9.49	51.96
73%:25%:02%	**0.89 ± 0.007**	**7.53**	**41.22**
72%:25%:03%	1.35 ± 0.15	9.21	50.47
69%:30%:01%	**0.98 ± 0.11**	**7.90**	**43.25**
68%:30%:02%	1.14 ± 0.20	8.50	46.53
67%:30%:03%	1.17 ± 0.08	8.61	47.15
64%:35%:01%	1.03 ± 0.14	8.07	44.21
63%:35%:02%	**0.99 ± 0.13**	**7.91**	**43.35**
62%:35%:03%	**0.95 ± 0.06**	**7.74**	**42.37**

(a) time = 1 year. (b) time = 30 years.

In summary, the 73%:25%:02%, 69%:30%:01%, 63%:35%:02% and 62%:35%:03% PG:Class C fly ash:Portland Type II cement composite combinations met the criteria for maximum allowable calcium and sulfate effective diffusion coefficients.

Field Submergence

Out of the four PG combination blocks submerged, only the 67%:30%:03% PG:Class C fly ash:Portland Type II cement and 63%:35%:02% PG:Class C fly ash:Portland Type II cement composites survived the nine month submergence test (Table 7, Figure 4). The 77%:20%:03% and 72%:25%:03% PG:Class C fly ash:Portland Type II cement blocks showed some degradation. Both blocks and briquettes of the 63%:35%:02% and 67%:30%:03% PG:Class C fly ash:Portland Type II cement showed promising results (Tables A-7, A-8). The field submergence performance of PG blocks is the same as PG briquettes.

Table 7. The Condition of the Original Four Combinations of PG Composite Blocks After Nine Months of Saltwater Submergence.

PG:Class C Fly Ash:Portland Type II Cement	Condition
77%:20%:03%	Severe Degradation
72%:25%:03%	Degradation
67%:30%:03%	**Good**
63%:35%:02%	**Good**

Figure 4. PG:Class C Fly Ash:Portland Type II Cement Briquettes After Nine Months of Submergence.

The conditions of the briquettes after four and seven months of submergence are presented in Figures 5 and 6. Out of the nine combinations submerged under natural saltwater conditions, the 73%:25%:02%, 67%:30%:03%, 63%:35%:02% and 62%:35%:03% PG:Class C fly ash:Portland Type II cement composites showed promising results with no signs of degradation after nine months of submergence (Figure 7). The dimensions of PG briquettes before and after nine months of field submergence are presented in Table 8. The composite combinations 77%:20%:03%, 72%:25%:03%, 69%:30%:01%, 68%:30%:02% and 64%:35%:01% PG:Class C fly ash:Portland Type II cement composites showed severe degradation after nine months of submergence (Table 8). Figure 8a illustrates the 77%:20%:03%, PG:Class C fly ash:Portland Type II cement composite before submergence in the saltwater, and Figure 8b illustrates severe degradation for the same composite after the first month of saltwater submergence. Due to dissolution in saltwater, the degraded briquettes came out of the color tags in which they were tied.

Table 8. The Condition of the Original Nine PG Briquette Combinations After Nine Months of Saltwater Submergence.

PG:Class C Fly Ash:Portland Type II Cement	Condition
77%:20%:03%	Severe degradation
73%:25%:02%	**Good**
72%:25%:03%	Degradation
69%:30%:01%	Degradation
68%:30%:02%	Degradation
67%:30%:03%	**Good**
64%:35%:01%	Degradation
63%:35%:02%	**Good**
62%:35%:03%	**Good**

Table 9. The Average (n=5) Dimension of Four PG Briquettes Changed Slightly After Nine Months of the Saltwater Field Submergence Test.

PG:Class C Fly Ash:Portland Type II Cement	Before Submergence (mm)			After 9 Months' Submergence (mm)		
	Length	Width	Height	Length	Width	Height
77%:20%:03%[a]	42.1	22.9	13.4	36.9	19.2	12.5
73%:25%:02% [a]	**42.5**	**23.0**	**13.6**	**42.2**	**21.2**	**14.0**
72%:25%:03%[c]	41.7	22.5	13.7	36.9	17.8	12.1
69%:30%:01%[b]	41.5	23.3	13.4	39.2	19.9	12.0
68%:30%:02%[b]	46.3	26.8	18.6	39.2	19.9	12.0
67%:30%:03%[a]	**46.3**	**26.8**	**18.6**	**39.5**	**21.3**	**13.8**
64%:35%:01%	46.3	27.6	18.5	39.6	20.2	13.3
63%:35%:02%	**41.3**	**21.8**	**13.2**	**40.3**	**19.8**	**13.9**
62%:35%:03%	**41.5**	**21.9**	**13.3**	**41.5**	**26.1**	**14.6**

(a) Lost one composite combination, (b) Lost two composite combinations, (c) Lost three composite combinations.

Figure 5. PG:Class C Fly Ash:Portland Type II Cement Composite Briquettes After Four Months of Submergence.

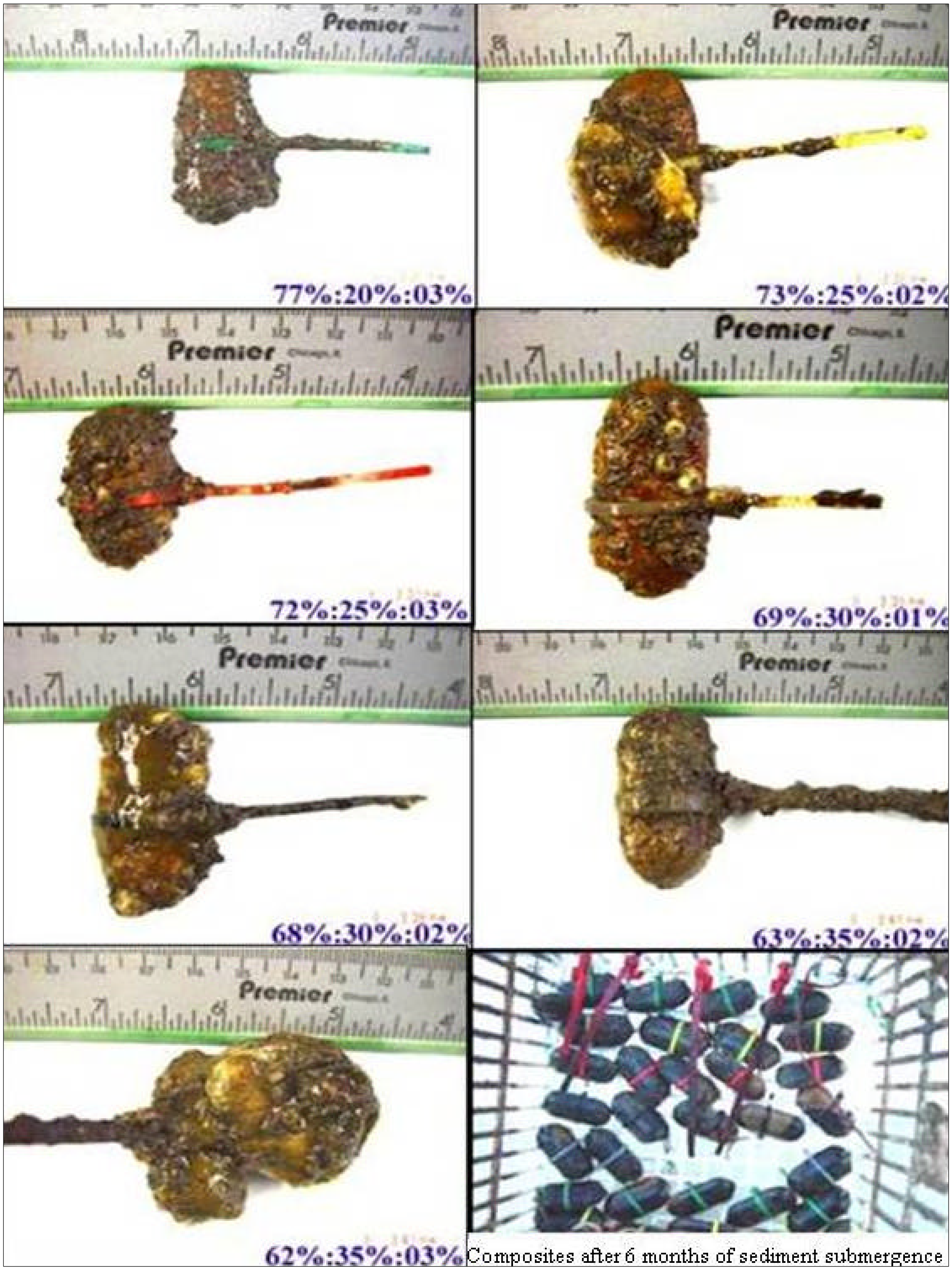

Figure 6. PG:Class C Fly Ash:Portland Type II Cement Composite Briquettes After Seven Months of Field Submergence.

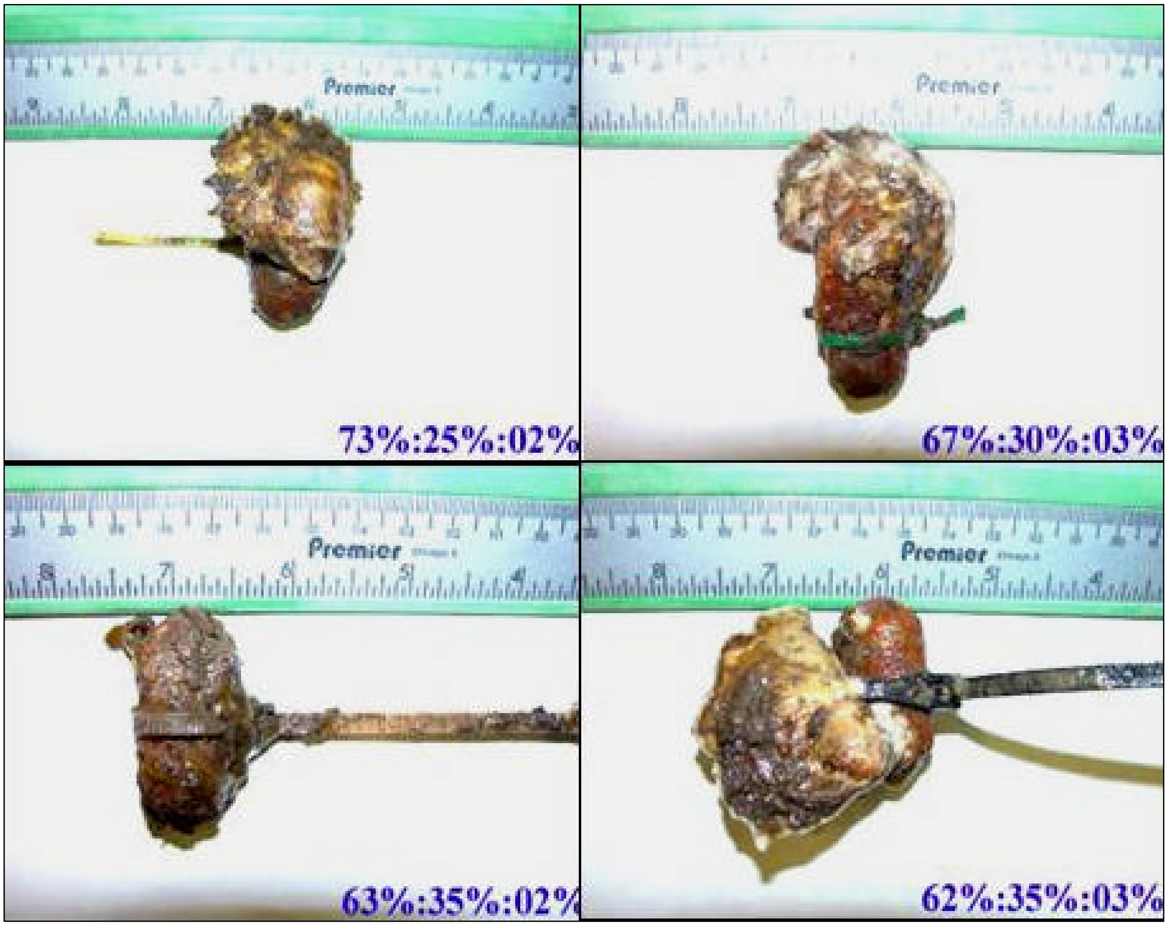

Figure 7. PG:Class C Fly Ash:Portland Type II Cement Composite Briquettes After Nine Months of Field Submergence.

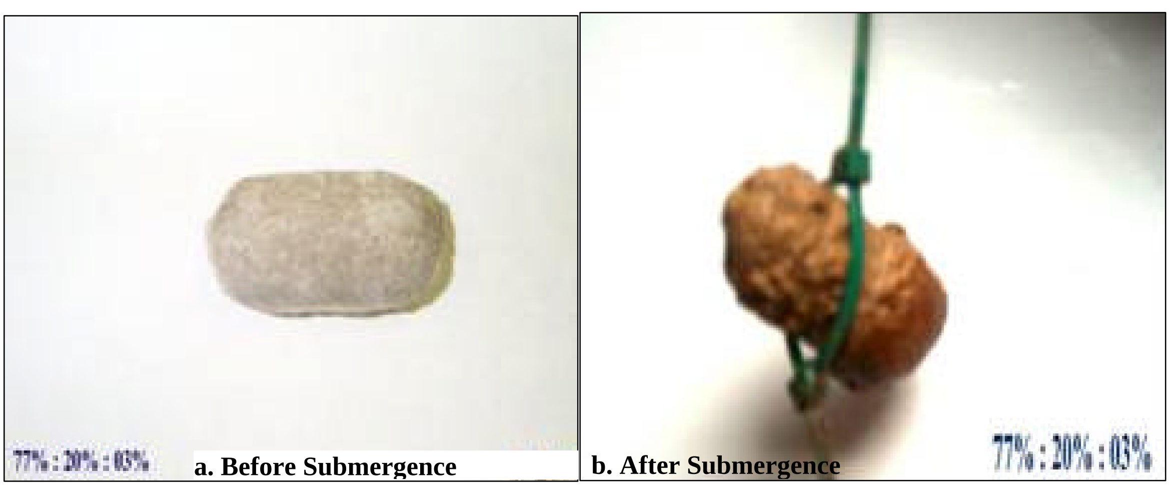

Figure 8. The 77%:20%:03% PG:Class C Fly Ash:Portland Type II Cement Composite Briquettes Shown Before and After One Month of Saltwater Submergence.

Compaction Tests and Sieve Analysis

Compaction tests were performed in triplicate using the Standard Proctor compaction method to assess the physical stability of the briquette when subjected to dynamic compaction. A standard compaction mold of volume 943.0 cm^3 was used to perform the test. Each combination was tested in triplicate, and the results showed that all the briquettes behaved similarly (Figure 9), with an average unit weight of 1.4 $g \cdot cm^{-3}$ (Table 10).

Table 10. Mean Unit Weights ± SD (n=3) Determined from the Standard Proctor Compaction Test Performed on the Nine PG:Class C Fly Ash:Portland Type II Cement Combinations.

PG:Class C Fly Ash:Portland Type II Cement	Mean Unit Weight ± SD ($g \cdot cm^{-3}$)
77%:20%:03%	1.4254 ± 0.0143
73%:25%:02%	1.4244 ± 0.0034
72%:25%:03%	1.4271 ± 0.0013
69%:30%:01%	1.3984 ± 0.0171
68%:30%:02%	1.3554 ± 0.0033
67%:30%:03%	1.3772 ± 0.0306
64%:35%:01%	1.3719 ± 0.0002
63%:35%:02%	1.3765 ± 0.0062
62%:35%:03%	1.3730 ± 0.0135

The gradation characteristics of all the briquette compositions after compaction using the Standard Proctor compaction method (ASTM D698 - 00a) indicate a relatively modest amount of degradation of the briquettes due to compaction. Before compaction, the briquettes were basically of uniform size with a length of 41.3 to 46.3 mm, width of 21.8 to 27.6 mm, and height of 11.3 to 18.6 mm. In effect, if perfectly shaped, 100% of the briquettes will be retained on a 1” sieve. After compaction, 100% of the sample will pass through a 1” sieve. Sieve analysis tests were conducted on the crushed material from the compaction tests, and Figure 9 shows a plot of percent finer by weight on a normal scale versus the particle size on a log scale. In the case of the briquettes, compaction actually improves the engineering properties and workability of the briquettes. The results indicate that the briquettes are reasonably well-graded material. Based on the behavior of naturally occurring soils, well-graded soils perform much better in construction applications such as embankments and structural fills than uniform soils. Using the Unified Soil Classification System, after degradation, the briquettes classify as well-graded gravel with little or no fines (GW). However, it should be recognized that the mineralogy of the briquette is significantly different from that of naturally occurring soils. However, the classification does give us some insight into the anticipated behavior of the briquettes when used as a construction material. Specifically, based on the Engineering Use Chart, naturally occurring soils with the same classification will exhibit the following generalized behavior:

- Permeability when compacted: pervious
- Shear strength when compacted and saturated: excellent
- Compressibility when compacted and saturated: excellent
- Workability as a construction material: excellent

Its desirability for use as the shell of an earth dam is excellent. It also has excellent erosion resistance. It would serve as an excellent foundation material in cases where the prevention of seepage is not important.

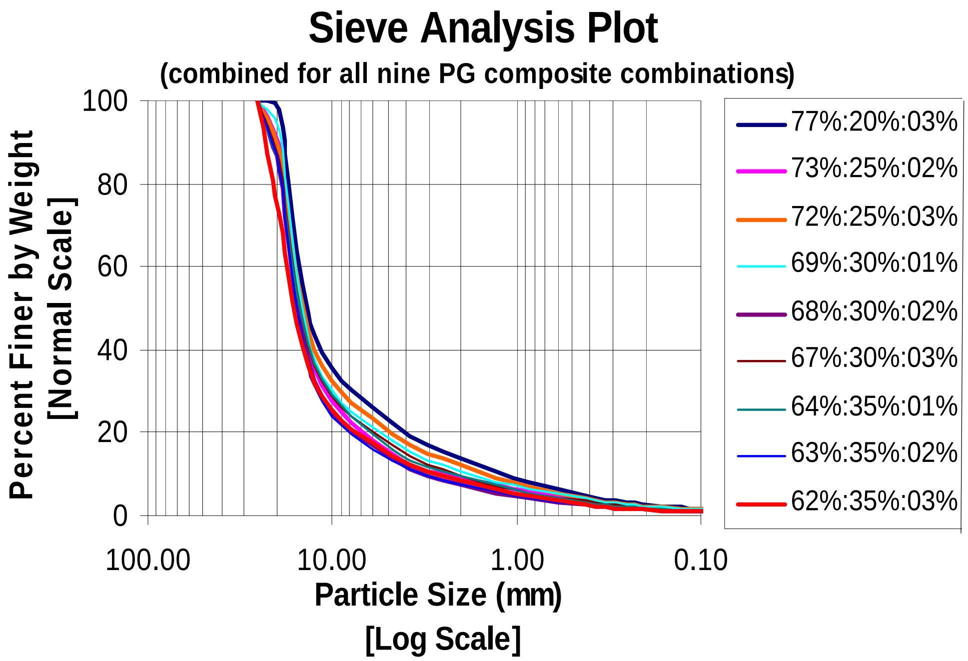

Figure 9. Plot of Percent Finer by Weight Versus Particle Size from the Sieve Analysis in Phase I Research Following Compaction.

Surface Hardness

Surface hardness tests were performed in triplicate on the control (not leached) and leached PG composite briquettes/blocks. Each PG composite was tested for surface hardness using a WF21510 cone penetrometer following the British Standards, Methods of Testing Soils for Engineering Purposes (BS1377:1975). The greater the depth penetrated, the lower the surface hardness.

Surface hardness analyses were performed on both leached and control PG blocks. Block composite was tested in duplicate. Twenty-six measurement points were recorded for each briquette/block. Six points were measured on each composite of the control and leached (PG briquettes from the dynamic leaching study) PG composites. The surface hardness in this study is defined as the inverse of the depth (in mm) penetrated. The results are tabulated in Table 11 for both control and leached PG composite briquettes and in Table 12 for PG blocks (the blocks were subjected to DLT for carrying out surface hardness analysis only, analysis of the leachate generated is not available). The leached PG composite briquettes showed lower surface hardness than the control PG briquettes.

Table 11. Mean Surface Hardness ± SD (n=3) of PG:Class C Fly Ash:Portland Type II Cement Composite Briquettes After 28-Day Curing and 28-Day Dynamic Leaching Test (DLT).

PG:Class C Fly Ash:Portland Type II Cement	Mean Surface Hardness ± SD (mm^{-1})	
	Cured	DLT
77%:20%:03%	39.06 ± 2.73	10.07 ± 1.96
73%:25%:02%	53.33 ± 2.90	29.34 ± 11.03
72%:25%:03%	44.64 ± 5.99	25.38 ± 8.98
69%:30%:01%	39.44 ± 3.73	47.20 ± 8.10
68%:30%:02%	45.86 ± 2.39	47.79 ± 19.67
67%:30%:03%	44.97 ± 10.31	57.13 ± 2.58
64%:35%:01%	39.81 ± 21.81	29.30 ± 8.27
63%:35%:02%	55.99 ± 6.24	20.79 ± 5.51
62%:35%:03%	45.09 ± 17.25	34.50 ± 14.73

Table 12. Surface Hardness of PG:Class C Fly Ash:Portland Type II Cement Blocks After 28-Day Curing and 28-Day Dynamic Leaching Test.

PG:Class C Fly Ash:Portland Type II Cement	Mean Surface Hardness ± SD (mm^{-1})	
	Cured	DLT*
77%:20%:03%	93.93 ± 3.15	66.39 ± 4.89
72%:25%:03%	86.76 ± 6.48	82.64 ± 4.07
63%:35%:02%	60.58 ± 9.32	67.51 ± 2.02

Pore Volume

The pore volume was calculated as pore water volume divided by composite volume. The pore volume results for the briquettes (Table 13 and Appendix H) showed that the 63%:35%:02% PG:Class C fly ash:Portland Type II cement and 62%:35%:03% PG:Class C fly ash:Portland Type II cement combinations had the lowest pore volumes. The combinations with smaller pore volume contain less space for water and air, resulting in a higher density and overall stronger composite. The pore volume increase (Table 13) after the dynamic leaching tests indicated that some of the stabilized PG blocks/briquettes dissolved during the process.

SEM Analysis

Scanning Electron Microscopy (SEM) studies were conducted to get a clear understanding of the microstructure of the briquettes and mechanisms of the stabilization and the saltwater dissolution potential of the composites. These studies helped to enhance the understanding of the process of transport of various elements during the dynamic leaching test.

Table 13. Mean Pore Volume ± SD (n=3) of the Nine PG:Class C Fly Ash:Portland Type II Cement Composite Briquette Combinations.

PG:Class C Fly Ash:Portland Type II Cement	Pore Volume [Mean ± SD] Before Dynamic Leaching (%)	Pore Volume [Mean ± SD] After Dynamic Leaching (%)	Increase in Pore Volume [Mean ± SD] After Dynamic Leaching (cm^3)
77%:20%:03%	14.6 ± 0.84	21.9 ± 1.01	0.62 ± 0.08
73%:25%:02%	13.6 ± 0.45	18.1 ± 1.02	0.38 ± 0.12
72%:25%:03%	14.2 ± 0.30	19.6 ± 0.62	0.46 ± 0.03
69%:30%:01%	14.2 ± 0.31	19.1 ± 0.73	0.41 ± 0.05
68%:30%:02%	13.8 ± 0.52	17.3 ± 0.34	0.30 ± 0.02
67%:30%:03%	14.4 ± 0.13	17.5 ± 0.66	0.27 ± 0.06
64%:35%:01%	13.6 ± 0.94	16.2 ± 1.27	0.22 ± 0.17
63%:35%:02%	13.4 ± 0.36	15.9 ± 1.03	0.21 ± 0.07
62%:35%:03%	13.2 ± 0.42	15.3 ± 0.90	0.18 ± 0.06

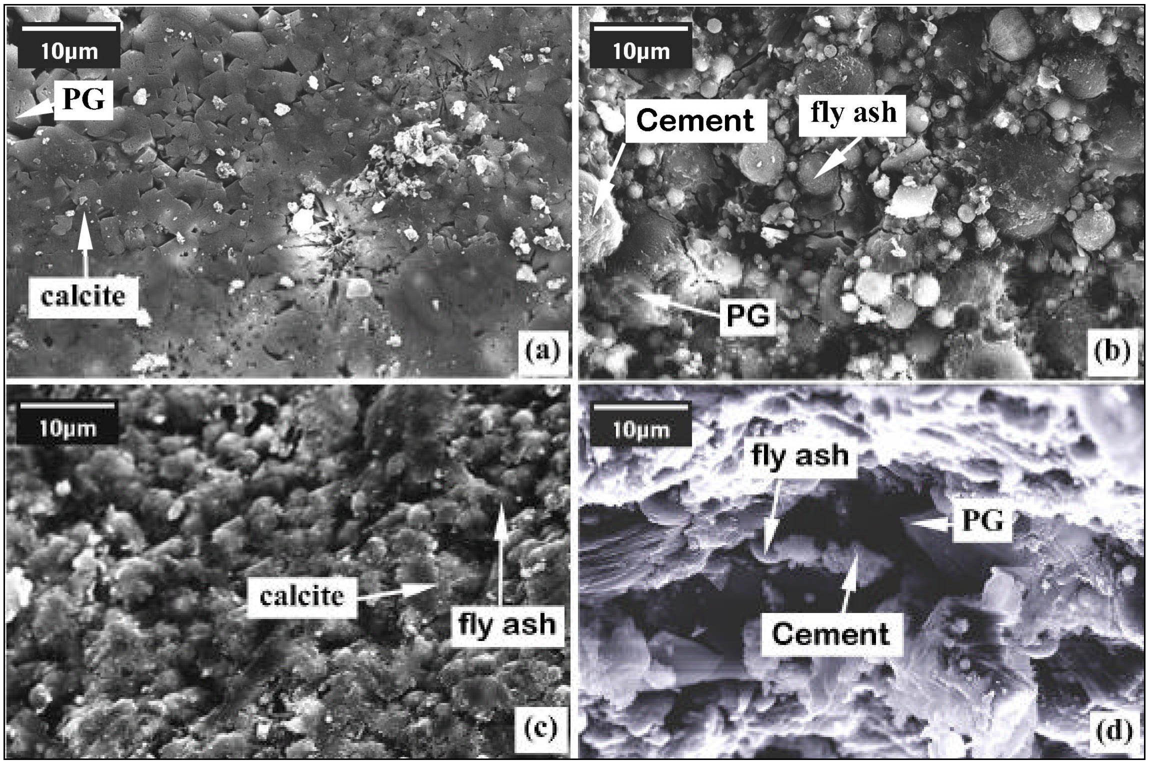

Figure 10. SEM Images of the 63%:35%:02% (a-b) and 62%:35%:03% (c-d) PG: Class C Fly Ash:Portland Type II Cement Composite Blocks After a 28-Day Saltwater Dynamic Leaching Test.

The SEM images of the leached PG composite blocks indicated formation of some coating on the surface (Figure 10a-10d). Figure 10a shows a coating layer on the surface of the 63%:35%:02% PG:Class C fly ash:Portland Type II cement block composite and Figure 10b shows the SEM image of the interior structure for the same composition. Figure 10b indicates the fly ash, gypsum and cement paste. X-ray analysis showed the coating is calcite. Similar results can be seen in the SEM images for the 67%:30%:03% PG:Class C fly ash:Portland Type II cement block combinations (Figure 10c and Figure 10d). Here, the coatings are seen in discontinued patches in contrast to the uniformity observed in Figure 10a.

Cost Analysis

The PG briquette production costs were obtained using the ingredient costs in Tampa, Florida for the year 2001 (Table 14). All nine PG composite combinations have a production cost below $13.62, the cost of the 62%:35%:03% PG:Class C fly ash:Portland Type II cement composite. The 73%:25%:02% PG:Class C fly ash:Portland Type II cement composite, which is showing promising results based on the field submergence, has a production cost of $10.62 per ton^{-1}, $3.00 per ton^{-1} less than the cost for 63%:35%:03% PG:Class C fly ash:Portland Type II cement composite. These costs do not include any offset for disposal.

Table 14. Nine PG:Class C Fly Ash:Portland Type II Cement Combinations with the Composite Production Costs, Considering the Ingredient Costs in Tampa, Florida, for 2001.

PG:Class C Fly Ash:Portland Type II Cement	Production Cost per Ton ($)
77%:20%:03%	10.15
73%:25%:02%	10.62
72%:25%:03%	11.30
69%:30%:01%	11.10
68%:30%:02%	11.78
67%:30%:03%	12.46
64%:35%:01%	12.26
63%:35%:02%	12.94
62%:35%:03%	13.62

Selection of the Best Four Combinations

Based on the results obtained from the field submergence study, it was noted that four out of the nine PG:Class C fly ash:Portland Type II cement composite combinations survived with no signs of degradation after nine months of submergence. Since the composites placed in natural saltwater conditions better demonstrate the true physical integrity of the PG briquettes, the results from the submergence tests were used as a major criterion for the screening. The effective calcium and sulfate diffusion coefficients from the 28-day dynamic leaching study indicated that five out of the nine PG composite combinations met the leaching criteria (Table 15). Although the 69%:30%:01% PG:Class C fly ash:Portland Type II cement composite met both the calcium and sulfate D_e criteria, the composite failed to demonstrate promising results in the field submergence tests and was thus eliminated.

The estimated cost ($13.62 per ton^{-1} for year 2001) of the control combination (62%:35%:03% PG Class C fly ash:Portland Type II cement composite) was used as a cut-off for selecting the combinations. The production costs per ton for all other combinations were below $13.62. In Table 15, the combinations meeting the respective criteria are marked as '✓' whereas the combinations that did not meet the respective criteria are marked as '×'.

Table 15. Evaluation Matrix Used for Determining the Best Four PG Briquette Combinations.

PG:Class C Fly Ash: Portland Type II Cement	Natural Saltwater Submergence	Calcium D_e, $m^2 \cdot s^{-1}$	Sulfate D_e, $m^2 \cdot s^{-1}$	Cement Proportion (> 1%)	Estimated Cost ($\$ \cdot ton^{-1}$)
77%:20%:03%	✗	✗	✗	✓	✓
73%:25%:02%	✓	✓	✓	✓	✓
72%:25%:03%	✗	✗	✗	✓	✓
69%:30%:01%	✗	✓	✓	✗	✓
68%:30%:02%	✗	✗	✗	✓	✓
67%:30%:03%	✓	✗	✗	✓	✓
64%:35%:01%	✗	✗	✗	✗	✓
63%:35%:02%	✓	✓	✓	✓	✓
62%:35%:03%	✓	✓	✓	✓	✓

The PG composite combinations meeting all selection criteria were selected for further testing. The only exception was the 67%:30%:03% PG composite that did not comply with the allowable calcium and sulfate D_e criteria, but was selected in the best four group based on its survivability results from the field submergence study. Furthermore, the effective calcium and sulfate D_e for the 67%:30%:03% PG composite were not significantly different from that of the set criteria. Although the 64%:35%:01% PG:Class C fly ash:Portland Type II cement composite met the sulfate D_e criteria, it was not selected for further testing because it did not survive in the field. Hence, the best four PG:Class C fly ash:Portland Type II cement composite briquette combinations selected were 73%:25%:02%, 67%:30%:03%, 63%:35%:02% and 62%:35%:03%, and are highlighted in bold in Table 15.

PHASE II. EVALUATION OF THE SELECTED FINAL FOUR COMBINATIONS

During Phase II research, the best four compositions were re-fabricated for further evaluation. To ensure reproducibility of the data collected during Phase I testing (due to change in moisture content), the briquettes in Phase II were again subjected to Phase I testing with the addition of TCLP analysis, radium and metal content analysis, and determination of angle of cohesion (ϕ) (direct shear test). For an in-depth analysis of the leaching process and to predict long-term survivability, the dynamic leaching test was conducted for 77 days. The calcium, sulfate and heavy metals (Cr^{3+}, Cu^{2+}, Zn^{2+}, Fe^{2+}, Pb^{2+} and Cd^{2+}) were analyzed in the leachate collected during the 77-day dynamic leaching test. For Ra^{226} analysis, the leachate collected for up to 28 days was used. The initial content of metals present in the briquettes ($C_{o,expr.}$, $mg \cdot cm^{-3}$) used to estimate effective diffusion coefficients was obtained by the acid digestion analysis (USEPA Method: 3050) because the theoretical values (as discussed for calcium/sulfate in Phase I) could not be calculated. For the estimation of the radium diffusion coefficients, the total radium content (i.e., C_o, $pCi \cdot cm^{-3}$) for each combination was calculated using the average radium concentration ($37.24\ pCi \cdot g^{-1}$) present in the raw PG. The concentrations of the trace elements that are on EPA's toxicity list (e.g., arsenic, cadmium, lead and selenium) were determined through the Toxicity Characteristics Leaching Procedure (TCLP) for the raw PG as well as the best four PG composite compositions.

Validation of the Regression Diffusion Model

The validity of the regression method with non-zero surface concentration diffusion model was investigated by comparing the diffusion coefficients obtained using the regression model with those obtained using the simple diffusion model with zero surface concentration (i.e., daily flux and cumulative flux methods).

Comparison of Effective Calcium Diffusion Coefficients from Simple Diffusion Models and Regression Model

The calcium release rates from the 77-day dynamic leaching experiments were used to calculate the effective calcium diffusion coefficients by the method of cumulative flux plots (Figure 11 and Appendix C) (El-Kamash and others 2002) and daily flux plots (Duedall and others 1983) (Figure 12). These effective diffusion coefficients were used to validate those obtained from the regression method developed in this research. The results from the regression method (Equation 25) are shown in Table 16.

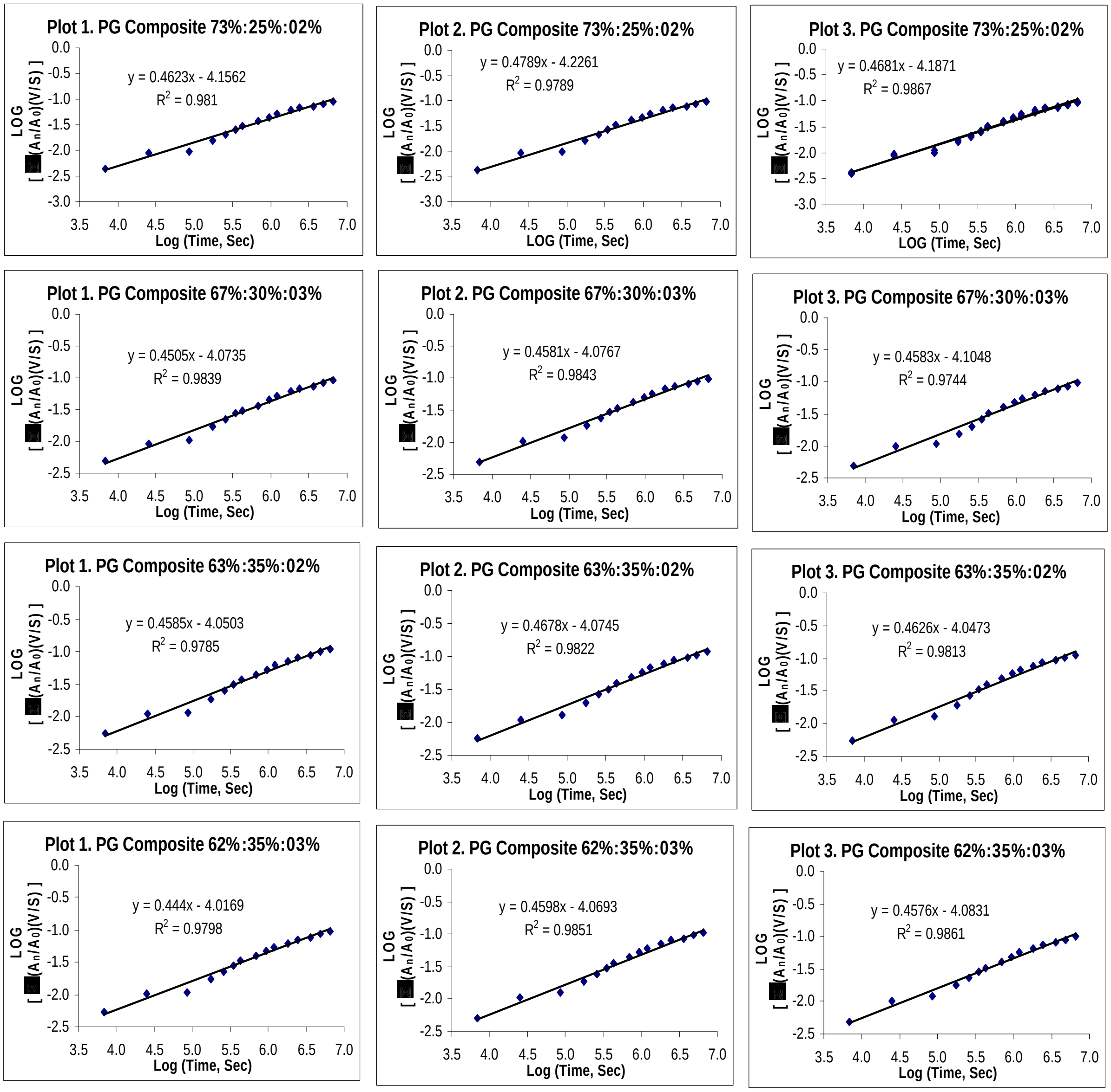

Figure 11. Cumulative Flux Plots Were Used to Calculate the Effective Calcium Diffusion Coefficients.

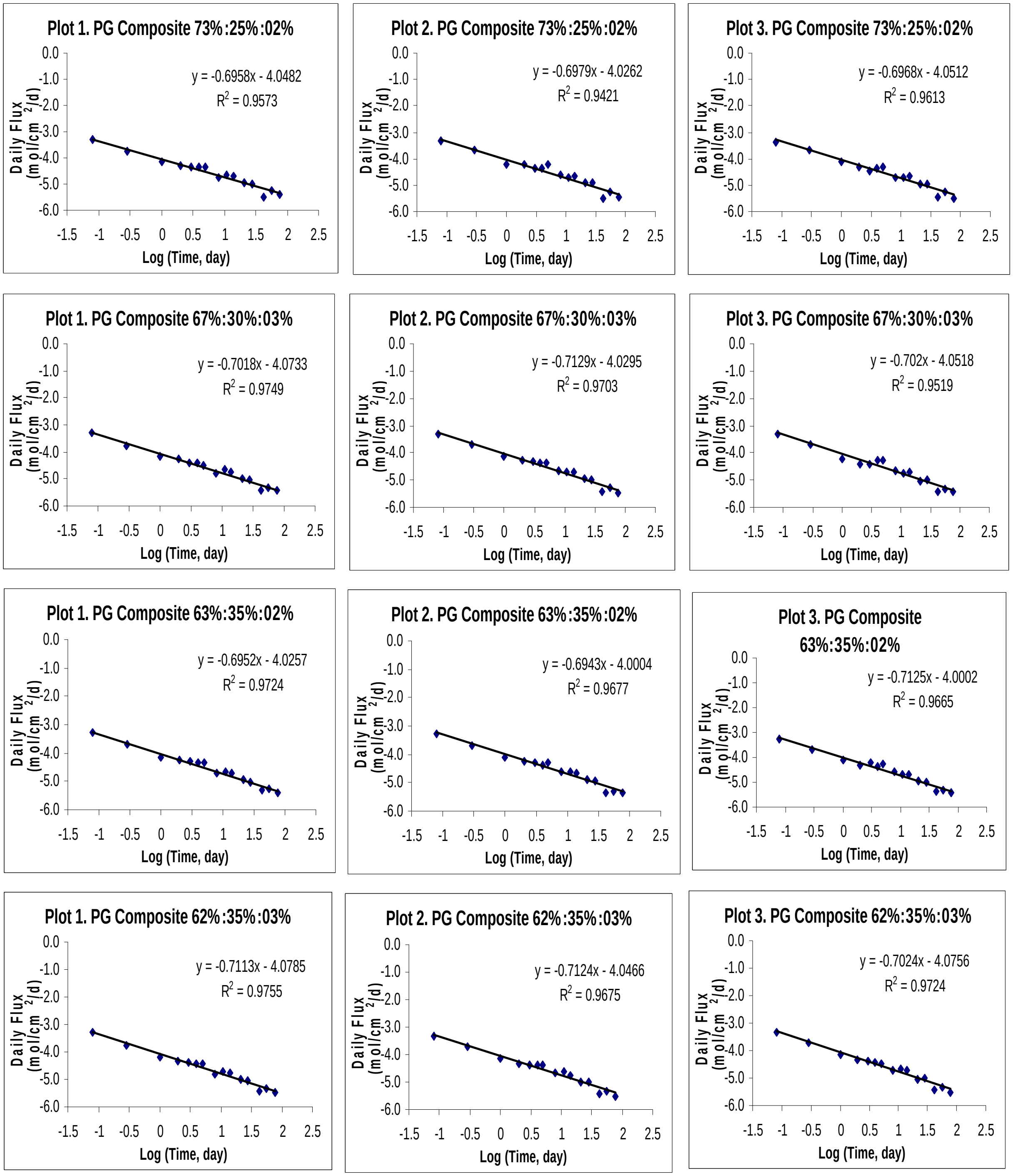

Figure 12. Daily Flux Plots Were Used to Calculate the Effective Calcium Diffusion Coefficients.

Table 16. K_1, K_2 and K_3, Critical Time and Effective Calcium Diffusion Coefficients for the PG Composite Combinations Calculated from the 77-Day Dynamic Leaching Data.

PG:Class C Fly Ash:Portland Type II Cement	K_1 (cm)	K_2 ($cm \cdot d^{-0.5}$)	K_3 ($cm \cdot d^{-1}$)	$t_{c, Calcium,}$ (d)	Calcium D_e ($m^2 \cdot s^{-1}$)
73%:25%:02%	-0.0017	0.0139	-0.0006	125	1.75×10^{-13}
67%:30%:03%	0.0000	0.0126	-0.0005	137	1.44×10^{-13}
63%:35%:02%	-0.0017	0.0122	-0.0005	122	2.48×10^{-13}
62%:35%:03%	0.0000	0.0165	-0.0007	137	1.36×10^{-13}

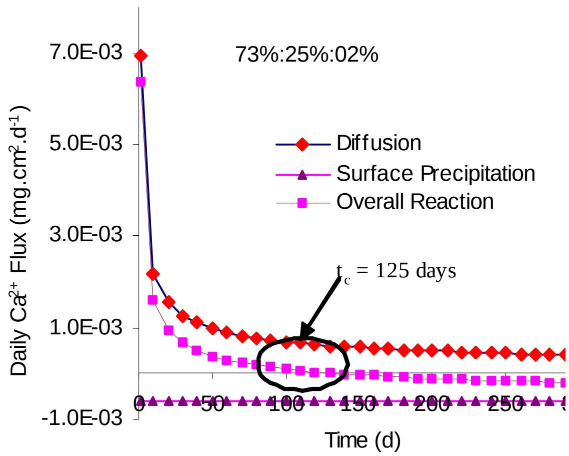

Figure 13. Plot of the Daily Flux Versus Time for Ca^{2+} Leached Out of 73%:25%:02% PG Composite.

SAS 8.2 verified the normality and uniform variance assumption for the error terms. Two of the K_1 values (Table 16) were equal to zero, indicating no immediate surface wash-off from the stabilized PG briquettes. The other two PG briquette combinations have some surface wash-off. The negative K_3 value implies that some precipitation reactions occurred, which removed calcium ions from solution. The rate of this precipitation reaction was 4-5% of the calcium diffusion process.

Flux curves for surface precipitation and diffusion of calcium ions were developed using Equation (26) to estimate the potential for long-term survivability (Figure 13, Table 16).

The t_c values for the calcium ions ranged from 122 to 137 days (Table 16). The variation in t_c value between the nine stabilized PG composites is largely attributed to the interaction of K_2 and/or D_e and K_3. Table 17 summarizes the effective calcium diffusion coefficients obtained from the new regression method (1.36 to 8.04×10^{-13} $m^2 \cdot s^{-1}$) and the cumulative flux (3.31 to 6.11×10^{-13} $m^2 \cdot s^{-1}$) and daily flux (5.95 to 7.93×10^{-13} $m^2 \cdot s^{-1}$) methods. All of these effective diffusion coefficients are in the same magnitude, indicating that effective diffusion coefficients obtained from the regression method developed in this research are comparable to those calculated using current cumulative flux and daily flux equations associated with the simple diffusion model.

Table 17. Comparison of the Effective Calcium Diffusion Coefficients ($m^2 \cdot s^{-1}$) Calculated from Methods of Regression and Cumulative Flux.

PG:Class C Fly Ash:Portland Type II Cement	Calcium D_e (Regression) ($m^2 \cdot s^{-1}$)	Calcium D_e (Cumulative Flux) ($m^2 \cdot s^{-1}$)	Calcium D_e (Daily Flux) ($m^2 \cdot s^{-1}$)
73%:25%:02%	1.75×10^{-13}	3.31×10^{-13}	5.95×10^{-13}
67%:30%:03%	1.44×10^{-13}	5.32×10^{-13}	6.34×10^{-13}
63%:35%:02%	2.48×10^{-13}	6.11×10^{-13}	7.93×10^{-13}
62%:35%:03%	1.36×10^{-13}	6.04×10^{-13}	6.61×10^{-13}

Comparison of Effective Sulfate Diffusion Coefficients from Current Models and Regression Model

The sulfate release rates from 77-day dynamic leaching experiments were used to calculate the effective sulfate diffusion coefficients by the method of cumulative flux plots (Figure 14) (El-Kamash and others 2002) daily flux plots (Duedall and others 1983) (Figure 15). The results from the regression method (Equation 25) were shown in Table 18. The K_1 values of all four PG briquette combinations were equal to zero, indicating no immediate sulfate surface wash-off.

Table 18. K_1, K_2 and K_3, Critical Time and Effective Sulfate Diffusion Coefficients for the PG Composite Combinations Calculated from the 77-Day Leaching Data.

PG:Class C Fly Ash:Portland Type II Cement	K_1 (cm)	K_2 ($cm \cdot d^{-0.5}$)	K_3 ($cm \cdot d^{-1}$)	$t_{c, Sulfate,}$ (d)	Sulfate D_e ($m^2 \cdot s^{-1}$)
73%:25%:02%	0	0.0172	-0.0010	77	2.96×10^{-13}
67%:30%:03%	0	0.0164	-0.0011	67	3.05×10^{-13}
63%:35%:02%	0	0.0204	-0.0012	64	3.25×10^{-13}
62%:35%:03%	0	0.0157	-0.0010	78	4.54×10^{-13}

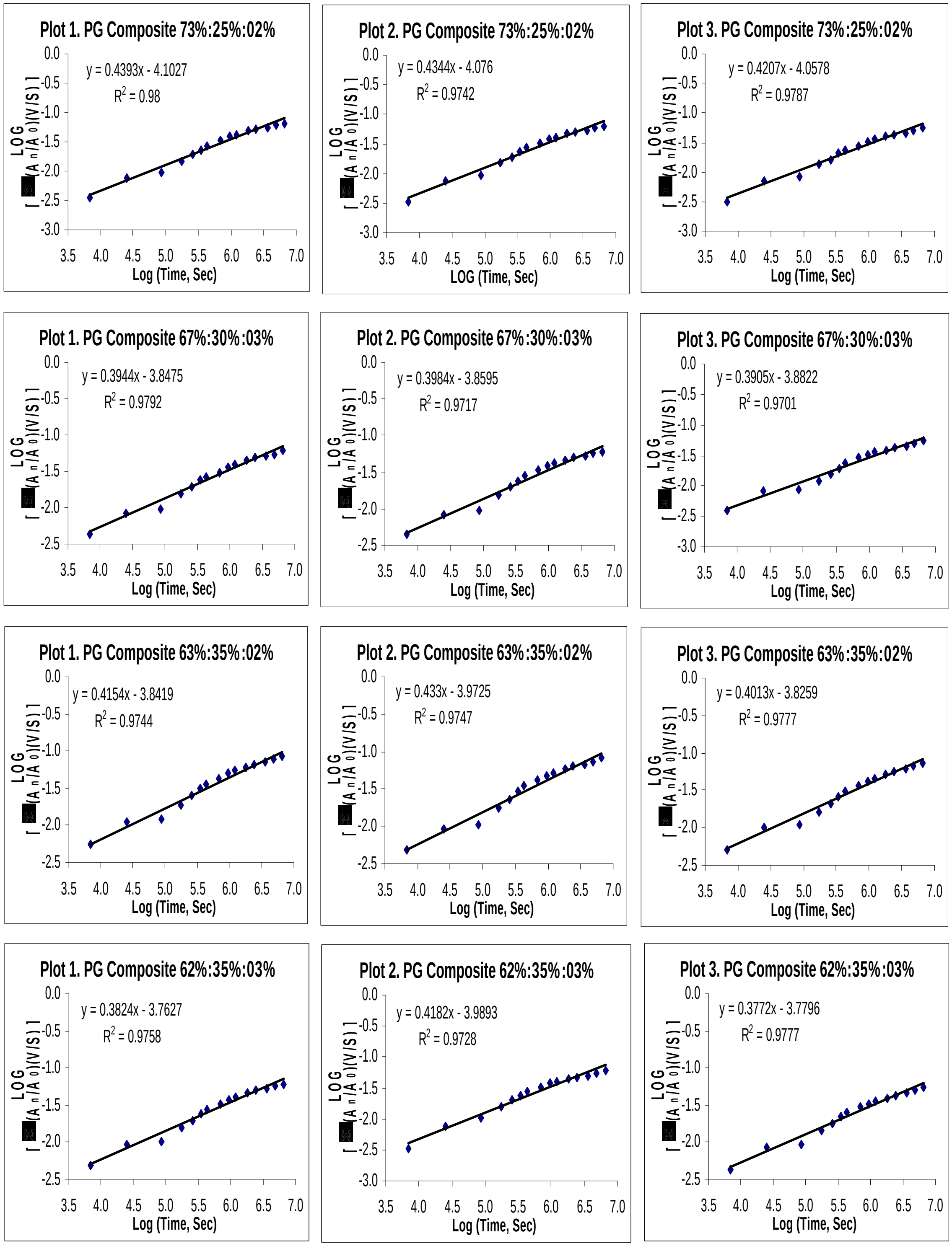

Figure 14. Cumulative Flux Plots Were Used to Calculate the Effective Sulfate Diffusion Coefficients.

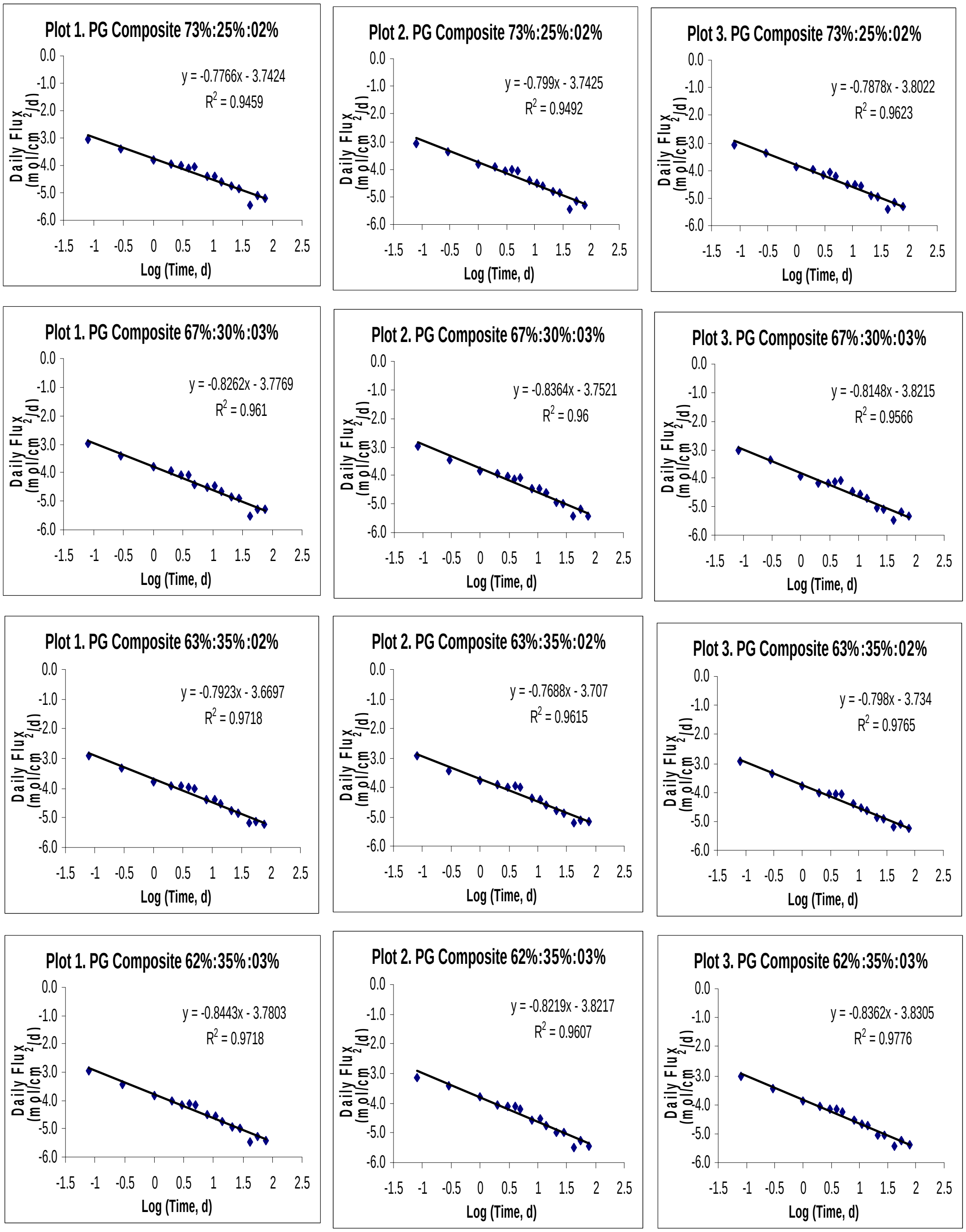

Figure 15. Daily Flux Plots Were Used to Calculate the Effective Sulfate Diffusion Coefficients for Sulfate.

The negative K_3 values for PG briquettes imply that some precipitation reactions occurred, which removed sulfate ions from solution (Table 18). The rate of this precipitation reaction was 5-6% of the sulfate diffusion process. SAS 8.2 verified all error term assumptions for the regression method. Table 19 summarizes the effective sulfate diffusion coefficients obtained from regression (2.96 to 4.54 × 10^{-13} $m^2 \cdot s^{-1}$), cumulative (5.48 × 10^{-13} to 1.78 × 10^{-12} $m^2 \cdot s^{-1}$) and daily flux method methods (2.15 to 3.25 × 10^{-12} $m^2 \cdot s^{-1}$).

Table 19. Comparison of the Effective Sulfate Diffusion Coefficients ($m^2 \cdot s^{-1}$).*

PG:Class C Fly Ash:Portland Type II Cement	Sulfate D_e (Regression) ($m^2 \cdot s^{-1}$)	Sulfate D_e (Cumulative Flux) ($m^2 \cdot s^{-1}$)	Sulfate D_e (Daily Flux) ($m^2 \cdot s^{-1}$)
73%:25%:02%	2.96×10^{-13}	5.48×10^{-13}	2.17×10^{-12}
67%:30%:03%	3.05×10^{-13}	1.47×10^{-12}	2.19×10^{-12}
63%:35%:02%	4.54×10^{-13}	1.78×10^{-12}	3.25×10^{-12}
62%:35%:03%	3.25×10^{-13}	1.42×10^{-12}	2.15×10^{-12}

*Calculated from different methods.

The differences between the effective diffusion coefficients from the new regression method and those from the cumulative flux and daily flux methods (simple diffusion model) are less than one magnitude. Therefore, the effective diffusion coefficients obtained from the regression method developed in this research are comparable to those calculated using the cumulative flux and daily flux equations associated with the simple diffusion model. Flux curves for surface precipitation and diffusion of sulfate ions were developed using Equation (26) to estimate the potential for long-term survivability (Figure 16, Table 19). The t_c values for the sulfate ions ranged from 64-78 days (Table 18). The variation in t_c value between the nine stabilized PG composites is largely attributed to the interaction of K_2 and/or D_e and K_3.

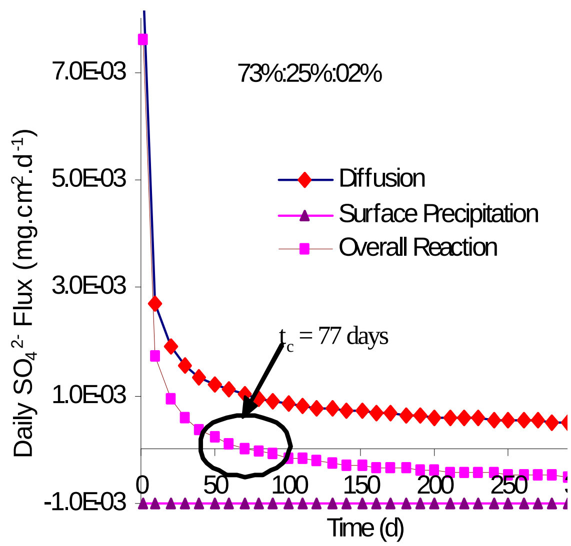

Figure 16. Plot of Daily Flux Versus Time for Sulfate Leached Out for the 73%:25%:02% PG Composite.

TCLP Test

The Toxicity Characteristic Leaching Procedure (TCLP, Method 1311) was performed in triplicate on raw ingredients and the four best PG composites to determine the maximum contaminant leachability of the PG composite briquettes. The contaminants present in the PG composite such as As, Cd, Pb and Se, identified as hazardous wastes by USEPA, were found to be below detection limits (Appendix I).

Diffusion of Heavy Metals

Plots of the cumulative flux rates versus time for the 77-day leaching period for Cr^{3+}, Cu^{2+}, Zn^{2+}, Fe^{2+}, Pb^{2+} and Cd^{2+} for the selected four PG composite combinations are presented in Figure 17 and Appendix K.

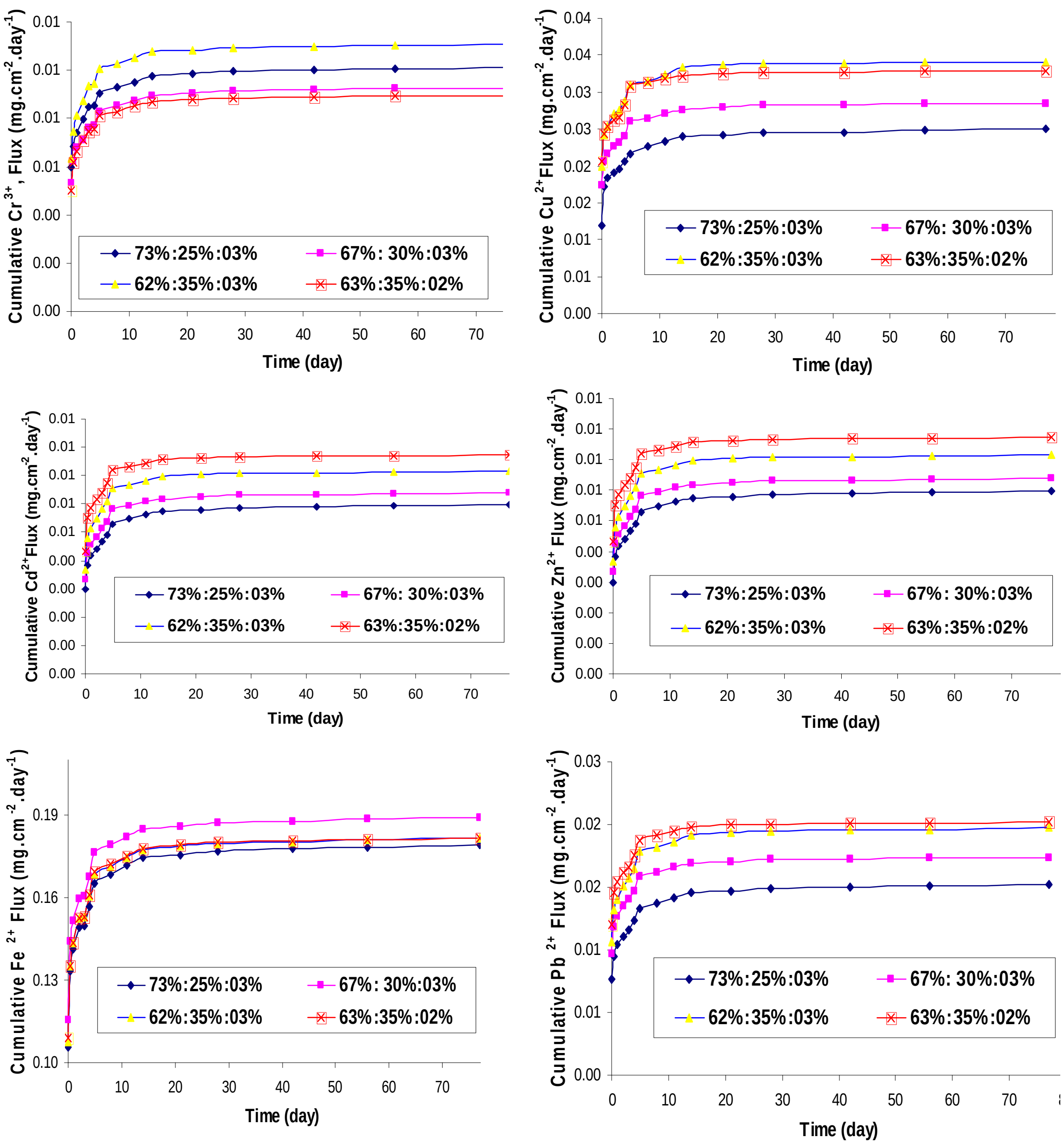

Figure 17. Cumulative Flux Rates for Chromium, Copper, Cadmium, Zinc, Iron and Lead in the Best Four PG Combinations.

The metal concentrations were well below the current USEPA toxicity limits (LaGrega and others 2001) for all PG combinations. The effective metal diffusion coefficients were obtained using the regression method for each composition. For Pb^{2+} and Cd^{2+}, the C_o values were below detection levels. Hence, the effective diffusion coefficients were not determined for Pb^{2+} and Cd^{2+}. Table 20 lists the effective diffusion coefficients for Cr^{3+}, Cu^{2+}, Zn^{2+} and Fe^{2+} from the regression method (Equation 26) with the new diffusion model. It was observed that the leachability of the species of interest in all of the compositions tested varied greatly. Of all the heavy metal species, Fe^{2+} had the lowest leaching rate. The orders of the mean leachability of the heavy metals were $Cu^{2+} > Cr^{3+} > Zn^{2+} > Fe^{2+}$. Li and Gregory (1974) studied the diffusion of ions in seawater. They conducted the diffusion experiment using a two-compartment system filled with the same diffusion medium (e.g., seawater agar gels), with the exception that one cell was homogeneously spiked with a radioactive tracer of a given ion. When compared with the tracer diffusion coefficients for Cr^{3+}, Cu^{2+}, Zn^{2+} and Fe^{2+} (obtained by Li and Gregory as listed in Table 20), much lower values of the effective D_e were observed for all the PG compositions. Poon and others (2001) conducted a flow-through leaching test to study the heavy metal diffusion for two types of synthetic sludge containing heavy metals and ordinary Portland cement mixed with pulverized fuel ash. Their results concluded that the diffusivity values increase continuously during the leaching period due to the degradation of the solidified waste matrix. The heavy metal diffusivities (obtained by Poon and others as listed in Table 20) were also higher than those obtained by conducting a 77-day dynamic leaching test for the PG composites in this research.

Table 20. Effective Metal Diffusion Coefficients (D_e) for the Best Four PG Compositions with a Comparison to the Literature Values.

PG Composite	Metal D_e ($m^2 \cdot s^{-1}$)			
	Cr^{3+}	Cu^{2+}	Zn^{2+}	Fe^{2+}
73%:25%:02%	9.63×10^{-13}	6.79×10^{-12}	4.23×10^{-14}	8.95×10^{-16}
67%:30%:03%	1.06×10^{-12}	1.21×10^{-11}	3.97×10^{-14}	9.17×10^{-16}
63%:35%:02%	1.69×10^{-12}	8.66×10^{-12}	9.10×10^{-14}	9.22×10^{-16}
63%:35%:02%	5.85×10^{-13}	6.46×10^{-12}	4.49×10^{-14}	7.94×10^{-16}
Tracer or self D_e in seawater (a)	5.94×10^{-10}	7.33×10^{-10}	7.15×10^{-10}	7.19×10^{-10}
Raw PG in saturated chloride solution (b)	4.1×10^{-10}	NA (c)	NA	4.89×10^{-10}
Stabilized synthetic waste (d)	9.0×10^{-9}	NA	$\sim 10^{-15}$	NA

(a) After Li and Gregory (1974), (b) After Gokmen (1995), (c) NA: Not available, (d) Samples contained heavy metals and ordinary Portland cement mixed with pulverized fuel ash (after Poon and others 2001).

Higher D_e values were also observed by Gokmen (1995), who estimated the diffusion coefficients of compacted raw PG specimens in a saturated chloride solution. Gokmen concluded that the chloride particles might attract some of the metals, thereby reducing their adsorption by solids and causing precipitation or some other aqueous phase reactions. However, a higher pH environment (usually 9 or greater) is needed for the solutions containing metals to reach their lowest solubility and produce respective insoluble precipitates of metal hydroxides (or metal-salts) (LaGrega and others 2001; Poon and others 2001; Yilmaz and others 2003). Thus, the possibility of the precipitation of the metal-salts in the leachate samples analyzed in this research is minimized, as the raw PG is acidic in nature and also the pH of the leachate containing stabilized PG composites ranged between 7 to 8. Furthermore, the lower diffusivity values of the heavy metals observed might be due to the higher compaction pressure and lower water content used to fabricate the best four PG composites. Figure 18 represents the flux curves of 73%:25%:02% PG composite for surface precipitation and diffusion for Cu^{2+}, Cr^{3+}, Zn^{2+} and Fe^{2+} ions developed using Equation (26) to estimate the potential for long-term survivability.

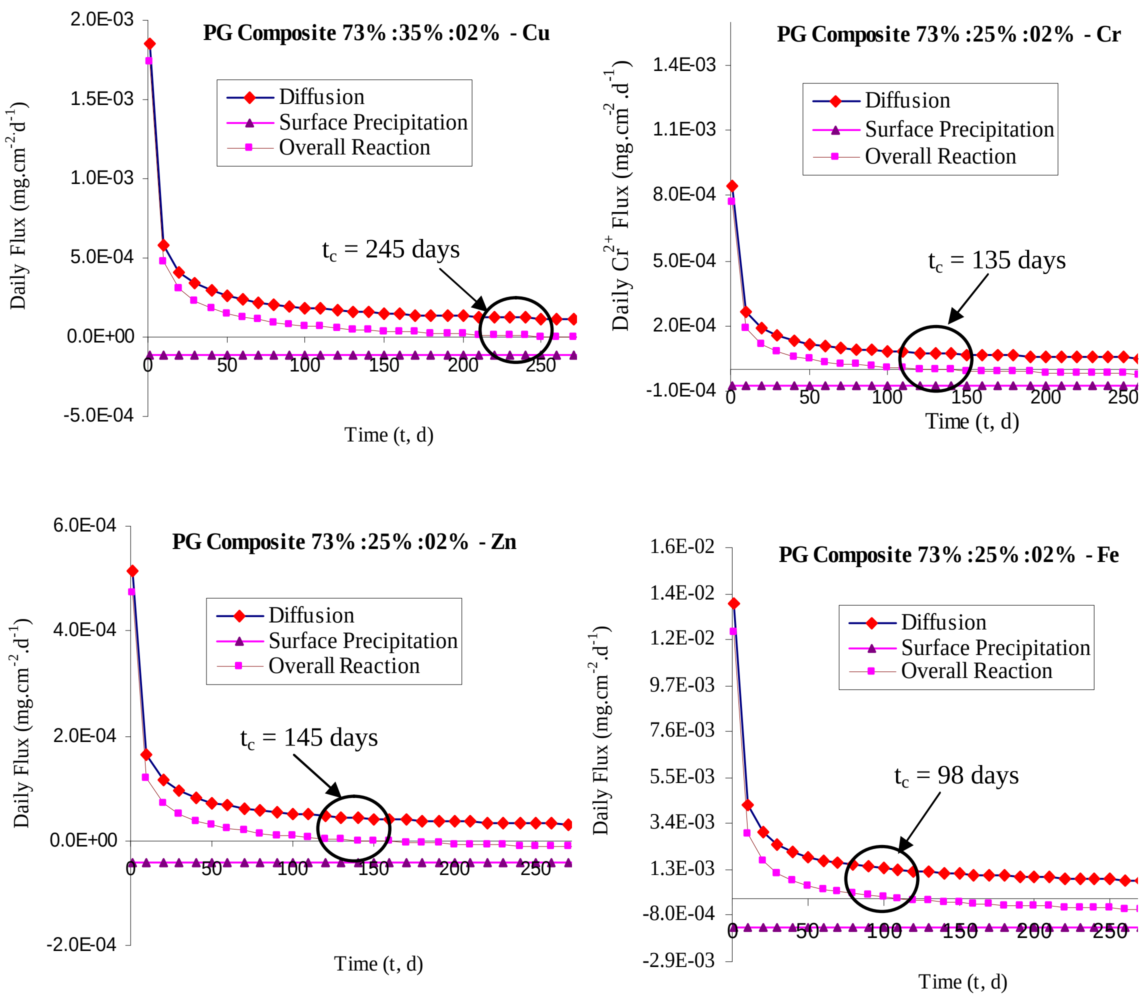

Figure 18. Daily Flux Versus Time for Surface Precipitation and Diffusion of the Cu^{2+}, Cr^{3+}, Zn^{2+} and $Pb2^{+}$ Concentration Leached from the 73%:25%:02% PG Composite.

The t_c values obtained for all the four PG composites are presented in Table 21. All the data pertaining to calculation of D_e, i.e., K_1, K_2, K_3 and flux plots for all the four PG composites are included in Appendix L.

Table 21. Critical Time t_c Values Obtained for the Four PG Composites.

Composite Combination	Copper t_c in days	Chromium t_c in days	Zinc t_c in days	Iron t_c in days
73%:20%:3%	245	135	145	98
67%:30%:3%	123	130	100	80
63%:35%:2%	78	168	108	79
62%:35%:3%	98	61	89	92

Diffusion of Ra^{226}

Figure 19 illustrates a combined plot for the cumulative radium flux rates ($pCi \cdot cm^{-2} \cdot d^{-1}$) during a 28-day dynamic leaching study performed in duplicate on the best four PG composite combinations. The cumulative amount of Ra^{226} leached showed an almost linear rate of increase through 6 days. The leach rates were higher in the first 3 to 5 days of the leaching time and then decreased gradually along with the leaching time periods. The Ra^{226} concentrations for all of the tested combinations ranged well below the USEPA's (2004) safe drinking water criterion of 5 $pCi \cdot L^{-1}$. The initial Ra^{226} concentration for the PG used in this study was 37.24 $pCi \cdot g^{-1}$ and the total amount of radium available for leaching from all combinations averaged 460.84 pCi. However, on an average, only 0.797 pCi of (cumulative) Ra^{226} was leached after the 28-day dynamic leach test. Hence, as listed in Table 22, the percent release of the available radium for each combination was found to be very low (highest value of 0.212%).

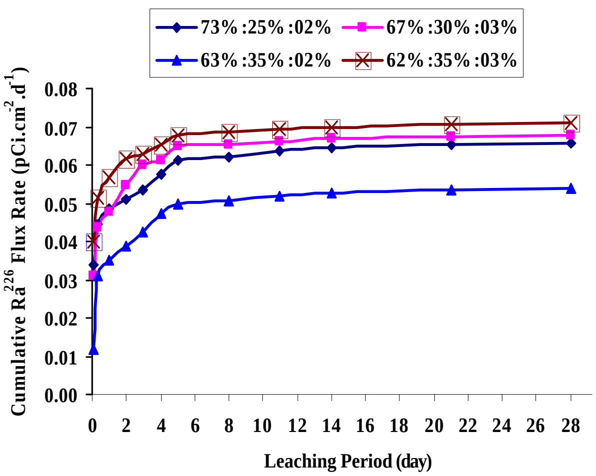

Figure 19. Cumulative Radium Flux Rates for the Best Four PG Combinations.

This indicates that 99.92% of the initial Ra^{226} present in the raw PG remained in the stabilized composite. Thus, the stabilization technique employed for the PG composites would result in a high degree of effectiveness. Flux curves for surface precipitation and diffusion of radium ions were developed using Equation (27) to estimate the potential for long-term survivability (Figure 20, Table 23, and Appendix J). The radium will stop leaching into the salt water within t_c = 37-119 days (Table 23).

Table 22. Summary of the Initial Ra^{226} Content, Cumulative Ra^{226} Leached After the 28-Day Dynamic Leaching Test and the % Release of the Available Ra^{226} for Each of the Best Four PG Composite Combinations.

PG:Class C Fly Ash:Portland Type II Cement	Initial Ra^{226} ($pCi \cdot cm^{-3}$)*	Total Ra^{226} Available for Leaching (pCi)	Cumulative Amount of Ra^{226} Leached (pCi)	% Release
73%:25%:02%	56.23	507.8	0.773	0.152
67%:30%:03%	51.61	466.1	0.793	0.170
63%:35%:02%	48.53	438.2	0.706	0.161
62%:35%:03%	47.76	431.3	0.915	0.212

*Initial Ra^{226} concentration for the raw PG used in this study was 37.24 $pCi \cdot g^{-1}$ (IMC-Agrico Co., Uncle Sam Operations, LA, 2003)

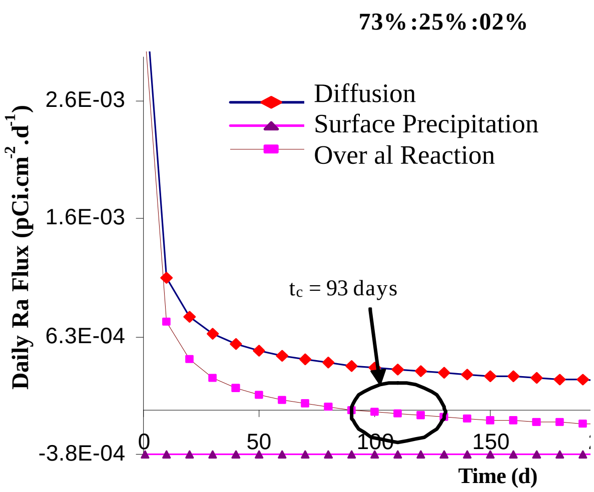

Figure 20. Representative Plot of Daily Ra^{226} Flux Versus Time for 73%:25%:2% PG Class C Fly Ash Portland Type II Cement.

Fan (1997) studied the leaching characteristics (especially the leaching of Ra^{226} and toxic metals such as Pb and As) and structural integrity of the cement-stabilized phosphogypsum (CSPG) composites subjected to both fresh and saltwater submergence, and the research concluded that the toxic constituents can be effectively solidified and stabilized in the cement-waste matrix. The effective Ra^{226} diffusion coefficients (1.46 to 2.90 $\times$ 10^{-17} $m^2 \cdot s^{-1}$) presented in this research (Table 23) were very close to the results of average apparent Ra^{226} diffusivities (10^{-17} to 10^{-16} $m^2 \cdot s^{-1}$) obtained by Fan (1997) for the stabilized PG:cement composites immersed in saltwater.

Table 23. Effective Radium Diffusion Coefficients (D_e) Calculated Using the Regression Analysis on the Data Obtained from the 28-Day Dynamic Leaching Study.

PG:Class C Fly Ash:Portland Type II Cement	$K_1(C_o - C_1)$ $pCi \cdot cm^{-2}$	$K_2(C_o - C_1)$ $pCi \cdot cm^{-2} \cdot d^{-0.5}$	$K_3(C_o - C_1)$ $pCi \cdot cm^{-2} \cdot d^{-1}$	t_c, Radium, (days)	Radium $D_e \times 10^{-17}$ ($m^2 \cdot s^{-1}$)
73%:25%:02%	0	0.00712	-0.00037	93	1.46
67%:30%:03%	0	0.00922	-0.00076	37	2.90
63%:35%:02%	0	0.00809	-0.00037	119	2.61
62%:35%:03%	0	0.00724	-0.00053	47	2.02

Field Submergence Study

The 73%:25%:02%, 67%:30%:03%, 63%:35%:02% and 62%:35%:03% PG composites exhibited less than 10% reduction in composite volume after 15 months of submergence indicating a good potential for a long-term survivability (Tables 24 and 25). On the other hand, the 77%:20%:03%, 72%:25%:03%, 69%:30%:01% and 68%:30%:02% PG composites showed degradation (i.e., change in the dimensions) after 15 months of submergence (Figure 21). For these combinations, the percent reductions in the volume of the briquettes were determined to be in the range of 23 to 37%.

Figure 21. Physical Conditions of the Nine PG Composite Combinations After Fifteen Months of Submergence.

Table 24. Physical Conditions of the Stabilized PG Briquettes After Fifteen Months of Submergence.

PG:Class C Fly Ash:Portland Type II Cement	Condition*
77%:20%:03%	Degradation
73%:25%:02%	Good
72%:25%:03%	Severe degradation
69%:30%:01%	Severe degradation
68%:30%:02%	Severe degradation
67%:30%:03%	Good
64%:35%:01%	Degradation
63%:35%:02%	Degradation
62%:35%:03%	Good

*Good: Less than 10% reduction; Degradation: 10-25% reduction; Severe degradation: Greater than 25% reduction in volume.

Table 25. Summary of the Quarterly Observations of the Submerged PG Composites.

PG:Class C Fly Ash:Portland Type II Cement	Mean Length (mm) ± SD	Mean Width (mm) ± SD	Mean Height (mm) ± SD
Before Submergence			
77%:20%:03%	42.1 ± 0.51	22.9 ± 0.65	13.4 ± 0.37
73%:25%:02%	42.5 ± 0.49	23.0 ± 0.29	13.6 ± 0.19
72%:25%:03%	41.7 ± 0.73	22.5 ± 0.21	13.7 ± 0.24
69%:30%:01%	41.5 ± 0.60	23.3 ± 2.64	13.4 ± 2.41
68%:30%:02%	41.7 ± 0.69	22.6 ± 1.32	13.5 ± 0.21
67%:30%:03%	42.0 ± 0.61	23.1 ± 1.44	13.5 ± 0.21
64%:35%:01%	42.1 ± 0.46	22.8 ± 1.00	13.5 ± 0.18
63%:35%:02%	41.3 ± 0.34	21.8 ± 0.25	13.2 ± 0.31
62%:35%:03%	41.5 ± 0.87	21.9 ± 0.47	13.3 ± 0.35
Three-Month Submergence			
77%:20%:03% [c]	38.4 ± 2.28	19.7 ± 1.88	13.0 ± 1.08
73%:25%:02%	37.9 ± 2.47	18.5 ± 1.71	12.3 ± 0.14
72%:25%:03% [a]	35.1 ± 5.09	14.2 ± 0.14	12.1 ± 0.00
69%:30%:01% [c]	38.0 ± 4.53	20.3 ± 1.36	13.2 ± 0.91
68%:30%:02% [b]	37.6 ± 5.59	20.8 ± 0.74	13.5 ± 0.26
67%:30%:03%	39.3 ± 5.08	21.1 ± 0.73	12.7 ± 2.08
64%:35%:01%	40.9 ± 1.46	21.1 ± 0.95	13.4 ± 0.75
63%:35%:02%	40.7 ± 1.62	21.2 ± 1.20	13.9 ± 0.82
62%:35%:03%	41.8 ± 1.23	20.9 ± 0.89	13.9 ± 0.58

NOTE: (a) Three samples missing, (b) Two samples missing, (c) One sample missing.

Table 25 (Cont.). Summary of the Quarterly Observations Recorded for the Submerged PG Composites.

PG:Class C Fly Ash:Portland Type II Cement	Mean Length (mm) ± SD	Mean Width (mm) ± SD	Mean Height (mm) ± SD
Six-Month Submergence			
77%:20%:03% c	38.6 ± 2.53	20.0 ± 1.43	14.2 ± 2.50
73%:25%:02% c	42.7 ± 0.57	21.2 ± 2.53	15.6 ± 4.00
72%:25%:03% a	38.2 ± 3.61	16.0 ± 3.75	16.4 ± 4.10
69%:30%:01% b	39.6 ± 1.65	18.6 ± 0.59	12.4 ± 0.31
68%:30%:02% b	40.6 ± 1.40	19.6 ± 0.50	12.5 ± 0.60
67%:30%:03% c	41.0 ± 0.31	20.6 ± 0.71	14.1 ± 0.85
64%:35%:01%	40.9 ± 1.71	20.9 ± 1.21	13.4 ± 0.62
63%:35%:02%	40.8 ± 1.35	20.0 ± 1.68	13.1 ± 0.59
62%:35%:03%	41.1 ± 0.66	20.4 ± 0.63	13.8 ± 1.31
Nine-Month Submergence			
77%:20%:03% c	36.9 ± 1.98	19.2 ± 0.68	12.5 ± 0.80
73%:25%:02% c	42.2 ± 0.83	21.2 ± 0.50	14.0 ± 0.86
72%:25%:03% a	36.9 ± 4.38	17.8 ± 0.28	12.1 ± 0.35
69%:30%:01% b	38.4 ± 2.08	18.0 ± 1.01	14.1 ± 2.16
68%:30%:02% b	39.2 ± 1.15	19.9 ± 1.18	12.0 ± 1.37
67%:30%:03% c	39.5 ± 1.50	21.3 ± 5.29	13.8 ± 1.98
64%:35%:01%	39.6 ± 1.61	20.2 ± 0.94	13.3 ± 0.69
63%:35%:02%	40.3 ± 0.96	19.8 ± 2.23	13.9 ± 1.20
62%:35%:03%	41.5 ± 0.93	26.1 ± 13.62	14.9 ± 3.53
Twelve-Month Submergence			
77%:20%:03% [c]	36.4 ± 2.2	18.6 ± 0.92	12.4 ± 0.42
73%:25%:02% [c]	42.3 ± 0.69	21.3 ± 2.44	13.6 ± 0.18
72%:25%:03% [a]	38.4 ± 5.09	20.4 ± 0.35	13.2 ± 0.21
69%:30%:01% [b]	39.2 ± 2.18	18.7 ± 0.06	12.5 ± 0.26
68%:30%:02% [b]	39.9 ± 1.33	20.4 ± 0.42	12.4 ± 0.21
67%:30%:03% [c]	40.4 ± 0.90	22.0 ± 2.59	14.3 ± 2.06
64%:35%:01%	40.9 ± 1.88	20.7 ± 1.04	13.3 ± 0.14
63%:35%:02%	40.6 ± 1.31	20.0 ± 2.02	13.2 ± 0.43
62%:35%:03%	41.2 ± 0.58	20.9 ± 0.31	13.1 ± 0.54
Fifteen-Month Submergence			
77%:20%:03% [c]	37.0 ± 1.55	16.6 ± 2.24	13.1 ± 1.05
73%:25%:02% [b]	42.8 ± 2.51	20.6 ± 1.85	14.0 ±1.66
72%:25%:03% [a]	33.0 ± 2.47	17.8 ± 4.03	13.1 ± 12.1
69%:30%:01% [d]	NA	NA	NA
68%:30%:02% [d]	NA	NA	NA
67%:30%:03% [b]	33.6 ± 1.86	20.3 ± 2.03	21.7 ± 1.15
64%:35%:01%[a]	38.8 ± 2.76	20.0 ± 2.76	14.5 ± 0.99
63%:35%:02%[b]	39.7 ± 2.22	19.0 ± 0.57	12.9 ± 0.67
62%:35%:03%	39.4 ± 1.41	20.0 ± 1.21	13.5 ± 0.69

NOTE: a = Three samples missing., b = Two samples missing, c = One sample missing, d = All samples missing.

Geotechnical Properties

Specific Gravity (G_s)

The fill material used in coastal protection devices should possess a high specific gravity (>1.50) because it increases the resistance of the coastal protection devices to the action of waves or currents (Whiteneck and Hockney 1989). All of the PG composite combinations exhibited similar values for specific gravity (Table 26 and Appendix E). These composites would be classified as normal weight aggregates. The mean differences were not significant at the 95% confidence interval.

Table 26. Specific Gravity (Mean ± S.D.) of the Best Four PG:Class C Fly Ash:Portland Type II Cement Combinations.

PG:Class C Fly Ash:Portland Type II Cement	Mean Specific Gravity ± S.D. (n = 3)
73%:25%:02%	2.24 ± 0.0195
67%:30%:03%	2.24 ± 0.0042
63%:35%:02%	2.21 ± 0.0125
62%:35%:03%	2.26 ± 0.0097

Compaction Tests and Sieve Analysis

The dry unit weight ($?_d$, $g \cdot cm^{-3}$) of the compacted PG composite material was determined using Equation (29) for each of the individual combination tested in triplicate. The material was compacted without added moisture. The mean dry unit weights of compaction for each combination are listed in Table 27. The average dry unit weight for all combinations ranged between 1.43-1.53 $g \cdot cm^{-3}$ (Table 27). The mean differences were not significant at the 95% confidence interval. The addition of Class C fly ash or Portland Type II cement to phosphogypsum yields slightly higher maximum dry density and optimum moisture content values for stabilized PG mixtures, in comparison with raw PG blends (Taha and Seals 1992).

Table 27. Compaction Dry Unit Weight (Mean ± S.D.) of the Best Four PG:Class C Fly Ash:Portland Type II Cement Combinations Was Determined by the Standard Proctor Compaction Test.

PG:Class C Fly Ash:Portland Type II Cement	Mean Compaction Dry Unit Weight (?d, $gm \cdot cm^{-3}$) ± S.D. (n = 3)
73%:25%:02%	1.43 ± 0.0175
67%:30%:03%	1.46 ± 0.0272
63%:35%:02%	1.53 ± 0.0145
62%:35%:03%	1.48 ± 0.0048

Before compaction, the briquettes were of uniform size (42.5 mm × 23.5 mm × 14.5 mm). The gradation characteristics obtained for all the briquette compositions after the standard Proctor compaction test indicate a relatively modest amount of degradation due to compaction. The general nature of the particle-size distribution curves for all of the PG composites corresponds to a relatively well-graded material rather than a material of uniform gradation. The crushing actually improves the engineering properties and workability of the briquettes. Based on the behavior of naturally occurring soils, well-graded soils perform much better in construction applications such as embankments and structural fills than uniform soils. Figure 22 shows the grain-size distribution obtained from the sieve analysis plotted as a semi-logarithmic graph with particle size (mm) plotted on a log scale and percent finer by weight plotted on the normal scale.

The uniformity coefficient (C_u) indicates the range of distribution of particle sizes for the compacted material. If C_u is nearly equal to one, the degraded particles are approximately of equal size and such material is usually referred to as poorly graded material. In geotechnical engineering practice, a material is considered well graded if $C_u \geq 6$ and the C_c value falls between 1 and 3 (Das 1997). Table 28 lists the uniformity coefficient (C_u) and coefficient of curvature (C_c) values, respectively, for each of the selected four PG composite combinations. For the 67%:30%:03% and 63%:35%:02% composites, the value of $C_u \geq 6$ (Appendices D and F).

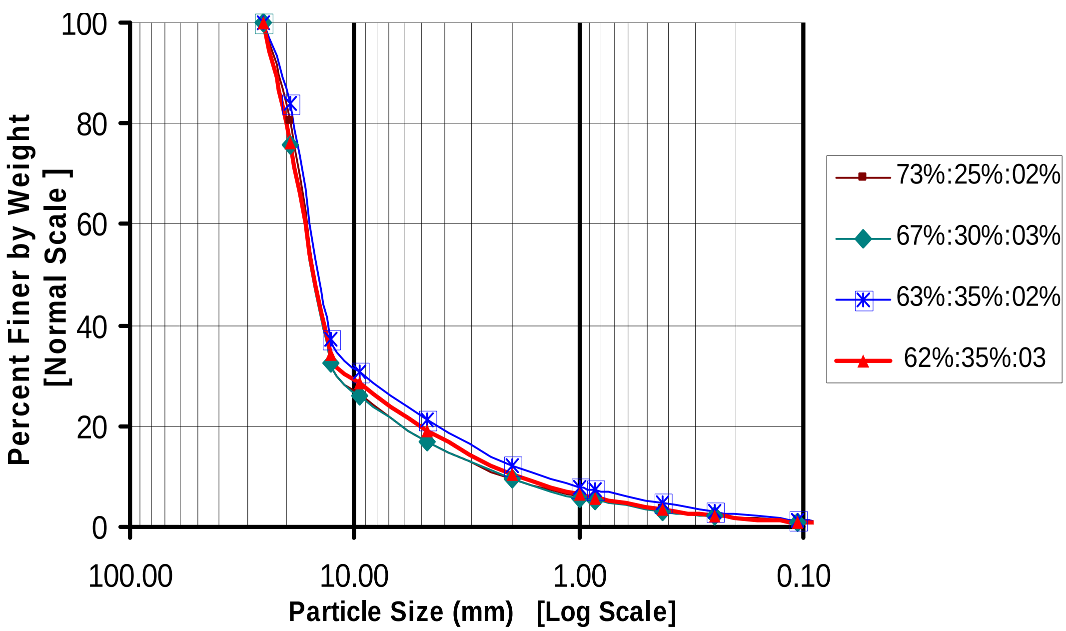

Figure 22. Particle Size Distribution Curves for the Selected Four PG:Class C Fly Ash:Portland Type II Cement Combinations Subsequent to Standard Proctor Compaction Tests.

Table 28. Coefficient of Particle Uniformity (C_u) and Coefficient of Curvature (C_c) Determined from the Sieve Analysis Data for Each of the Best Four PG Composite Combinations After Compaction Tests.

PG:Class C Fly Ash:Portland Type II Cement	Uniformity Coefficient (C_u)	Coefficient of Curvature (C_c)
73%:25%:02%	5.67	1.25
67%:30%:03%	6.00	1.19
63%:35%:02%	6.60	1.36
62%:35%:03%	5.71	1.43

The Unified Soil Classification System (USCS) would classify the PG briquettes as well-graded gravel ($C_u \geq 4$) or sand ($C_u \geq 6$) with little or no fines (i.e., GW or SW), as the percent gravel fraction (GF) of the crushed material (i.e., the percent fraction retained on US Sieve # 4) for all of the PG combinations exceeded 15%. It was also noted that the fraction smaller than the US Sieve # 200 did not exceed 5%. The crushed material has a wide range of grain sizes and substantial amounts of all intermediate particle sizes. Generally, a well-graded compactable aggregate provides a suitable base and drain field material. Excellent workability characteristics of the PG composites would qualify them as a potential fill material in embankment construction. However, it should be recognized that the mineralogy of the briquette is significantly different than that of naturally occurring soils. The classification helps to speculate about the behavior of the PG briquettes when used as a construction material. Based on a typical Engineering Use Chart, the characteristics of a well-graded soil material pertaining to embankments or foundations usually exhibit good compaction with a pervious permeability ($K > 10^{-2}$ $cm \cdot sec^{-1}$), good bearing value for foundations and negligible plasticity. Excellent shear strength and compressibility characteristics can also be expected from a well-graded material when compacted and saturated.

Surface Hardness

The surface hardness study results are tabulated in Table 29 and Appendix G for both the control and leached PG composite briquettes.

Table 29. Mean Surface Hardness ± S.D. (n=3) of PG:Class C Fly Ash:Portland Type II Cement Composite Briquettes After 28-Day Curing Process and 77-Day Dynamic Leaching Test.

PG:Class C Fly Ash:Portland Type II Cement	Mean Surface Hardness (mm^{-1}) ± S.D. (n = 3)	
	Control Briquettes	Leached Briquettes
73%:25%:02%	73.3 ± 6.74	17.1 ± 4.14
67%:30%:03%	89.3 ± 10.42	24.7 ± 7.26
63%:35%:02%	87.1 ± 5.78	12.2 ± 4.78
62%:35%:03%	74.1 ± 6.99	45.2 ± 13.51

The results may not be directly comparable for the performance of each composite combination tested for surface hardness because the test conditions were different and the tests were run on a different set of briquettes. However, these results do give some indication about the composite surface characteristics. The greater the depth penetrated, the lower the surface hardness. Most of the leached PG briquettes exhibited lower surface hardness than the control PG briquettes. In comparison, the 67%:30%:03% and 63%:35%:02% PG:Class C fly ash:Portland Type II cement composites possessed relatively greater surface hardness before submergence (Figure 23) and the mean differences were not significant at the 95% confidence interval. These composites also showed good results in the field submergence study. On the other hand, the leached composites showed significant differences in the mean surface hardness at the 95% confidence interval and the 67%:30%:03% and 62%:35%:03% PG:Class C fly ash:Portland Type II cement composites possessed greater surface hardness after submergence.

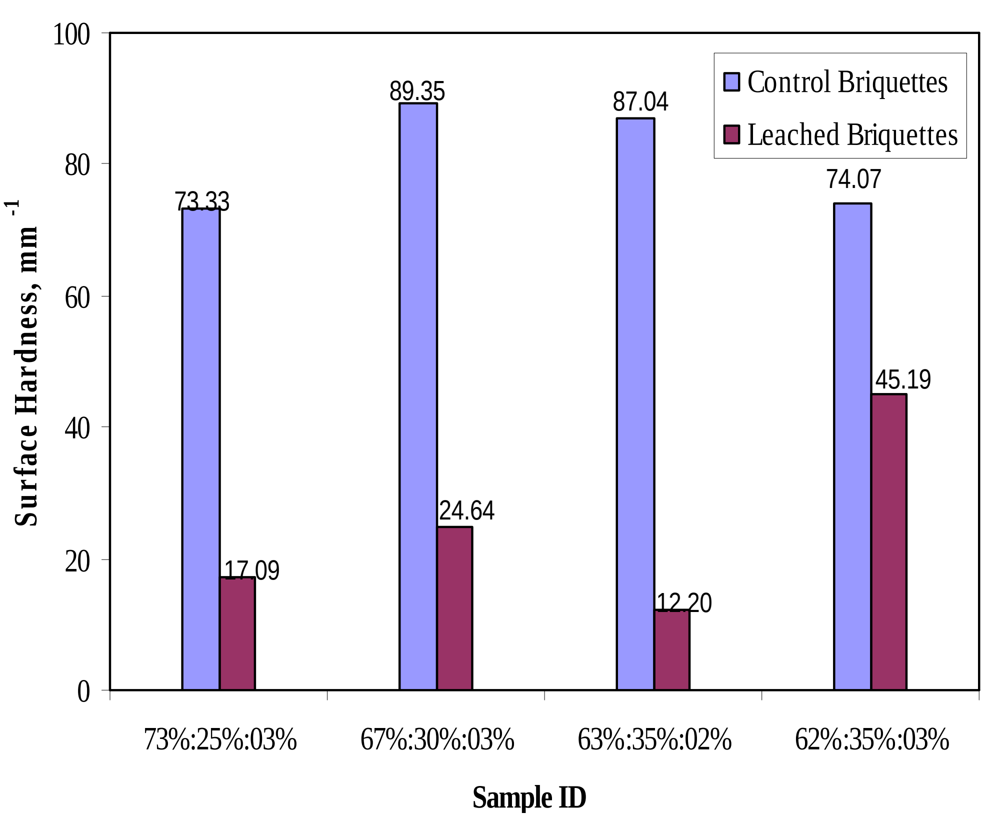

Figure 23. Comparison of the Surface Hardness of Control and Leached PG Briquettes.

Pore Volume Study

The pore volume study results for both the control and leached PG briquettes are summarized in Table 30, and Figure 24 summarizes the pore volume results for the PG composite combinations for their increase in pore space volume when subjected to a 77-

day dynamic leaching study. Lower values of the increase in the pore volume after submergence may indicate an intact structure of the composite.

Table 30. Mean Pore Volume of the Best Four PG:Class C Fly Ash:Portland Type II Cement Composite Briquette Combinations.

PG:Class C Fly Ash:Portland Type II Cement	Mean ± S.D. (n = 3)		
	Porosity (%) of Control Briquettes	Porosity (%) of Leached Briquettes	Increase in Pore Volume (cm^3) After Dynamic Leaching
73%:25%:02%	9.52 ± 1.40	14.20 ± 0.23	0.42 ± 0.12
67%:30%:03%	9.97 ± 0.58	12.28 ± 0.33	0.21 ± 0.05
63%:35%:02%	11.07 ± 0.31	17.25 ± 0.13	0.36 ± 0.02
62%:35%:03%	9.77 ± 0.55	11.99 ± 0.28	0.20 ± 0.03

These results indicated that the 67%:30%:03% and 62%:35%:03% PG:Class C fly ash:Portland Type II cement composites possessed minimum pore volume and a smaller increase in pore volume after dynamic leaching. However, the mean porosities for the 63%:35%:02% and 62%:35%:03% composites before submergence were significantly different at the 95% confidence interval.

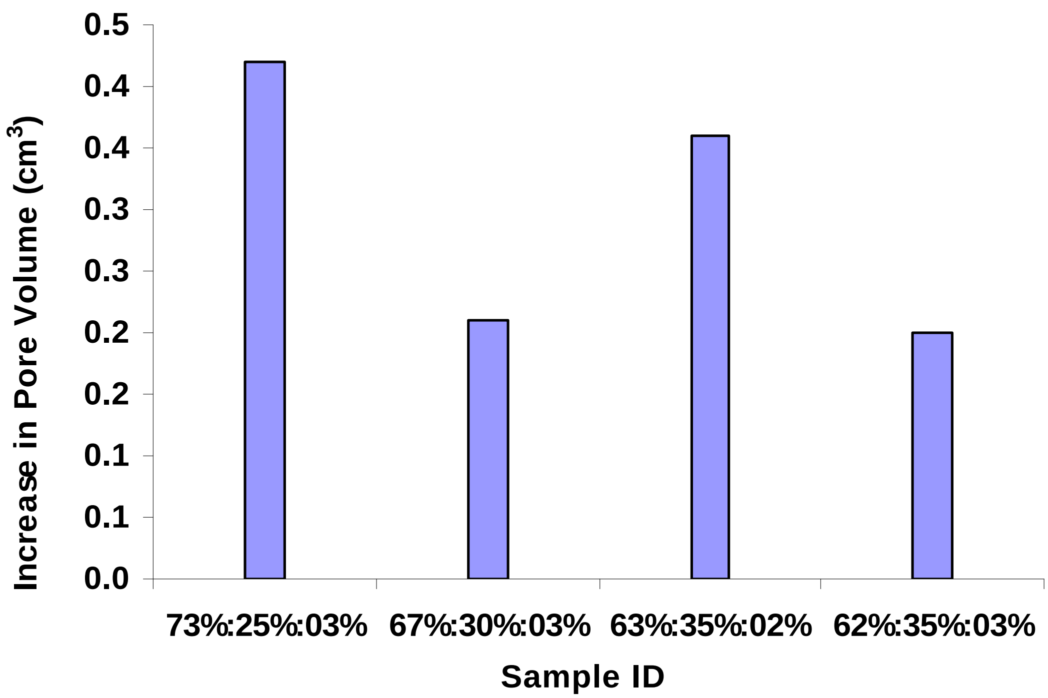

Figure 24. Comparison of the Increase in Pore Volume for the PG Briquettes Subjected to the 77-Day Dynamic Leaching Study.

Computing the increase in pore water volume may not be an accurate measure of the porosity of the PG composites so other tests must determine it (e.g., mercury intrusion method), whereas the results obtained here do give an insight into the pore spaces formed due to diffusion of contaminants under submerged conditions and are used only for the purpose of characterizing the composites.

Direct Shear Test

The direct shear test was conducted on the four composite combinations. The angle of internal friction (ϕ) for the four PG composites was determined to be 49° (Figure 25 and Appendix M). It can be seen that the 73%:25%:02% composite has ϕ = 50°, slightly higher than the other three composite combinations. However, all the composite combinations have ϕ values similar to limestone and sandstone (27°-50°) (Day 1999).

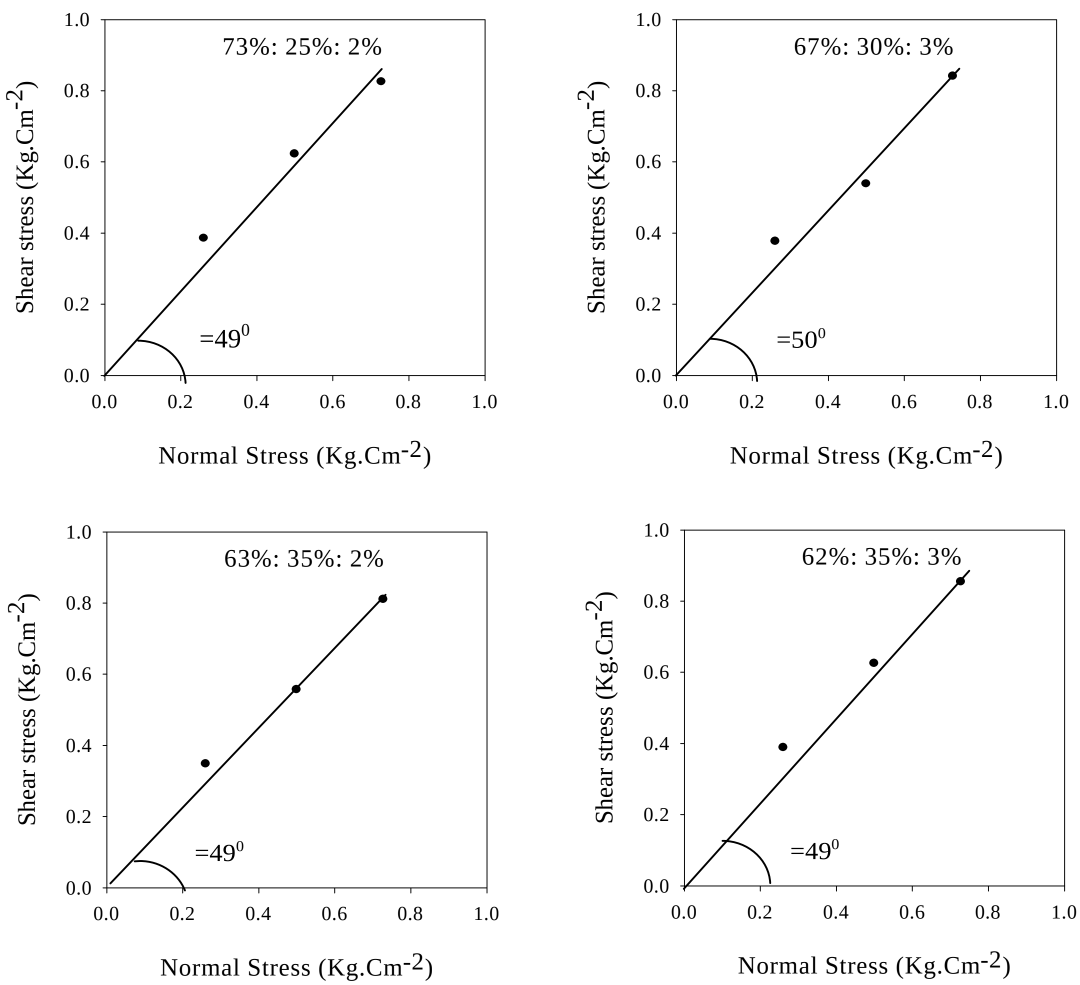

Figure 25. Plots of Normal Stress Versus Shear Stress for the Four PG Combinations.

The samples obtained subsequent to shearing under different normal loads were subjected to sieve analysis to determine the grain size distribution (Figure 26). It was observed that less than 1% of the sample subjected to shear underwent deterioration; the remaining sample retained its integrity. All data generated while shearing the sample and the subsequent sieve analysis are included in Appendix N.

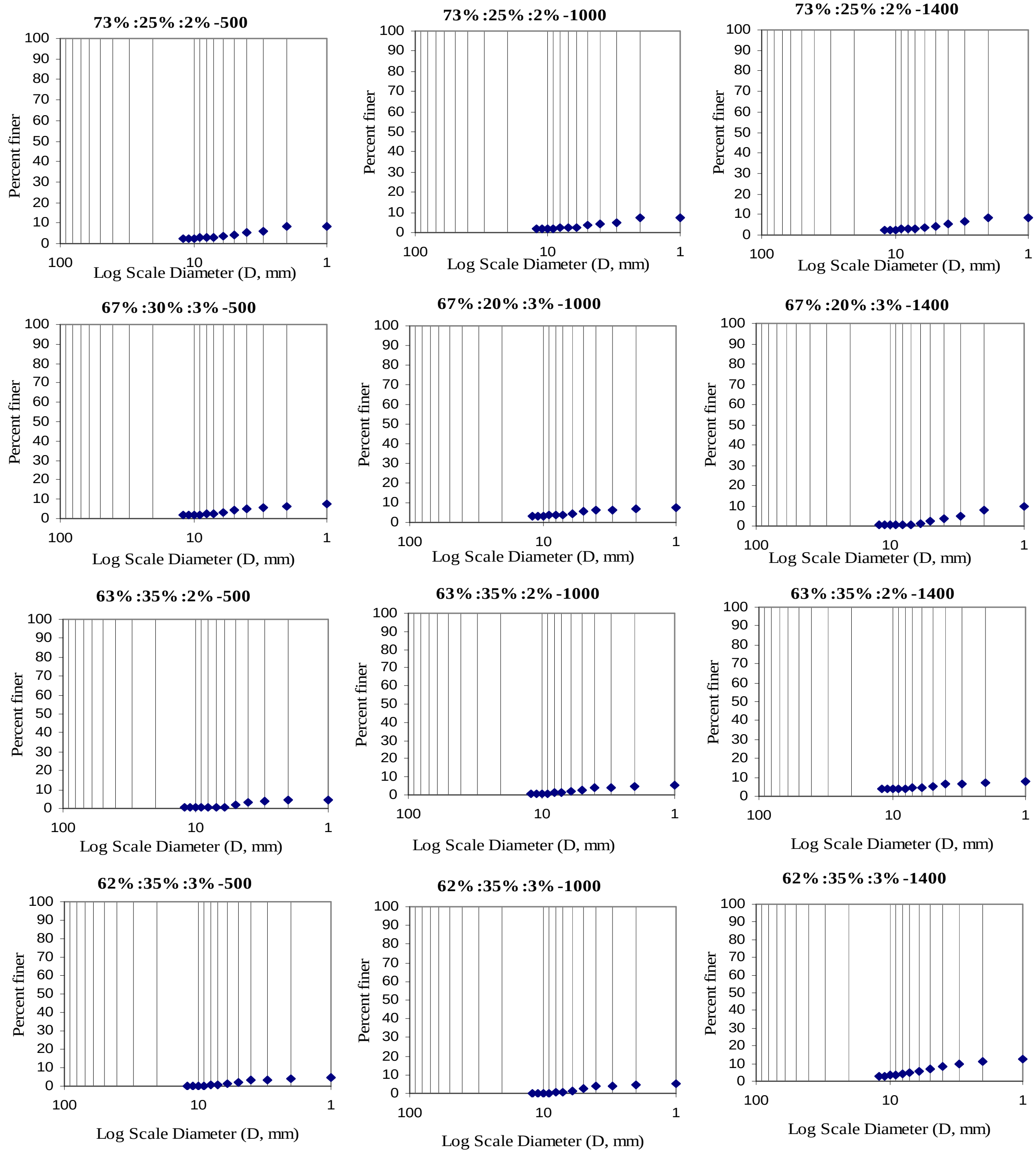

Figure 26. Particle Gradation of Samples After Shearing Under Different Normal Loads.

Cost Analysis

The commercial production costs of stabilized PG briquettes were updated to 2003 values. The Tampa, Florida local costs (Davis 2003) of Portland Type II cement ($85.20 per ton^{-1}) and Class C fly ash ($29.38 per ton^{-1}) were used for the cost estimate for the year of 2003. The Baton Rouge, Louisiana local costs (Knapp 2003) of Portland Type II cement ($90.04 per ton^{-1}) and Class C fly ash ($28.46 per ton^{-1}) were used for the cost estimate for the year of 2003. The commercial production costs for each PG composite combination was determined using the economic analysis developed by Rusch and others (2001) (FIPR Publication No. 01-162-182). The economic analysis was based on the annual cost of a hypothetical PG briquetting plant located in Riverview, Florida with 4.1 million metric tons annual briquette production capacity and a ten-year service life. These costs were obtained using the ingredient costs in Florida and Louisiana for the year 2001 without offsetting the PG disposal costs, whereas, for comparison purposes, the current year (2003) costs of the ingredients (Portland Type II cement and Class C fly ash) in Florida and Louisiana were also obtained. Table 31 lists a comparative summary of the economic analysis performed to estimate the past and current production costs of the briquettes for the years 2001 and 2003 in both Florida and Louisiana. It was found that the lowest cost for the best four PG briquettes was $11.96 per ton^{-1} at the State of Florida.

Table 31. A Comparative Summary of the Economic Analysis Performed to Estimate the Production Costs of the PG Composites for the Years 2001 and 2003 in Both Florida and Louisiana.

PG:Class C Fly Ash:Portland Type II Cement	Production Cost ($ per Ton^{-1})			
	Year – 2001		Year – 2003	
	Florida	Louisiana	Florida	Louisiana
77%:20%:03%	10.15	9.03	11.36	11.33
73%:25%:02%	10.62	9.12	11.94	11.81
72%:25%:03%	11.30	9.86	12.72	12.65
69%:30%:01%	11.10	9.22	12.51	12.30
68%:30%:02%	11.78	9.96	13.30	13.13
67%:30%:03%	12.46	10.70	14.08	13.96
64%:35%:01%	12.26	10.05	13.87	13.61
63%:35%:02%	12.94	10.79	14.66	14.45
62%:35%:03%	13.62	11.53	15.45	15.28

CONCLUSIONS

(1) The 73%:25%:02%, 67%:30%:03%, 63%:35%:02% and 62%:35%:03% PG:Class C fly ash:Portland Type II cement composites showed promising results with no signs of degradation after more than one year of natural saltwater submergence.

(2) A regression model with one-dimensional diffusion processes based on Fick's second law with a non-zero surface concentration at the solid-solution interface was developed to calculate effective calcium and sulfate diffusion coefficients of composites placed in saltwater. This model determined that the effective calcium, sulfate and Ra^{226} diffusion coefficients ranged $1.36\text{-}8.04 \times 10^{-13}\ m^2{\cdot}s^{-1}$, $2.96\text{-}7.20 \times 10^{-13}\ m^2{\cdot}s^{-1}$ and $1.46\text{-}2.90 \times 10^{-17}\ m^2{\cdot}s^{-1}$, respectively. This model predicted that calcium, sulfate and Ra^{226} will stop leaching at critical time (t_c) of 64-78, 122-137 and 150-470 days, when the leaching processes are balanced by precipitation reactions.

(3) The Ra^{226} concentrations in the TCLP leachate were well below the current EPA regulation value for drinking water (5 $pCi{\cdot}L^{-1}$). The metal concentrations in the TCLP leachate were well below the USEPA toxicity characteristics limits. The effective diffusion coefficients and t_c of Cu, Cr, Zn, and Fe were between 10^{-12} to 10^{-16} ($m^2{\cdot}s^{-1}$).

(4) The engineering properties test results indicated that the composite material could be classified as well-graded gravel or well-graded sand with little or no fines. The USCS classification would also qualify the PG briquettes as a potential fill material in embankment construction having excellent workability characteristics.

(5) The engineering properties test results indicated that the composite material could be classified as well-graded gravel or well-graded sand with little or no fines. The direct shear test determined the angle of internal friction as 49-50º. The USCS classification would also qualify the PG briquettes as a potential fill material in embankment construction having excellent workability characteristics. The economic analysis indicated that the commercial production cost for the selected four stabilized PG composites ranged from \$11.94 to 15.45 per ton^{-1} (value at 2003) in Tampa, Florida vs. \$35 per ton^{-1} (average cost for year 2003) for granite backfill (15-30.5 cm) in the state of Florida.

RECOMMENDATIONS

The durability and saltwater survivability of stabilized PG briquettes under tidal conditions ("wet/dry" cycling) in the coastal area should be investigated. A "test strip" representing a segment of a coastal protection device that consists of PG briquettes and geotextile fabric as the fill material and limestone or granite as the armoring should be tested. Although the growth of marine organisms on the composite surface appears to be beneficial to maintaining the composite's physical integrity, it is necessary to further investigate the kind of aquatic organisms attached to and growing on the composite surface. In particular, the potential for bioaccumulation of trace metals and radium by the aquatic organisms must be investigated.

EDUCATIONAL OUTREACH

1. One international talk, "Stabilization and Marketability of Phosphogypsum for Marine Applications" was presented at the "Global Gypsum Conference," Miami, Florida, 2002 by Dr. Kelly A. Rusch.

2. Master's thesis titled "The Determination of Appropriate Phosphogypsum:Class C Fly Ash: Portland Type II Cement Compositions for Use in Marine Applications," has been completed by S.P. Deshpande and approved by Louisiana State University, 2003.

3. A peer-reviewed journal manuscript "Identification of Dynamic Leaching Kinetics of Stabilized, Water-Soluble Waste," Environmental Science and Technology, 38(2), 603-608, 2004, (authors: Tingzong Guo, S.P. Deshpande and Kelly Rusch) has been published.

4. A conference paper "Dissolution Potential and Chemical Characteristics of Stabilized Phosphogypsum for Low Profile Fill Material in Coastal Protection Devices" was presented at the "19th International Conference on Solid Waste Technology and Management" by Dr. Tingzong Guo, Philadelphia, PA, on 23 March 2004.

5. Four other manuscripts are being developed and will be submitted to environmental-related journals.

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Appendix A

FIELD SUBMERGENCE DATA

FIELD SUBMERGENCE

Table A-1. Physical Observations of Initial Nine Combinations of PG Composite Briquettes Before and After Submergence.

Before Submergence: 04/22/02					After Submergence: 05/25/02			
PG:Class C Fly Ash:Type II Portland Cement					PG:Class C Fly Ash:Type II Portland Cement			
77%:20%:03%					77%:20%:03%			
	Length (mm)	Width (mm)	Height (mm)			Length (mm)	Width (mm)	Height (mm)
1	41.5	22.7	13.5		1	41.6	20.8	13.2
2	42.4	23.6	12.9		2	41.3	20.3	12.7
3	42.8	23.6	13.9		3	41.7	21.1	13.0
4	42.0	22.5	13.4		4	31.9	19.9	12.6
5	41.8	22.2	13.2		5	39.5	20.4	12.6
Mean	42.1	22.9	13.4		Mean	39.2	20.5	12.8
St.Dev.(n=5)	0.51	0.65	0.37		St.Dev.(n=5)	4.18	0.46	0.27
73%:25%:02%					73%:25%:02%			
1	42.2	23.5	13.8		1	43.0	23.0	14.0
2	43.0	22.9	13.4		2	43.7	22.0	13.5
3	42.2	22.8	13.7		3	44.7	22.2	13.5
4	43.0	22.9	13.4		4	43.6	21.6	13.6
5	42.0	22.8	13.7		5	43.5	41.5	13.9
Mean	42.5	23.0	13.6		Mean	43.7	26.1	13.7
St.Dev.(n=5)	0.49	0.29	0.19		St.Dev.(n=5)	0.62	8.65	0.23
72%:25%:03%					72%:25%:03%			
1	42.0	22.6	13.8		1	45.1	21.3	13.9
2	40.8	22.5	13.3		2	42.4	20.9	13.2
3	42.7	22.6	13.8		3	42.0	20.8	13.1
4	41.8	22.1	13.5		4	42.4	21.8	13.8
5	41.2	22.5	13.9		5	42.3	21.5	13.2
Mean	41.7	22.5	13.7		Mean	42.8	21.3	13.4
St.Dev.(n=5)	0.73	0.21	0.24		St.Dev.(n=5)	1.29	0.42	0.38
69%:30%:01%					69%:30%:01%			
1	41.4	21.4	12.5		1	40.8	20.7	12.2
2	41.6	21.1	12.5		2	40.5	20.2	12.5
3	42.3	21.8	12.3		3	41.4	20.4	12.1
4	40.6	25.9	12.0		4	40.2	20.4	12.5
5	41.6	26.5	17.7		5	41.2	20.9	13.5
Mean	41.5	23.3	13.4		Mean	40.8	20.5	12.6
St.Dev.(n=5)	0.60	2.64	2.41		St.Dev.(n=5)	0.49	0.28	0.55

Table A-1 (Cont.). Physical Observations of Initial Nine Combinations of PG Composite Briquettes Before and After Submergence.

Before Submergence: 04/22/02					After Submergence: 05/25/02			
68%:30%:02%					**68%:30%:02%**			
1	40.9	21.1	13.2		1	39.7	21.5	12.9
2	41.9	24.1	13.5		2	42.2	21.7	13.0
3	42.5	21.6	13.6		3	41.8	20.9	12.6
4	42.2	22.5	13.7		4	38.7	20.4	12.5
5	41.1	23.8	13.7		5	41.0	21.1	12.3
Mean	41.7	22.6	13.5		Mean	40.7	21.1	12.7
St.Dev.(n=5)	0.69	1.32	0.21		St.Dev.(n=5)	1.46	0.51	0.29
67%:30%:03%					**67%:30%:03%**			
1	42.6	25.0	13.5		1	42.8	21.3	13.8
2	42.5	21.4	13.7		2	42.2	21.6	13.8
3	41.7	23.2	13.8		3	42.3	22.1	13.3
4	42.0	24.0	13.3		4	40.1	20.6	13.4
5	41.1	22.1	13.4		5	41.3	22.7	13.5
Mean	42.0	23.1	13.5		Mean	41.7	21.7	13.6
St.Dev.(n=5)	0.61	1.44	0.21		St.Dev.(n=5)	1.06	0.80	0.23
64%:35%:01%					**64%:35%:01%**			
1	42.5	22.5	13.5		1	42.5	21.3	13.0
2	41.5	24.2	13.3		2	41.6	21.4	13.4
3	41.7	23.2	13.5		3	41.7	21.9	13.1
4	42.5	21.5	13.5		4	42.6	21.6	13.9
5	42.1	22.5	13.8		5	40.1	21.2	12.6
Mean	42.1	22.8	13.5		Mean	41.7	21.5	13.2
St.Dev.(n=5)	0.46	1.00	0.18		St.Dev.(n=5)	1.00	0.28	0.48
63%:35%:02%					**63%:35%:02%**			
1	41.0	21.6	12.9		1	41.0	21.3	12.7
2	41.8	22.0	13.7		2	40.9	21.0	12.9
3	41.4	22.0	13.2		3	42.0	21.2	12.7
4	41.4	21.4	13.4		4	39.8	20.6	12.5
5	40.9	21.8	13.0		5	41.2	21.2	13.0
Mean	41.3	21.8	13.2		Mean	41.0	21.1	12.8
St.Dev.(n=5)	0.34	0.25	0.31		St.Dev.(n=5)	0.79	0.28	0.19
62%:35%:03%					**62%:35%:03%**			
1	42.2	22.1	13.3		1	39.9	21.2	12.8
2	41.9	22.5	13.6		2	41.6	21.3	12.7
3	40.2	21.8	13.8		3	41.8	21.4	13.5
4	42.2	21.5	13.1		4	42.1	21.0	12.9
5	41.0	21.4	12.9		5	42.9	21.3	13.2
Mean	41.5	21.9	13.3		Mean	41.7	21.2	13.0
St.Dev.(n=5)	0.87	0.47	0.35		St.Dev.(n=5)	1.10	0.15	0.33

Table A-2. Physical Observations of Initial Nine Combinations of PG Composite Briquettes After Two and Three Months of Submergence.

Two Month Submergence: 06/27/02					Three Month Submergence: 07/30/02			
PG:Class C Fly Ash:Type II Portland Cement					PG:Class C Fly Ash:Type II Portland Cement			
77%:20%:03%					77%:20%:03%			
	Length (mm)	Width (mm)	Height (mm)			Length (mm)	Width (mm)	Height (mm)
1	40.8	20.8	13.0		1	36.4	19.3	11.8
2	39.9	20.0	13.1		2	41.3	21.8	14.4
3	38.2	17.1	12.2		3	39.2	17.3	12.7
4	37.5	20.5	12.6		4	36.8	20.2	12.9
5	40.9	20.4	12.3		5	-	-	-
Mean	39.5	19.8	12.6		Mean	38.4	19.7	13.0
St.Dev.(n=5)	1.54	1.51	0.40		St.Dev.(n=5)	2.28	1.88	1.08
73%:25%:02%					73%:25%:02%			
1	43.7	22.2	13.5		1	38.7	18.9	12.2
2	44.6	21.9	13.8		2	34.6	17.9	12.4
3	42.5	21.9	13.7		3	36.3	15.9	12.4
4	46.4	22.2	13.7		4	38.7	19.1	12.4
5	42.4	20.9	13.6		5	41.0	20.5	12.1
Mean	43.9	21.8	13.7		Mean	37.9	18.5	12.3
St.Dev.(n=5)					St.Dev.(n=5)	2.47	1.71	0.14
72%:25%:03%					72%:25%:03%			
1	39.2	20.3	13.5		1	31.5	14.3	12.1
2	41.4	19.4	13.1		2	38.7	14.1	12.1
3	36.7	16.3	11.2		3	-	-	-
4	41.6	20.8	13.1		4	-	-	-
5	41.1	21.0	13.1		5	-	-	-
Mean	40.0	19.6	12.8		Mean	35.1	14.2	12.1
St.Dev.(n=5)	2.08	1.92	0.91		St.Dev.(n=5)	5.09	0.14	0.00
69%:30%:01%					69%:30%:01%			
1	42.1	19.4	12.4		1	39.3	19.2	13.9
2	41.7	21.9	13.4		2	-	-	-
3	41.3	20.8	12.2		3	31.3	21.3	11.9
4	30.9	20.5	12.7		4	41.3	19.0	13.4
5	42.1	20.7	12.8		5	40.0	21.6	13.7
Mean	39.6	20.7	12.7		Mean	38.0	20.3	13.2
St.Dev.(n=5)	4.89	0.89	0.46		St.Dev.(n=5)	4.53	1.36	0.91

Table A-2 (Cont.). Physical Observations of Initial Nine Combinations of PG Composite Briquettes After Two and Three Months of Submergence.

68%:30%:02%					**68%:30%:02%**			
1	41.3	21.1	12.8		1	31.2	21.6	13.6
2	40.0	20.9	12.6		2	39.8	20.2	13.2
3	41.1	20.3	12.1		3	41.7	20.5	13.7
4	41.3	21.0	13.5		4	-	-	-
5	40.3	22.1	13.1		5	-	-	-
Mean	40.8	21.1	12.8		Mean	37.6	20.8	13.5
St.Dev.(n=5)	0.61	0.65	0.53		St.Dev.(n=5)	5.59	0.74	0.26
67%:30%:03%					**67%:30%:03%**			
1	41.3	19.7	13.8		1	40.9	21.0	9.1
2	40.9	17.6	13.1		2	41.2	20.2	12.9
3	42.2	21.4	13.8		3	42.2	21.8	14.0
4	40.3	22.3	13.8		4	42.1	20.5	13.3
5	-	-	-		5	30.3	21.8	14.2
Mean	41.2	20.3	13.6		Mean	39.3	21.1	12.7
St.Dev.(n=5)	0.80	2.07	0.35		St.Dev.(n=5)	5.08	0.73	2.08
64%:35%:01%					**64%:35%:01%**			
1	41.1	21.1	13.2		1	41.8	21.3	14.0
2	44.5	21.1	13.4		2	38.4	19.5	13.3
3	42.3	21.8	15.4		3	42.1	21.7	13.6
4	42.1	21.3	13.3		4	41.0	21.9	13.8
5	42.0	21.9	13.0		5	41.1	21.0	12.1
Mean	42.4	21.4	13.7		Mean	40.9	21.1	13.4
St.Dev.(n=5)	41.1	21.1	13.2		St.Dev.(n=5)	1.46	0.95	0.75
63%:35%:02%					**63%:35%:02%**			
1	42.2	21.5	12.7		1	41.7	20.6	15.4
2	42.1	21.2	14.9		2	39.2	19.5	13.6
3	42.5	21.0	13.2		3	41.9	21.9	13.6
4	41.2	20.4	12.6		4	38.6	22.6	13.6
5	41.3	22.0	12.8		5	41.9	21.4	13.5
Mean	41.9	21.2	13.2		Mean	40.7	21.2	13.9
St.Dev.(n=5)	0.58	0.59	0.96		St.Dev.(n=5)	1.62	1.20	0.82
62%:35%:03%					**62%:35%:03%**			
1	41.0	21.9	13.9		1	41.2	21.5	13.7
2	41.6	20.2	12.1		2	41.0	19.5	13.0
3	41.2	21.9	14.3		3	41.4	21.8	14.0
4	41.7	21.5	13.1		4	41.5	20.8	14.6
5	41.3	21.4	13.6		5	44.0	21.0	14.0
Mean	41.4	21.4	13.4		Mean	41.8	20.9	13.9
St.Dev.(n=5)	0.29	0.70	0.85		St.Dev.(n=5)	1.23	0.89	0.58

Table A-3. Physical Observations of Initial Nine Combinations of PG Composite Briquettes After Four and Six Months of Submergence.

Four Month Submergence: 08/16/02					Six Month Submergence: 10/09/02			
PG:Class C Fly Ash:Type II Portland Cement					PG:Class C Fly Ash:Type II Portland Cement			
77%:20%:03%					77%:20%:03%			
	Length (mm)	Width (mm)	Height (mm)			Length (mm)	Width (mm)	Height (mm)
1	41.8	21.8	14.2		1	39.8	18.6	17.8
2	36.7	20.5	12.7		2	41.2	21.6	13.9
3	38.2	17.1	12.8		3	38.2	20.8	12.9
4	36.1	19.7	14.0		4	35.3	19.0	12.2
5	-	-	-		5	-	-	-
Mean	38.2	19.8	13.4		Mean	38.6	20.0	14.2
St.Dev.(n=5)	2.56	1.98	0.78		St.Dev.(n=5)	2.53	1.43	2.50
73%:25%:02%					73%:25%:02%			
1	42.9	22.7	14.2		1	43.4	23.3	21.6
2	38.6	17.7	14.3		2	42.3	21.7	13.4
3	43.4	17.4	14.7		3	-	-	-
4	41.3	21.9	14.4		4	42.2	17.5	13.4
5	41.0	19.6	14.4		5	43.0	22.1	14.1
Mean	41.4	19.9	14.4		Mean	42.7	21.2	15.6
St.Dev.(n=5)	1.89	2.40	0.19		St.Dev.(n=5)	0.57	2.53	4.00
72%:25%:03%					72%:25%:03%			
1	34.8	19.7	13.9		1	35.6	18.6	13.5
2	42.2	18.3	14.0		2	40.7	13.3	19.3
3	-	-	-		3	-	-	-
4	-	-	-		4	-	-	-
5	-	-	-		5	-	-	-
Mean	38.5	19.0	14.0		Mean	38.2	16.0	16.4
St.Dev.(n=5)	5.23	0.99	0.07		St.Dev.(n=5)	3.61	3.75	4.10
69%:30%:01%					69%:30%:01%			
1	-	-	-		1	-	-	-
2	-	-	-		2	-	-	-
3	41.2	19.0	12.6		3	37.7	18.8	12.3
4	41.6	19.5	13.1		4	40.6	17.9	12.1
5	40.5	21.2	13.4		5	40.5	19.0	12.7
Mean	41.1	19.9	13.0		Mean	39.6	18.6	12.4
St.Dev.(n=5)	0.56	1.15	0.40		St.Dev.(n=5)	1.65	0.59	0.31

Table A-3 (Cont.). Physical Observations of Initial Nine Combinations of PG Composite Briquettes After Four and Six Months of Submergence.

68%:30%:02%					68%:30%:02%			
1	41.6	20.2	12.5		1	41.7	20.1	13.1
2	38.3	21.4	12.3		2	39.0	19.1	12.5
3	-	-	-		3	-	-	-
4	40.4	20.3	12.2		4	41.0	19.6	11.9
5	-	-	-		5	-	-	-
Mean	40.1	20.6	12.3		Mean	40.6	19.6	12.5
St.Dev.(n=5)	1.67	0.67	0.15		St.Dev.(n=5)	1.40	0.50	0.60
67%:30%:03%					67%:30%:03%			
1	40.2	20.9	13.8		1	41.2	21.3	13.8
2	38.2	18.0	12.4		2	40.6	20.7	13.4
3	-	-	-		3	-	-	-
4	39.9	20.7	13.1		4	41.0	20.7	13.7
5	39.6	23.2	13.9		5	41.3	19.6	15.3
Mean	39.5	20.7	13.3		Mean	41.0	20.6	14.1
St.Dev.(n=5)	0.88	2.13	0.70		St.Dev.(n=5)	0.31	0.71	0.85
64%:35%:01%					64%:35%:01%			
1	39.1	19.3	13.5		1	37.9	19.9	13.2
2	39.7	21.6	13.7		2	41.3	22.0	13.4
3	40.0	19.6	13.5		3	42.0	19.5	14.3
4	39.4	27.7	13.9		4	41.2	22.2	13.6
5	42.4	21.4	13.5		5	42.0	21.1	12.6
Mean	40.1	21.9	13.6		Mean	40.9	20.9	13.4
St.Dev.(n=5)	1.32	3.39	0.18		St.Dev.(n=5)	1.71	1.21	0.62
63%:35%:02%					63%:35%:02%			
1	42.6	21.5	13.7		1	41.7	20.3	14.0
2	38.9	19.4	13.6		2	38.6	17.1	13.0
3	33.0	19.0	13.0		3	42.0	21.3	13.3
4	36.1	20.0	13.6		4	40.5	20.6	12.5
5	35.5	20.0	13.5		5	41.1	20.9	12.7
Mean	37.2	20.0	13.5		Mean	40.8	20.0	13.1
St.Dev.(n=5)	3.67	0.95	0.28		St.Dev.(n=5)	1.35	1.68	0.59
62%:35%:03%					62%:35%:03%			
1	39.6	26.6	13.5		1	40.5	20.9	14.7
2	39.1	25.5	12.9		2	41.1	20.9	12.6
3	35.7	19.6	14.0		3	40.5	19.4	15.7
4	36.4	19.7	13.6		4	41.2	20.2	13.0
5	38.4	20.8	14.3		5	42.1	20.6	13.2
Mean	37.8	22.4	13.7		Mean	41.1	20.4	13.8
St.Dev.(n=5)	1.71	3.35	0.53		St.Dev.(n=5)	0.66	0.63	1.31

Table A-4. Physical Observations of Initial Nine Combinations of PG Composite Briquettes After Nine and Twelve Months of Submergence.

Nine Month Submergence: 01/15/03				Twelve Month Submergence: 04/14/03			
PG:Class C Fly Ash:Type II Portland Cement				PG:Class C Fly Ash:Type II Portland Cement			
	Length (mm)	Width (mm)	Height (mm)		Length (mm)	Width (mm)	Height (mm)
77%:20%:03%				77%:20%:03%			
1	38.7	20.1	13.2	1	38.1	19.4	12.9
2	36.9	18.5	11.5	2	38.0	17.3	12.6
3	37.7	18.9	12.2	3	33.4	19.0	12.0
4	34.1	19.3	13.1	4	36.1	18.8	12.1
5	-	-	-	5	-	-	-
Mean	36.9	19.2	12.5	Mean	36.4	18.6	12.4
St.Dev.(n=5)	1.98	0.68	0.80	St.Dev.(n=5)	2.20	0.92	0.42
73%:25%:02%				73%:25%:02%			
1	43.1	20.9	15.2	1	42.2	21.7	13.8
2	42.4	20.8	13.8	2	42.8	21.5	13.5
3	-	-	-	3	-	-	-
4	41.1	21.9	13.5	4	41.3	18.0	13.7
5	42.3	21.2	13.3	5	42.7	23.9	13.4
Mean	42.2	21.2	14.0	Mean	42.3	21.3	13.6
St.Dev.(n=5)	0.83	0.50	0.86	St.Dev.(n=5)	0.69	2.44	0.18
72%:25%:03%				72%:25%:03%			
1	33.8	17.6	11.8	1	34.8	20.1	13.3
2	40.0	18.0	12.3	2	42.0	20.6	13.0
3	-	-	-	3	-	-	-
4	-	-	-	4	-	-	-
5	-	-	-	5	-	-	-
Mean	36.9	17.8	12.1	Mean	38.4	20.4	13.2
St.Dev.(n=5)	4.38	0.28	0.35	St.Dev.(n=5)	5.09	0.35	0.21
69%:30%:01%				69%:30%:01%			
1	-	-	-	1	-	-	-
2	-	-	-	2	-	-	-
3	36.0	16.9	11.7	3	36.7	18.7	12.4
4	39.7	18.2	14.7	4	40.7	18.7	12.3
5	39.5	18.9	15.9	5	40.2	18.6	12.8
Mean	38.4	18.0	14.1	Mean	39.2	18.7	12.5
St.Dev.(n=5)	2.08	1.01	2.16	St.Dev.(n=5)	2.18	0.06	0.26

Table A-4 (Cont.). Physical Observations of Initial Nine Combinations of PG Composite Briquettes After Nine and Twelve Months of Submergence.

68%:30%:02%			
1	39.3	18.9	11.1
2	38.0	19.6	11.4
3	-	-	-
4	40.3	21.2	13.6
5	-	-	-
Mean	39.2	19.9	12.0
St.Dev.(n=5)	1.15	1.18	1.37
67%:30%:03%			
1	40.5	18.7	12.7
2	39.2	17.0	12.0
3	-	-	-
4	40.8	20.4	13.8
5	37.5	28.9	16.5
Mean	39.5	21.3	13.8
St.Dev.(n=5)	1.50	5.29	1.98
64%:35%:01%			
1	36.9	20.3	13.1
2	40.0	19.9	13.2
3	40.7	19.0	13.1
4	39.5	21.6	14.4
5	40.9	20.4	12.5
Mean	39.6	20.2	13.3
St.Dev.(n=5)	1.61	0.94	0.69
63%:35%:02%			
1	41.1	21.7	15.1
2	39.1	16.1	12.8
3	41.4	20.8	14.6
4	39.9	19.4	12.4
5	39.8	21.0	14.5
Mean	40.3	19.8	13.9
St.Dev.(n=5)	0.96	2.23	1.20
62%:35%:03%			
1	40.9	19.0	12.7
2	41.7	20.7	12.9
3	42.4	19.8	13.5
4	42.4	20.4	14.2
5	40.3	50.4	21.1
Mean	41.5	26.1	14.9
St.Dev.(n=5)	0.93	13.62	3.53

68%:30%:02%			
1	40.7	20.1	12.6
2	38.4	20.9	12.2
3	-	-	-
4	40.7	20.3	12.3
5	-	-	-
Mean	39.9	20.4	12.4
St.Dev.(n=5)	1.33	0.42	0.21
67%:30%:03%			
1	39.3	19.8	13.2
2	41.0	21.4	13.6
3	-	-	-
4	41.2	20.9	13.1
5	39.9	25.7	17.4
Mean	40.4	22.0	14.3
St.Dev.(n=5)	0.90	2.59	2.06
64%:35%:01%			
1	37.7	19.9	13.1
2	42.4	21.2	13.4
3	41.8	19.5	13.7
4	40.9	22.1	13.6
5	41.8	20.7	12.7
Mean	40.9	20.7	13.3
St.Dev.(n=5)	1.88	1.04	0.41
63%:35%:02%			
1	41.7	20.4	13.3
2	39.4	16.6	13.9
3	42.1	21.9	13.2
4	39.2	20.4	12.9
5	40.6	20.9	12.8
Mean	40.6	20.0	13.2
St.Dev.(n=5)	1.31	2.02	0.43
62%:35%:03%			
1	40.3	20.5	13.5
2	41.3	20.7	12.2
3	41.9	21.0	13.4
4	41.4	21.0	13.4
5	41.1	21.3	12.9
Mean	41.2	20.9	13.1
St.Dev.(n=5)	0.58	0.31	0.54

Appendix B

28-DAY DYNAMIC LEACHING STUDY RESULTS

28-DAY DYNAMIC LEACHING STUDY RESULTS

Table B-1. Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 0.08		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		391.3444	99.7928	31.8502	31.8502	1.4988
2	77%:20%:03%	405.0247	103.2813	35.3387	35.3387	1.6630
3		397.3409	101.3219	33.3793	33.3793	1.5708
4		387.0825	98.7060	30.7634	30.7634	1.4477
5	73%:25%:02%	360.1098	91.8280	23.8854	23.8854	1.1240
6		367.8698	93.8068	25.8642	25.8642	1.2171
7		361.8111	92.2618	24.3192	24.3192	1.1444
8	72%:25%:03%	359.3352	91.6305	23.6879	23.6879	1.1147
9		376.6983	96.0581	28.1155	28.1155	1.3231
10		343.7617	87.6592	19.7166	19.7166	0.9278
11	69%:30%:01%	351.1322	89.5387	21.5961	21.5961	1.0163
12		332.1637	84.7017	16.7591	16.7591	0.7887
13		325.8992	83.1043	15.1617	15.1617	0.7135
14	68%:30%:02%	362.4854	92.4338	24.4912	24.4912	1.1525
15		362.8911	92.5372	24.5946	24.5946	1.1574
16		369.5329	94.2309	26.2883	26.2883	1.2371
17	67%:30%:03%	362.3136	92.3900	24.4474	24.4474	1.1505
18		364.9949	93.0737	25.1311	25.1311	1.1826
19		381.3251	97.2379	29.2953	29.2953	1.3786
20	64%:35%:01%	344.0657	87.7368	19.7942	19.7942	0.9315
21		357.7276	91.2205	23.2779	23.2779	1.0954
22		346.7738	88.4273	20.4847	20.4847	0.9640
23	63%:35%:02%	352.7251	89.9449	22.0023	22.0023	1.0354
24		342.1266	87.2423	19.2997	19.2997	0.9082
25		358.5255	91.4240	23.4814	23.4814	1.1050
26	62%:35%:03%	344.8659	87.9408	19.9982	19.9982	0.9411
27		354.1046	90.2967	22.3541	22.3541	1.0520

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 0.29		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		337.2904	86.0090	18.0664	49.9167	2.3490
2	77%:20%:03%	347.2996	88.5614	20.6188	55.9575	2.6333
3		353.4659	90.1338	22.1912	55.5705	2.6151
4		333.6072	85.0698	17.1272	47.8907	2.2537
5	73%:25%:02%	331.2454	84.4676	16.5250	40.4104	1.9017
6		330.7597	84.3437	16.4011	42.2653	1.9890
7		337.3704	86.0294	18.0868	42.4061	1.9956
8	72%:25%:03%	340.5903	86.8505	18.9079	42.5958	2.0045
9		346.2689	88.2986	20.3560	48.4714	2.2810
10		322.8287	82.3213	14.3787	34.0953	1.6045
11	69%:30%:01%	327.9155	83.6184	15.6758	37.2720	1.7540
12		329.4247	84.0033	16.0607	32.8198	1.5445
13		336.7201	85.8636	17.9210	33.0827	1.5568
14	68%:30%:02%	351.7500	89.6962	21.7536	46.2448	2.1762
15		337.0835	85.9563	18.0137	42.6083	2.0051
16		329.0963	83.9195	15.9769	42.2652	1.9890
17	67%:30%:03%	347.4096	88.5894	20.6468	45.0942	2.1221
18		340.4637	86.8182	18.8756	44.0067	2.0709
19		326.5608	83.2730	15.3304	44.6257	2.1000
20	64%:35%:01%	343.5858	87.6144	19.6718	39.4659	1.8572
21		336.7164	85.8627	17.9201	41.1980	1.9387
22		322.7851	82.3102	14.3676	34.8523	1.6401
23	63%:35%:02%	327.7872	83.5857	15.6431	37.6454	1.7715
24		324.0587	82.6350	14.6924	33.9920	1.5996
25		321.3339	81.9401	13.9975	37.4789	1.7637
26	62%:35%:03%	320.5439	81.7387	13.7961	33.7943	1.5903
27		327.9243	83.6207	15.6781	38.0322	1.7897

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 1		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		444.6054	113.3744	45.4318	95.3485	4.4870
2	77%:20%:03%	485.1320	123.7087	55.7661	111.7235	5.2576
3		490.2219	125.0066	57.0640	112.6345	5.3004
4		429.6465	109.5598	41.6172	89.5079	4.2121
5	73%:25%:02%	431.2744	109.9750	42.0324	82.4427	3.8797
6		418.5953	106.7418	38.7992	81.0645	3.8148
7		440.2599	112.2663	44.3237	86.7298	4.0814
8	72%:25%:03%	444.8314	113.4320	45.4894	88.0852	4.1452
9		455.5489	116.1650	48.2224	96.6938	4.5503
10		426.8030	108.8348	40.8922	74.9875	3.5288
11	69%:30%:01%	417.7012	106.5138	38.5712	75.8432	3.5691
12		435.0986	110.9501	43.0075	75.8274	3.5683
13		444.7201	113.4036	45.4610	78.5438	3.6962
14	68%:30%:02%	441.1155	112.4845	44.5419	90.7867	4.2723
15		426.9635	108.8757	40.9331	83.5414	3.9314
16		425.4931	108.5007	40.5581	82.8234	3.8976
17	67%:30%:03%	422.4087	107.7142	39.7716	84.8658	3.9937
18		447.3927	114.0851	46.1425	90.1493	4.2423
19		415.5271	105.9594	38.0168	82.6425	3.8891
20	64%:35%:01%	430.0896	109.6728	41.7302	81.1962	3.8210
21		435.4719	111.0453	43.1027	84.3007	3.9671
22		422.1701	107.6534	39.7108	74.5631	3.5089
23	63%:35%:02%	414.3784	105.6665	37.7239	75.3693	3.5468
24		418.9617	106.8352	38.8926	72.8847	3.4299
25		384.7483	98.1108	30.1682	67.6472	3.1834
26	62%:35%:03%	382.6254	97.5695	29.6269	63.4212	2.9845
27		399.3078	101.8235	33.8809	71.9130	3.3841

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 2		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1	77%:20%:03%	453.6160	115.6721	47.7295	143.0779	6.7331
2		470.4974	119.9768	52.0342	163.7578	7.7062
3		481.2237	122.7120	54.7694	167.4040	7.8778
4	73%:25%:02%	431.5704	110.0504	42.1078	131.6157	6.1937
5		441.4333	112.5655	44.6229	127.0656	5.9796
6		433.7622	110.6094	42.6668	123.7313	5.8226
7	72%:25%:03%	470.5712	119.9957	52.0531	138.7828	6.5310
8		484.2576	123.4857	55.5431	143.6283	6.7590
9		449.5137	114.6260	46.6834	143.3772	6.7472
10	69%:30%:01%	423.4237	107.9731	40.0305	115.0180	5.4126
11		420.1245	107.1318	39.1892	115.0323	5.4133
12		401.1871	102.3027	34.3601	110.1875	5.1853
13	68%:30%:02%	439.0177	111.9495	44.0069	122.5507	5.7671
14		434.4509	110.7850	42.8424	133.6291	6.2884
15		425.5306	108.5103	40.5677	124.1091	5.8404
16	67%:30%:03%	421.1833	107.4018	39.4592	122.2825	5.7545
17		433.1184	110.4452	42.5026	127.3684	5.9938
18		440.4068	112.3037	44.3611	134.5104	6.3299
19	64%:35%:01%	415.1636	105.8667	37.9241	120.5666	5.6737
20		418.2374	106.6505	38.7079	119.9041	5.6425
21		435.0239	110.9311	42.9885	127.2892	5.9901
22	63%:35%:02%	434.0875	110.6923	42.7497	117.3128	5.5206
23		423.1008	107.8907	39.9481	115.3175	5.4267
24		415.3914	105.9248	37.9822	110.8669	5.2173
25	62%:35%:03%	411.2783	104.8760	36.9334	104.5805	4.9214
26		422.6574	107.7776	39.8350	103.2562	4.8591
27		417.0447	106.3464	38.4038	110.3168	5.1914

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 3		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		424.5502	108.2603	40.3177	183.3956	8.6304
2	77%:20%:03%	399.2078	101.7980	33.8554	197.6132	9.2994
3		400.0806	102.0206	34.0780	201.4819	9.4815
4		382.9611	97.6551	29.7125	161.3282	7.5919
5	73%:25%:02%	366.8023	93.5346	25.5920	152.6576	7.1839
6		367.0436	93.5961	25.6535	149.3848	7.0299
7		389.2501	99.2588	31.3162	170.0990	8.0047
8	72%:25%:03%	405.6011	103.4283	35.4857	179.1140	8.4289
9		416.5022	106.2081	38.2655	181.6427	8.5479
10		384.9191	98.1544	30.2118	145.2297	6.8343
11	69%:30%:01%	370.0533	94.3636	26.4210	141.4533	6.6566
12		367.9679	93.8318	25.8892	136.0767	6.4036
13		381.6673	97.3252	29.3826	151.9332	7.1498
14	68%:30%:02%	377.8136	96.3425	28.3999	162.0289	7.6249
15		382.3954	97.5108	29.5682	153.6774	7.2319
16		384.3111	97.9993	30.0567	152.3393	7.1689
17	67%:30%:03%	375.5903	95.7755	27.8329	155.2013	7.3036
18		397.0485	101.2474	33.3048	167.8152	7.8972
19		370.6228	94.5088	26.5662	147.1328	6.9239
20	64%:35%:01%	376.2691	95.9486	28.0060	147.9102	6.9605
21		386.1421	98.4662	30.5236	157.8129	7.4265
22		372.1292	94.8929	26.9503	144.2632	6.7889
23	63%:35%:02%	375.3828	95.7226	27.7800	143.0975	6.7340
24		357.6380	91.1977	23.2551	134.1220	6.3116
25		372.1176	94.8900	26.9474	131.5279	6.1895
26	62%:35%:03%	365.3317	93.1596	25.2170	128.4732	6.0458
27		366.3432	93.4175	25.4749	135.7917	6.3902

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day4		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		424.5502	108.2603	40.3177	223.7133	10.5277
2	77%:20%:03%	399.2078	101.7980	33.8554	231.4685	10.8926
3		400.0806	102.0206	34.0780	235.5599	11.0852
4		382.9611	97.6551	29.7125	191.0407	8.9902
5	73%:25%:02%	366.8023	93.5346	25.5920	178.2496	8.3882
6		367.0436	93.5961	25.6535	175.0383	8.2371
7		389.2501	99.2588	31.3162	201.4152	9.4784
8	72%:25%:03%	405.6011	103.4283	35.4857	214.5996	10.0988
9		416.5022	106.2081	38.2655	219.9081	10.3486
10		384.9191	98.1544	30.2118	175.4415	8.2561
11	69%:30%:01%	370.0533	94.3636	26.4210	167.8743	7.9000
12		367.9679	93.8318	25.8892	161.9659	7.6219
13		381.6673	97.3252	29.3826	181.3158	8.5325
14	68%:30%:02%	377.8136	96.3425	28.3999	190.4288	8.9614
15		382.3954	97.5108	29.5682	183.2456	8.6233
16		384.3111	97.9993	30.0567	182.3960	8.5833
17	67%:30%:03%	375.5903	95.7755	27.8329	183.0343	8.6134
18		397.0485	101.2474	33.3048	201.1199	9.4645
19		370.6228	94.5088	26.5662	173.6990	8.1741
20	64%:35%:01%	376.2691	95.9486	28.0060	175.9162	8.2784
21		386.1421	98.4662	30.5236	188.3365	8.8629
22		372.1292	94.8929	26.9503	171.2135	8.0571
23	63%:35%:02%	375.3828	95.7226	27.7800	170.8775	8.0413
24		357.6380	91.1977	23.2551	157.3770	7.4060
25		372.1176	94.8900	26.9474	158.4753	7.4577
26	62%:35%:03%	365.3317	93.1596	25.2170	153.6902	7.2325
27		366.3432	93.4175	25.4749	161.2667	7.5890

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 5		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		397.8525	101.4524	33.5098	257.2231	12.1046
2	77%:20%:03%	378.6518	96.5562	28.6136	260.0821	12.2392
3		377.1067	96.1622	28.2196	263.7795	12.4132
4		343.3725	87.5600	19.6174	210.6581	9.9133
5	73%:25%:02%	341.3032	87.0323	19.0897	197.3393	9.2866
6		346.7342	88.4172	20.4746	195.5129	9.2006
7		365.7441	93.2648	25.3222	226.7373	10.6700
8	72%:25%:03%	391.9790	99.9546	32.0120	246.6117	11.6053
9		383.2195	97.7210	29.7784	249.6865	11.7500
10		362.5016	92.4379	24.4953	199.9368	9.4088
11	69%:30%:01%	361.8356	92.2681	24.3255	192.1998	9.0447
12		361.7954	92.2578	24.3152	186.2812	8.7662
13		374.4217	95.4775	27.5349	208.8507	9.8283
14	68%:30%:02%	378.2597	96.4562	28.5136	218.9424	10.3032
15		375.7227	95.8093	27.8667	211.1123	9.9347
16		368.8134	94.0474	26.1048	208.5008	9.8118
17	67%:30%:03%	371.3220	94.6871	26.7445	209.7788	9.8719
18		370.5726	94.4960	26.5534	227.6734	10.7140
19		365.4240	93.1831	25.2405	198.9396	9.3619
20	64%:35%:01%	342.7511	87.4015	19.4589	195.3751	9.1941
21		372.0920	94.8835	26.9409	215.2774	10.1307
22		361.4465	92.1689	24.2263	195.4398	9.1972
23	63%:35%:02%	362.6905	92.4861	24.5435	195.4210	9.1963
24		361.8050	92.2603	24.3177	181.6947	8.5503
25		363.9324	92.8028	24.8602	183.3355	8.6276
26	62%:35%:03%	358.8995	91.5194	23.5768	177.2669	8.3420
27		367.3734	93.6802	25.7376	187.0043	8.8002

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 8		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		529.9174	135.1289	67.1863	324.4094	15.2663
2	77%:20%:03%	523.5177	133.4970	65.5544	325.6366	15.3241
3		539.6312	137.6059	69.6633	333.4429	15.6914
4		480.3659	122.4933	54.5507	265.2088	12.4804
5	73%:25%:02%	473.2991	120.6913	52.7487	250.0880	11.7688
6		476.9594	121.6246	53.6820	249.1950	11.7268
7		502.8513	128.2271	60.2845	287.0218	13.5069
8	72%:25%:03%	534.9598	136.4148	68.4722	315.0838	14.8275
9		500.5123	127.6306	59.6880	309.3745	14.5588
10		470.5308	119.9853	52.0427	251.9795	11.8579
11	69%:30%:01%	473.2450	120.6775	52.7349	244.9347	11.5263
12		478.0690	121.9076	53.9650	240.2461	11.3057
13		492.9126	125.6927	57.7501	266.6008	12.5459
14	68%:30%:02%	495.5147	126.3562	58.4136	277.3561	13.0521
15		501.2896	127.8289	59.8863	270.9986	12.7529
16		505.1076	128.8024	60.8598	269.3606	12.6758
17	67%:30%:03%	497.2780	126.8059	58.8633	268.6421	12.6420
18		507.9351	129.5235	61.5809	289.2542	13.6120
19		484.2512	123.4841	55.5415	254.4810	11.9756
20	64%:35%:01%	496.6684	126.6505	58.7079	254.0830	11.9568
21		482.6233	123.0689	55.1263	270.4037	12.7249
22		502.5422	128.1483	60.2057	255.6454	12.0304
23	63%:35%:02%	488.7369	124.6279	56.6853	252.1063	11.8638
24		476.4252	121.4884	53.5458	235.2405	11.0701
25		492.6160	125.6171	57.6745	241.0100	11.3416
26	62%:35%:03%	491.0737	125.2238	57.2812	234.5481	11.0376
27		479.3670	122.2386	54.2960	241.3003	11.3553

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 11		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		480.8992	122.6293	54.6867	379.0961	17.8398
2	77%:20%:03%	482.7921	123.1120	55.1694	380.8059	17.9203
3		481.0481	122.6673	54.7247	388.1675	18.2667
4		435.3825	111.0225	43.0799	308.2887	14.5077
5	73%:25%:02%	410.8479	104.7662	36.8236	286.9116	13.5017
6		416.7985	106.2836	38.3410	287.5360	13.5311
7		464.8627	118.5400	50.5974	337.6192	15.8880
8	72%:25%:03%	461.1005	117.5806	49.6380	364.7219	17.1634
9		446.1880	113.7779	45.8353	355.2099	16.7158
10		408.1273	104.0725	36.1299	288.1094	13.5581
11	69%:30%:01%	407.6113	103.9409	35.9983	280.9330	13.2204
12		404.0574	103.0346	35.0920	275.3382	12.9571
13		441.3605	112.5469	44.6043	311.2052	14.6449
14	68%:30%:02%	434.0426	110.6809	42.7383	320.0943	15.0633
15		433.0320	110.4232	42.4806	313.4791	14.7520
16		438.3948	111.7907	43.8481	313.2087	14.7392
17	67%:30%:03%	438.9722	111.9379	43.9953	312.6374	14.7123
18		451.0916	115.0284	47.0858	336.3400	15.8278
19		402.6812	102.6837	34.7411	289.2221	13.6105
20	64%:35%:01%	425.5608	108.5180	40.5754	294.6584	13.8663
21		417.9561	106.5788	38.6362	309.0399	14.5431
22		422.3405	107.6968	39.7542	295.3997	13.9012
23	63%:35%:02%	422.5832	107.7587	39.8161	291.9224	13.7375
24		411.5194	104.9375	36.9949	272.2354	12.8111
25		405.8488	103.4915	35.5489	276.5588	13.0145
26	62%:35%:03%	417.6564	106.5024	38.5598	273.1079	12.8521
27		419.3383	106.9313	38.9887	280.2889	13.1901

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day14		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		461.7440	117.7447	49.8021	428.8983	20.1834
2	77%:20%:03%	459.2261	117.1026	49.1600	429.9660	20.2337
3		483.4377	123.2766	55.3340	443.5015	20.8707
4		420.3095	107.1789	39.2363	347.5250	16.3541
5	73%:25%:02%	423.7819	108.0644	40.1218	327.0334	15.3898
6		419.5692	106.9901	39.0475	326.5835	15.3686
7		444.4143	113.3257	45.3831	383.0022	18.0236
8	72%:25%:03%	469.8951	119.8232	51.8806	416.6025	19.6048
9		457.4222	116.6426	48.7000	403.9099	19.0075
10		430.2139	109.7045	41.7619	329.8713	15.5234
11	69%:30%:01%	422.6412	107.7735	39.8309	320.7639	15.0948
12		427.1094	108.9129	40.9703	316.3085	14.8851
13		439.8985	112.1741	44.2315	355.4367	16.7264
14	68%:30%:02%	433.3771	110.5112	42.5686	362.6629	17.0665
15		431.1301	109.9382	41.9956	355.4747	16.7282
16		435.8003	111.1291	43.1865	356.3952	16.7715
17	67%:30%:03%	451.2685	115.0735	47.1309	359.7682	16.9303
18		443.6466	113.1299	45.1873	381.5272	17.9542
19		419.2135	106.8995	38.9569	328.1790	15.4437
20	64%:35%:01%	430.9479	109.8917	41.9491	336.6075	15.8404
21		426.4198	108.7370	40.7944	349.8344	16.4628
22		433.4500	110.5298	42.5872	337.9868	15.9053
23	63%:35%:02%	427.9404	109.1248	41.1822	333.1046	15.6755
24		413.0771	105.3347	37.3921	309.6274	14.5707
25		407.7719	103.9818	36.0392	312.5981	14.7105
26	62%:35%:03%	432.4201	110.2671	42.3245	315.4324	14.8439
27		421.4304	107.4648	39.5222	319.8111	15.0499

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 21		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		624.5559	159.2617	91.3191	520.2174	24.4808
2	77%:20%:03%	591.8168	150.9133	82.9707	512.9367	24.1382
3		624.1840	159.1669	91.2243	534.7259	25.1636
4		557.0778	142.0548	74.1122	421.6373	19.8418
5	73%:25%:02%	542.0377	138.2196	70.2770	397.3104	18.6970
6		526.0904	134.1530	66.2104	392.7940	18.4844
7		585.0172	149.1794	81.2368	464.2390	21.8465
8	72%:25%:03%	601.8379	153.4687	85.5261	502.1286	23.6296
9		592.8772	151.1837	83.2411	487.1510	22.9248
10		536.0918	136.7034	68.7608	398.6321	18.7592
11	69%:30%:01%	545.7592	139.1686	71.2260	391.9899	18.4466
12		542.0537	138.2237	70.2811	386.5896	18.1924
13		567.6815	144.7588	76.8162	432.2529	20.3413
14	68%:30%:02%	570.1385	145.3853	77.4427	440.1056	20.7109
15		573.8702	146.3369	78.3943	433.8690	20.4174
16		583.7011	148.8438	80.9012	437.2964	20.5787
17	67%:30%:03%	574.1744	146.4145	78.4719	438.2401	20.6231
18		587.9471	149.9265	81.9839	463.5112	21.8123
19		499.5943	127.3965	59.4539	387.6329	18.2415
20	64%:35%:01%	560.3470	142.8885	74.9459	411.5534	19.3672
21		560.2387	142.8609	74.9183	424.7526	19.9884
22		529.1575	134.9352	66.9926	404.9794	19.0579
23	63%:35%:02%	537.9070	137.1663	69.2237	402.3283	18.9331
24		532.2023	135.7116	67.7690	377.3964	17.7598
25		556.5144	141.9112	73.9686	386.5666	18.1914
26	62%:35%:03%	552.6451	140.9245	72.9819	388.4143	18.2783
27		545.3422	139.0623	71.1197	390.9308	18.3967

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-1 (Cont.). Calculation of Cumulative Calcium Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Calcium Leaching Study Data: Day 28		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1		579.9474	147.8866	79.9440	600.1614	28.2429
2	77%:20%:03%	802.0306	204.5178	136.5752	649.5119	30.5653
3		602.4336	153.6206	85.6780	620.4038	29.1955
4		508.0535	129.5536	61.6110	483.2483	22.7411
5	73%:25%:02%	515.8907	131.5521	63.6095	460.9199	21.6903
6		514.2661	131.1379	63.1953	455.9892	21.4583
7		553.4587	141.1320	73.1894	537.4284	25.2907
8	72%:25%:03%	543.4347	138.5758	70.6332	572.7618	26.9535
9		562.7621	143.5043	75.5617	562.7127	26.4806
10		509.2061	129.8476	61.9050	460.5371	21.6723
11	69%:30%:01%	515.6726	131.4965	63.5539	455.5438	21.4374
12		516.3077	131.6585	63.7159	450.3054	21.1908
13		530.9696	135.3972	67.4546	499.7075	23.5156
14	68%:30%:02%	541.8218	138.1646	70.2220	510.3276	24.0154
15		533.6473	136.0800	68.1374	502.0064	23.6238
16		548.5467	139.8794	71.9368	509.2332	23.9639
17	67%:30%:03%	551.0860	140.5269	72.5843	510.8244	24.0388
18		544.3698	138.8143	70.8717	534.3829	25.1474
19		509.8780	130.0189	62.0763	449.7092	21.1628
20	64%:35%:01%	515.6035	131.4789	63.5363	475.0897	22.3572
21		518.9552	132.3336	64.3910	489.1436	23.0185
22		510.6806	130.2236	62.2810	467.2603	21.9887
23	63%:35%:02%	510.5018	130.1779	62.2353	464.5636	21.8618
24		510.3661	130.1433	62.2007	439.5972	20.6869
25		511.3678	130.3988	62.4562	449.0228	21.1305
26	62%:35%:03%	518.4562	132.2063	64.2637	452.6781	21.3025
27		533.1034	135.9414	67.9988	458.9295	21.5967

Specimen Volume (cm^3) =	8.5		Mean Ca^{2+} in BLK (mg) =	67.942
Surface Area (cm^2) =	21.25			

Table B-2. Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 0.08		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1798.6377	458.6526	105.9781	105.9781	4.9872
2	77%:20%:03%	1784.4850	455.0437	102.3692	102.3692	4.8174
3		1812.9338	462.2981	109.6236	109.6236	5.1588
4		1724.8503	439.8368	87.1623	87.1623	4.1018
5	73%:25%:02%	1765.0006	450.0752	97.4007	97.4007	4.5836
6		1737.4155	443.0410	90.3665	90.3665	4.2525
7		1745.2956	445.0504	92.3759	92.3759	4.3471
8	72%:25%:03%	1741.7590	444.1486	91.4741	91.4741	4.3047
9		1826.3446	465.7179	113.0434	113.0434	5.3197
10		1699.4208	433.3523	80.6778	80.6778	3.7966
11	69%:30%:01%	1767.8901	450.8120	98.1375	98.1375	4.6182
12		1684.7336	429.6071	76.9326	76.9326	3.6204
13		1627.6170	415.0423	62.3678	62.3678	2.9350
14	68%:30%:02%	1774.6243	452.5292	99.8547	99.8547	4.6990
15		1776.8740	453.1029	100.4284	100.4284	4.7260
16		1757.0060	448.0365	95.3620	95.3620	4.4876
17	67%:30%:03%	1765.1407	450.1109	97.4364	97.4364	4.5852
18		1686.8811	430.1547	77.4802	77.4802	3.6461
19		1700.5096	433.6300	80.9555	80.9555	3.8097
20	64%:35%:01%	1688.4536	430.5557	77.8812	77.8812	3.6650
21		1713.4446	436.9284	84.2539	84.2539	3.9649
22		1681.1257	428.6870	76.0125	76.0125	3.5771
23	63%:35%:02%	1714.5753	437.2167	84.5422	84.5422	3.9785
24		1680.4264	428.5087	75.8342	75.8342	3.5687
25		1721.4410	438.9674	86.2929	86.2929	4.0608
26	62%:35%:03%	1724.8708	439.8420	87.1675	87.1675	4.1020
27		1699.7272	433.4304	80.7559	80.7559	3.8003

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 0.29		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1747.4693	445.6047	92.9302	198.9083	9.3604
2	77%:20%:03%	1769.2012	451.1463	98.4718	200.8410	9.4513
3		1812.3512	462.1495	109.4750	219.0987	10.3105
4		1724.6795	439.7933	87.1188	174.2811	8.2015
5	73%:25%:02%	1725.1632	439.9166	87.2421	184.6428	8.6891
6		1731.4511	441.5200	88.8455	179.2120	8.4335
7		1764.2187	449.8758	97.2013	189.5771	8.9213
8	72%:25%:03%	1776.2234	452.9370	100.2625	191.7365	9.0229
9		1795.6819	457.8989	105.2244	218.2678	10.2714
10		1667.4764	425.2065	72.5320	153.2098	7.2099
11	69%:30%:01%	1728.6184	440.7977	88.1232	186.2607	8.7652
12		1711.1425	436.3413	83.6668	160.5994	7.5576
13		1740.4908	443.8252	91.1507	153.5185	7.2244
14	68%:30%:02%	1827.6602	466.0533	113.3788	213.2335	10.0345
15		1739.0963	443.4695	90.7950	191.2234	8.9987
16		1697.0109	432.7378	80.0633	175.4253	8.2553
17	67%:30%:03%	1821.6918	464.5314	111.8569	209.2933	9.8491
18		1788.2754	456.0102	103.3357	180.8159	8.5090
19		1686.1642	429.9719	77.2974	158.2528	7.4472
20	64%:35%:01%	1764.6865	449.9951	97.3206	175.2017	8.2448
21		1705.8205	434.9842	82.3097	166.5636	7.8383
22		1735.3138	442.5050	89.8305	165.8431	7.8044
23	63%:35%:02%	1743.4679	444.5843	91.9098	176.4520	8.3036
24		1712.0238	436.5661	83.8916	159.7258	7.5165
25		1679.5939	428.2964	75.6219	161.9149	7.6195
26	62%:35%:03%	1709.0101	435.7976	83.1231	170.2906	8.0137
27		1743.1913	444.5138	91.8393	172.5952	8.1221

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 1		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1859.4116	474.1500	121.4755	320.3837	15.0769
2	77%:20%:03%	1967.3869	501.6837	149.0092	349.8501	16.4635
3		1978.6107	504.5457	151.8712	370.9699	17.4574
4		1773.4248	452.2233	99.5488	273.8299	12.8861
5	73%:25%:02%	1727.5113	440.5154	87.8409	272.4837	12.8228
6		1713.2738	436.8848	84.2103	263.4223	12.3963
7		1778.2466	453.4529	100.7784	290.3555	13.6638
8	72%:25%:03%	1805.6290	460.4354	107.7609	299.4974	14.0940
9		1863.6271	475.2249	122.5504	340.8182	16.0385
10		1775.8359	452.8381	100.1636	253.3734	11.9235
11	69%:30%:01%	1770.4183	451.4567	98.7822	285.0428	13.4138
12		1807.1840	460.8319	108.1574	268.7568	12.6474
13		1779.2017	453.6964	101.0219	254.5404	11.9784
14	68%:30%:02%	1796.4591	458.0971	105.4226	318.6561	14.9956
15		1782.5515	454.5506	101.8761	293.0995	13.7929
16		1793.4935	457.3408	104.6663	280.0916	13.1808
17	67%:30%:03%	1755.4423	447.6378	94.9633	304.2566	14.3180
18		1797.3772	458.3312	105.6567	286.4726	13.4811
19		1751.7242	446.6897	94.0152	252.2680	11.8714
20	64%:35%:01%	1780.1725	453.9440	101.2695	276.4712	13.0104
21		1729.9667	441.1415	88.4670	255.0306	12.0014
22		1713.9862	437.0665	84.3920	250.2350	11.7758
23	63%:35%:02%	1680.1902	428.4485	75.7740	252.2260	11.8695
24		1726.9467	440.3714	87.6969	247.4227	11.6434
25		1579.6592	402.8131	50.1386	212.0535	9.9790
26	62%:35%:03%	1583.6689	403.8356	51.1611	221.4517	10.4213
27		1659.5617	423.1882	70.5137	243.1089	11.4404

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 2		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1924.8703	490.8419	138.1674	458.5512	21.5789
2	77%:20%:03%	1961.1389	500.0904	147.4159	497.2661	23.4008
3		1915.8268	488.5358	135.8613	506.8312	23.8509
4		1822.5623	464.7534	112.0789	385.9088	18.1604
5	73%:25%:02%	1806.7876	460.7308	108.0563	380.5400	17.9078
6		1837.5099	468.5650	115.8905	379.3128	17.8500
7		1898.9993	484.2448	131.5703	421.9258	19.8553
8	72%:25%:03%	1974.5742	503.5164	150.8419	450.3394	21.1924
9		1839.4571	469.0616	116.3871	457.2052	21.5155
10		1841.1446	469.4919	116.8174	370.1908	17.4207
11	69%:30%:01%	1787.1597	455.7257	103.0512	388.0940	18.2632
12		1746.8707	445.4520	92.7775	361.5344	17.0134
13		1822.7186	464.7932	112.1187	366.6592	17.2545
14	68%:30%:02%	1840.7047	469.3797	116.7052	435.3613	20.4876
15		1767.0855	450.6068	97.9323	391.0318	18.4015
16		1793.6731	457.3866	104.7121	384.8038	18.1084
17	67%:30%:03%	1766.3843	450.4280	97.7535	402.0101	18.9181
18		1793.5664	457.3594	104.6849	391.1575	18.4074
19		1736.3571	442.7711	90.0966	342.3645	16.1113
20	64%:35%:01%	1775.1123	452.6536	99.9791	376.4504	17.7153
21		1753.6176	447.1725	94.4980	349.5286	16.4484
22		1785.0065	455.1766	102.5021	352.7372	16.5994
23	63%:35%:02%	1793.7776	457.4133	104.7388	356.9648	16.7983
24		1751.6183	446.6627	93.9882	341.4109	16.0664
25		1773.2945	452.1901	99.5156	311.5691	14.6621
26	62%:35%:03%	1799.6108	458.9008	106.2263	327.6779	15.4201
27		1728.1602	440.6809	88.0064	331.1153	15.5819

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 3		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1800.7630	459.1946	106.5201	565.0712	26.5916
2	77%:20%:03%	1770.4415	451.4626	98.7881	596.0541	28.0496
3		1738.5653	443.3341	90.6596	597.4909	28.1172
4		1718.0728	438.1086	85.4341	471.3429	22.1808
5	73%:25%:02%	1725.3612	439.9671	87.2926	467.8326	22.0157
6		1688.8735	430.6627	77.9882	457.3011	21.5201
7		1700.0797	433.5203	80.8458	502.7717	23.6598
8	72%:25%:03%	1723.5715	439.5107	86.8362	537.1756	25.2789
9		1763.2059	449.6175	96.9430	554.1482	26.0776
10		1735.1624	442.4664	89.7919	459.9827	21.6462
11	69%:30%:01%	1730.7788	441.3486	88.6741	476.7681	22.4361
12		1713.0616	436.8307	84.1562	445.6905	20.9737
13		1686.3871	430.0287	77.3542	444.0134	20.8947
14	68%:30%:02%	1715.0245	437.3313	84.6568	520.0181	24.4714
15		1739.7223	443.6292	90.9547	481.9865	22.6817
16		1728.9827	440.8906	88.2161	473.0199	22.2598
17	67%:30%:03%	1721.6960	439.0325	86.3580	488.3681	22.9820
18		1731.0329	441.4134	88.7389	479.8964	22.5834
19		1679.5252	428.2789	75.6044	417.9690	19.6691
20	64%:35%:01%	1659.6741	423.2169	70.5424	446.9928	21.0350
21		1694.3028	432.0472	79.3727	428.9013	20.1836
22		1637.5464	417.5743	64.8998	417.6370	19.6535
23	63%:35%:02%	1701.8389	433.9689	81.2944	438.2592	20.6240
24		1689.0459	430.7067	78.0322	419.4431	19.7385
25		1678.2483	427.9533	75.2788	386.8479	18.2046
26	62%:35%:03%	1689.6799	430.8684	78.1939	405.8718	19.0999
27		1655.4500	422.1397	69.4652	400.5805	18.8508

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 4		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1727.8703	440.6069	87.9324	653.0036	30.7296
2	77%:20%:03%	1738.7775	443.3883	90.7138	686.7679	32.3185
3		1633.6144	416.5717	63.8972	661.3880	31.1241
4		1564.8052	399.0253	46.3508	517.6937	24.3621
5	73%:25%:02%	1547.5178	394.6170	41.9425	509.7751	23.9894
6		1585.8272	404.3859	51.7114	509.0125	23.9535
7		1657.2447	422.5974	69.9229	572.6945	26.9503
8	72%:25%:03%	1635.9978	417.1794	64.5049	601.6805	28.3144
9		1724.5519	439.7607	87.0862	641.2345	30.1757
10		1584.3652	404.0131	51.3386	511.3213	24.0622
11	69%:30%:01%	1609.8254	410.5055	57.8310	534.5991	25.1576
12		1576.1789	401.9256	49.2511	494.9417	23.2914
13		1604.8662	409.2409	56.5664	500.5798	23.5567
14	68%:30%:02%	1598.3719	407.5848	54.9103	574.9284	27.0555
15		1556.4079	396.8840	44.2095	526.1961	24.7622
16		1602.4136	408.6155	55.9410	528.9608	24.8923
17	67%:30%:03%	1565.2964	399.1506	46.4761	534.8442	25.1691
18		1579.8308	402.8568	50.1823	530.0788	24.9449
19		1558.5754	397.4367	44.7622	462.7312	21.7756
20	64%:35%:01%	1591.6249	405.8644	53.1899	500.1826	23.5380
21		1567.5335	399.7211	47.0466	475.9479	22.3975
22		1546.2767	394.3006	41.6261	459.2631	21.6124
23	63%:35%:02%	1570.6826	400.5241	47.8496	486.1088	22.8757
24		1562.2877	398.3834	45.7089	465.1520	21.8895
25		1581.4689	403.2746	50.6001	437.4479	20.5858
26	62%:35%:03%	1524.3079	388.6985	36.0240	441.8958	20.7951
27		1563.9163	398.7986	46.1241	446.7047	21.0214

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 5		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1714.6391	437.2330	84.5585	737.5621	34.7088
2	77%:20%:03%	1605.7015	409.4539	56.7794	743.5473	34.9905
3		1635.3661	417.0183	64.3438	725.7319	34.1521
4		1561.9391	398.2945	45.6200	563.3136	26.5089
5	73%:25%:02%	1560.7821	397.9994	45.3249	555.1001	26.1224
6		1578.5949	402.5417	49.8672	558.8797	26.3002
7		1601.1096	408.2829	55.6084	628.3030	29.5672
8	72%:25%:03%	1598.3157	407.5705	54.8960	656.5765	30.8977
9		1590.5742	405.5964	52.9219	694.1564	32.6662
10		1582.8547	403.6280	50.9535	562.2748	26.4600
11	69%:30%:01%	1583.3826	403.7626	51.0881	585.6872	27.5618
12		1592.3825	406.0575	53.3830	548.3247	25.8035
13		1611.6267	410.9648	58.2903	558.8701	26.2998
14	68%:30%:02%	1593.1190	406.2454	53.5709	628.4993	29.5764
15		1565.2118	399.1290	46.4545	572.6506	26.9483
16		1534.8059	391.3755	38.7010	567.6618	26.7135
17	67%:30%:03%	1563.8057	398.7705	46.0960	580.9401	27.3384
18		1596.4239	407.0881	54.4136	584.4923	27.5055
19		1519.8898	387.5719	34.8974	497.6286	23.4178
20	64%:35%:01%	1588.0586	404.9549	52.2804	552.4631	25.9983
21		1574.5834	401.5188	48.8443	524.7921	24.6961
22		1607.0638	409.8013	57.1268	516.3898	24.3007
23	63%:35%:02%	1565.7716	399.2718	46.5973	532.7061	25.0685
24		1613.6887	411.4906	58.8161	523.9681	24.6573
25		1587.6907	404.8611	52.1866	489.6346	23.0416
26	62%:35%:03%	1507.3395	384.3716	31.6971	473.5929	22.2867
27		1561.2543	398.1198	45.4453	492.1500	23.1600

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 8		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1750.5418	446.3882	93.7137	831.2758	39.1189
2	77%:20%:03%	1710.9372	436.2890	83.6145	827.1618	38.9253
3		1731.1177	441.4350	88.7605	814.4924	38.3291
4		1631.5816	416.0533	63.3788	626.6925	29.4914
5	73%:25%:02%	1713.1609	436.8560	84.1815	639.2816	30.0838
6		1605.4735	409.3957	56.7212	615.6010	28.9695
7		1687.5884	430.3350	77.6605	705.9635	33.2218
8	72%:25%:03%	1730.3697	441.2443	88.5698	745.1463	35.0657
9		1683.1743	429.2095	76.5350	770.6914	36.2678
10		1650.3988	420.8517	68.1772	630.4520	29.6683
11	69%:30%:01%	1609.1014	410.3209	57.6464	643.3336	30.2745
12		1662.3228	423.8923	71.2178	619.5425	29.1549
13		1659.7562	423.2378	70.5633	629.4334	29.6204
14	68%:30%:02%	1638.9809	417.9401	65.2656	693.7649	32.6478
15		1673.3024	426.6921	74.0176	646.6682	30.4314
16		1679.2722	428.2144	75.5399	643.2017	30.2683
17	67%:30%:03%	1654.4576	421.8867	69.2122	650.1523	30.5954
18		1650.2729	420.8196	68.1451	652.6374	30.7123
19		1645.9598	419.7197	67.0452	564.6738	26.5729
20	64%:35%:01%	1681.2557	428.7202	76.0457	628.5088	29.5769
21		1623.7292	414.0509	61.3764	586.1686	27.5844
22		1700.2404	433.5613	80.8868	597.2766	28.1071
23	63%:35%:02%	1625.3093	414.4539	61.7794	594.4855	27.9758
24		1612.3895	411.1593	58.4848	582.4529	27.4095
25		1648.2613	420.3066	67.6321	557.2667	26.2243
26	62%:35%:03%	1621.7209	413.5388	60.8643	534.4572	25.1509
27		1626.4659	414.7488	62.0743	554.2243	26.0811

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 11		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1551.6181	395.6626	42.9881	874.2639	41.1418
2	77%:20%:03%	1532.3179	390.7411	38.0666	865.2283	40.7166
3		1536.6088	391.8352	39.1607	853.6531	40.1719
4		1425.4728	363.4956	10.8211	637.5135	30.0006
5	73%:25%:02%	1392.4516	355.0751	2.4006	641.6822	30.1968
6		1374.3923	350.4700	-2.2045	613.3965	28.8657
7		1510.5447	385.1889	32.5144	738.4779	34.7519
8	72%:25%:03%	1488.0942	379.4640	26.7895	771.9358	36.3264
9		1461.5494	372.6951	20.0206	790.7119	37.2100
10		1386.5548	353.5715	0.8970	631.3489	29.7105
11	69%:30%:01%	1386.9199	353.6646	0.9901	644.3236	30.3211
12		1380.4789	352.0221	-0.6524	618.8901	29.1242
13		1426.1389	363.6654	10.9909	640.4243	30.1376
14	68%:30%:02%	1399.4559	356.8613	4.1868	697.9517	32.8448
15		1426.2082	363.6831	11.0086	657.6768	30.9495
16		1428.4811	364.2627	11.5882	654.7899	30.8136
17	67%:30%:03%	1471.1456	375.1421	22.4676	672.6199	31.6527
18		1403.6740	357.9369	5.2624	657.8998	30.9600
19		1366.6493	348.4956	-4.1789	560.4949	26.3762
20	64%:35%:01%	1439.5359	367.0817	14.4072	642.9160	30.2549
21		1367.9228	348.8203	-3.8542	582.3144	27.4030
22		1115.8639	284.5453	-68.1292	529.1474	24.9011
23	63%:35%:02%	1406.4078	358.6340	5.9595	600.4449	28.2562
24		1338.0020	341.1905	-11.4840	570.9689	26.8691
25		1365.3230	348.1574	-4.5171	552.7496	26.0117
26	62%:35%:03%	1336.9483	340.9218	-11.7527	522.7046	24.5979
27		1358.8984	346.5191	-6.1554	548.0689	25.7915

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 14		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		1757.8578	448.2537	95.5792	969.8431	45.6397
2	77%:20%:03%	1728.6960	440.8175	88.1430	953.3713	44.8645
3		1728.2020	440.6915	88.0170	941.6701	44.3139
4		1609.6736	410.4668	57.7923	695.3058	32.7203
5	73%:25%:02%	1553.1500	396.0532	43.3787	685.0610	32.2382
6		1644.1875	419.2678	66.5933	679.9898	31.9995
7		1686.7640	430.1248	77.4503	815.9283	38.3966
8	72%:25%:03%	1766.2849	450.4026	97.7281	869.6640	40.9254
9		1707.3555	435.3756	82.7011	873.4131	41.1018
10		1658.8062	422.9956	70.3211	701.6700	33.0198
11	69%:30%:01%	1656.0339	422.2887	69.6142	713.9378	33.5971
12		1673.0782	426.6349	73.9604	692.8506	32.6047
13		1667.3802	425.1820	72.5075	712.9318	33.5497
14	68%:30%:02%	1590.5485	405.5899	52.9154	750.8670	35.3349
15		1683.8043	429.3701	76.6956	734.3724	34.5587
16		1670.0520	425.8633	73.1888	727.9787	34.2578
17	67%:30%:03%	1662.6195	423.9680	71.2935	743.9134	35.0077
18		1665.7376	424.7631	72.0886	729.9884	34.3524
19		1609.6756	410.4673	57.7928	618.2877	29.0959
20	64%:35%:01%	1656.1133	422.3089	69.6344	712.5503	33.5318
21		1622.3644	413.7029	61.0284	643.3428	30.2750
22		1638.9013	417.9198	65.2453	594.3928	27.9714
23	63%:35%:02%	1710.7006	436.2287	83.5542	683.9991	32.1882
24		1634.3186	416.7512	64.0767	635.0457	29.8845
25		1611.6355	410.9670	58.2925	611.0421	28.7549
26	62%:35%:03%	1607.7659	409.9803	57.3058	580.0104	27.2946
27		1595.2575	406.7907	54.1162	602.1851	28.3381

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 21		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		2288.0559	583.4543	230.7798	1200.6229	56.4999
2	77%:20%:03%	2175.3246	554.7078	202.0333	1155.4046	54.3720
3		2176.4163	554.9862	202.3117	1143.9818	53.8344
4		1998.5536	509.6312	156.9567	852.2625	40.1065
5	73%:25%:02%	2153.4305	549.1248	196.4503	881.5113	41.4829
6		2056.8957	524.5084	171.8339	851.8237	40.0858
7		2123.3014	541.4418	188.7673	1004.6956	47.2798
8	72%:25%:03%	2129.4375	543.0066	190.3321	1059.9960	49.8822
9		2111.9862	538.5565	185.8820	1059.2951	49.8492
10		2057.2249	524.5923	171.9178	873.5878	41.1100
11	69%:30%:01%	2058.0514	524.8031	172.1286	886.0664	41.6972
12		2036.1286	519.2128	166.5383	859.3889	40.4418
13		2057.9511	524.7775	172.1030	885.0348	41.6487
14	68%:30%:02%	2023.5862	516.0145	163.3400	914.2070	43.0215
15		2096.7483	534.6708	181.9963	916.3687	43.1232
16		2063.7564	526.2579	173.5834	901.5620	42.4264
17	67%:30%:03%	2079.6530	530.3115	177.6370	921.5504	43.3671
18		2044.3732	521.3152	168.6407	898.6290	42.2884
19		1946.1848	496.2771	143.6026	761.8903	35.8537
20	64%:35%:01%	2053.1945	523.5646	170.8901	883.4404	41.5737
21		2051.3289	523.0889	170.4144	813.7572	38.2945
22		1979.8777	504.8688	152.1943	746.5871	35.1335
23	63%:35%:02%	1906.2466	486.0929	133.4184	817.4175	38.4667
24		1897.0848	483.7566	131.0821	766.1278	36.0531
25		1953.1894	498.0633	145.3888	756.4309	35.5967
26	62%:35%:03%	1989.9807	507.4451	154.7706	734.7809	34.5779
27		1969.4819	502.2179	149.5434	751.7285	35.3755

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-2 (Cont.). Calculation of Cumulative Sulfate Flux for 28-Day Dynamic Leaching Test.

Initial Nine PG Compositions				Sulfate Leaching Study Data: Day 28		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1		2072.3876	528.4588	175.7843	1376.4072	64.7721
2	77%:20%:03%	2033.0185	518.4197	165.7452	1321.1498	62.1718
3		2073.6973	528.7928	176.1183	1320.1001	62.1224
4		1951.1044	497.5316	144.8571	997.1196	46.9233
5	73%:25%:02%	1892.1672	482.5026	129.8281	1011.3394	47.5924
6		1917.9545	489.0784	136.4039	988.2276	46.5048
7		1959.3737	499.6403	146.9658	1151.6614	54.1958
8	72%:25%:03%	2028.7241	517.3247	164.6502	1224.6462	57.6304
9		1981.4407	505.2674	152.5929	1211.8879	57.0300
10		1901.6149	484.9118	132.2373	1005.8251	47.3329
11	69%:30%:01%	1870.6212	477.0084	124.3339	1010.4003	47.5482
12		1852.1642	472.3019	119.6274	979.0162	46.0714
13		1876.2740	478.4499	125.7754	1010.8102	47.5675
14	68%:30%:02%	1900.2157	484.5550	131.8805	1046.0875	49.2276
15		1907.0293	486.2925	133.6180	1049.9866	49.4111
16		1935.3671	493.5186	140.8441	1042.4061	49.0544
17	67%:30%:03%	1910.6758	487.2223	134.5478	1056.0982	49.6987
18		1879.0955	479.1694	126.4949	1025.1239	48.2411
19		1891.2025	482.2566	129.5821	891.4724	41.9516
20	64%:35%:01%	1838.5050	468.8188	116.1443	999.5847	47.0393
21		1865.4471	475.6890	123.0145	936.7717	44.0834
22		1825.5310	465.5104	112.8359	859.4230	40.4434
23	63%:35%:02%	1842.4482	469.8243	117.1498	934.5673	43.9796
24		1873.6714	477.7862	125.1117	891.2395	41.9407
25		1844.5212	470.3529	117.6784	874.1093	41.1346
26	62%:35%:03%	1823.1015	464.8909	112.2164	846.9973	39.8587
27		1848.6588	471.4080	118.7335	870.4620	40.9629

Specimen Volume (cm^3) =	8.5		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	21.25			

Table B-3. Effective Calcium and Sulfate Diffusion Coefficients for the Initial Nine PG Composite Combinations Calculated Using Theoretical C_o Values.

Calcium Effective Diffusion Coefficients (Using Theoretical C_o)								
PG Composite	K_1 $(C_o - C_1)$ $mg \cdot cm^{-2}$	$K_2(C_o - C_1)$ $mg \cdot cm^{-2} \cdot d^{-0.5}$	$K_3(C_o - C_1)$ $mg \cdot cm^{-2} \cdot d^{-1}$	$C_{o,Theo.}$ (mg/cc)	C_1 (mg/cc)	K_2 ($cm/day^{0.5}$)	K_3 (cm/day)	D_e m^2/sec
77%:20%:03%	0	5.2628	0.0456	284.75	0.47	0.0185	0.000161	3.12E-13
73%:25%:02%	0	4.2516	0.0000	269.96	0.42	0.0158	0.000000	2.26E-13
72%:25%:03%	0	4.8877	0.0000	266.26	0.45	0.0184	0.000000	3.07E-13
69%:30%:01%	0	3.8556	0.0413	255.16	0.42	0.0151	0.000162	2.08E-13
68%:30%:02%	0	4.2859	0.0433	251.47	0.43	0.0171	0.000173	2.65E-13
67%:30%:03%	0	4.3254	0.0590	247.77	0.44	0.0175	0.000238	2.78E-13
64%:35%:01%	0	4.2064	0.0000	236.67	0.42	0.0178	0.000000	2.88E-13
63%:35%:02%	0	3.8642	0.0455	232.98	0.42	0.0166	0.000196	2.51E-13
62%:35%:03%	-0.4059	3.8662	0.0493	229.28	0.42	0.0169	0.000215	2.59E-13

Sulfate Effective Diffusion Coefficients (Using Theoretical C_o)								
PG Composite	K_1 $(C_o - C_1)$ $mg \cdot cm^{-2}$	K_2 $(C_o - C_1)$ $mg \cdot cm^{-2} \cdot d^{-0.5}$	$K_3(C_o - C_1)$ $mg \cdot cm^{-2} \cdot d^{-1}$	$C_{o,Theo.}$ (mg/cc)	C_1 (mg/cc)	K_2 ($cm/day^{0.5}$)	K_3 (cm/day)	D_e m^2/sec
77%:20%:03%	2.43984	14.9137	-0.7328	682.52	1.82	0.02191	-0.001076	4.36E-13
73%:25%:02%	3.09174	10.6480	-0.5205	647.06	1.71	0.01650	-0.000807	2.47E-13
72%:25%:03%	2.65647	13.1675	-0.6454	638.20	1.77	0.02069	-0.001014	3.89E-13
69%:30%:01%	2.41051	11.1484	-0.5826	611.61	1.71	0.01828	-0.000955	3.04E-13
68%:30%:02%	2.80752	11.5571	-0.6143	602.74	1.72	0.01923	-0.001022	3.36E-13
67%:30%:03%	3.07991	11.1668	-0.5387	593.88	1.72	0.01886	-0.000910	3.23E-13
64%:35%:01%	2.69879	10.1456	-0.4945	567.29	1.69	0.01794	-0.000874	2.93E-13
63%:35%:02%	2.48468	10.3239	-0.6060	558.42	1.68	0.01854	-0.001089	3.13E-13
62%:35%:03%	2.91682	8.9952	-0.4129	549.56	1.67	0.01642	-0.000754	2.45E-13

FINAL FOUR Combinations			
Composite	SO_4^{2-} D_e m^2/sec	Ca^{2+} D_e m^2/sec	Ratio Sulfate D_e/Calcium D_e
73%:25%:03%	2.47E-13	2.26E-13	1.1
67%:30%:03%	3.23E-13	2.78E-13	1.2
63%:35%:02%	3.13E-13	2.51E-13	1.2
62%:35%:03%	2.45E-13	2.59E-13	0.9
Average	3.2E-13	2.7E-13	1.2

Calcium Diffusion Coefficient in saltwater = 7.5E-10 m^2/sec Sulfate Diffusion Coefficient in saltwater = 9.8 E-10 m^2/sec	After Li and Gregory (1974)
Hence the Ratio: Sulfate D_e/Calcium D_e = 9.8/7.5 = 1.31	

Appendix C

77-DAY DYNAMIC LEACHING STUDY RESULTS

77-DAY DYNAMIC LEACHING STUDY RESULTS

Table C-1. Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 0.08]

Sample Date:		10/28/2002					Analysts:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	4.98		50	0.0	0.1	2	
		Check Std.1	9.21		50	0.1	5.5	108	
Small / Oven dried	73%:25%:02%	1A	7.35	7.67	50	5.5	10.7	104	111.00
		1B	7.69		50	10.7	16.3	112	
		$1C_1$	7.84		50	16.3	22.1	116	
		$1C_2$	7.79		50	22.1	27.7	112	
Small / Oven dried	67%:30%:03%	2A	7.73	7.72	50	27.7	33.5	116	110.00
		2B	7.84		50	33.5	39.4	118	
		2C	7.59		50	39.4	44.2	96	
Small / Oven dried	62%:35%:03%	3A	7.84	7.70	50	0.0	5.8	116	112.00
		3B	7.81		50	5.8	11.6	116	
		3C	7.46		50	11.6	16.8	104	
		Check Std.2	9.48		50	16.8	22.5	114	
Small / Oven dried	63%:35%:02%	4A	7.65	7.71	50	22.5	28.4	118	118.00
		4B	7.73		50	28.4	34.2	116	
		4C	7.75		50	34.2	40.1	118	
Large/ Oven dried	63%:35%:02%	$5A_1$	7.80	7.82	50	40.1	45.9	116	116.00
		$5A_2$	7.84		50	0.0	5.3	106	
		5B	7.81		50	5.3	11.3	120	
		5C	7.81		50	11.3	17.2	118	
Small / Air dried	63%:35%:02%	6A	7.74	7.74	50	17.2	23.0	116	115.33
		6B	7.75		50	23.0	28.9	118	
		6C	7.72		50	28.9	34.5	112	
		Check Std.3	9.42		50	34.5	40.2	114	
Large/ Air dried	63%:35%:02%	7A	7.78	7.80	50	40.2	46.4	124	119.33
		7B	7.78		50	0.0	5.8	116	
		7C	7.85		50	5.8	11.7	118	
		Saltwater Blk.	7.72		50	11.7	17.0	106	
		Check Std.4	9.46		50	17.0	23.0	120	
		Blank 2	4.97		50	23.0	23.1	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 0.29]

Sample Date:		10/28/2002					Analyst:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	4.54		50	0.0	0.1	2	
		Check Std.1	9.55		50	0.1	6.2	122	
Small / Oven dried	73%:25%:02%	1A	7.74	7.78	50	6.2	11.9	114	114.00
		1B	7.76		50	11.9	17.6	114	
		$1C_1$	7.80		50	17.6	23.4	116	
		$1C_2$	7.81		50	23.4	29.0	112	
Small / Oven dried	67%:30%:03%	2A	7.79	7.79	50	29.0	34.5	110	112.00
		2B	7.76		50	34.5	40.1	112	
		2C	7.82		50	40.1	45.8	114	
Small / Oven dried	62%:35%:03%	3A	7.78	7.77	50	0.0	5.6	112	115.33
		3B	7.73		50	5.6	11.3	114	
		3C	7.80		50	11.3	17.3	120	
		Check Std.2	9.66		50	17.3	23.5	124	
Small / Oven dried	63%:35%:02%	4A	7.75	7.76	50	23.5	29.4	118	111.33
		4B	7.76		50	29.4	34.4	100	
		4C	7.78		50	34.4	40.2	116	
Large/ Oven dried	63%:35%:02%	5A	7.80	7.81	50	40.2	46.2	120	114.00
		5B	7.82		50	0.0	5.9	118	
		5C	7.80		50	5.9	11.1	104	
		6A	7.76	7.77	50	11.1	17.4	126	116.50
Small / Air dried	63%:35%:02%	6B	7.75		50	17.4	23.2	116	
		$6C_1$	7.78		50	23.2	29.3	122	
		6C2	7.79		50	29.3	34.4	102	
		Check Std.3	9.43		50	34.4	40.1	114	
Large/ Air dried	63%:35%:02%	7A	7.81	7.80	50	40.1	46.1	120	116.00
		7B	7.79		50	0.0	5.9	118	
		7C	7.81		50	5.9	11.4	110	
		Blank 3	4.60		50	11.4	11.5	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 1]

Sample Date:	10/29/2002						Analyst:		Pradyot / Amy
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	4.98		50	0.0	0.1	2	
		Check Std.1	9.38		50	0.1	6.2	122	
Small / Oven dried	73%:25%:02%	1A	7.66	7.64	50	6.2	11.8	112	112.00
		1B	7.65		50	11.8	17.4	112	
		$1C_1$	7.62		50	17.4	23.0	112	
		$1C_2$	7.62		50	23.0	28.6	112	
Small / Oven dried	67%:30%:03%	2A	7.68	7.66	50	28.6	34.1	110	108.67
		2B	7.67		50	34.1	39.6	110	
		2C	7.63		50	39.6	44.9	106	
Small / Oven dried	62%:35%:03%	3A	7.65	7.71	50	0.0	5.4	108	108.00
		3B	7.75		50	5.4	11.1	114	
		3C	7.72		50	11.1	16.2	102	
		Check Std.2	9.53		50	16.2	22.0	116	
Small / Oven dried	63%:35%:02%	4A	7.66	7.70	50	22.1	27.9	116	117.33
		4B	7.71		50	27.9	33.8	118	
		4C	7.74		50	33.8	39.7	118	
Large/ Oven dried	63%:35%:02%	$5A_1$	7.85	7.84	50	39.7	45.2	110	117.50
		$5A_2$	7.83		50	0.0	6.1	122	
		5B	7.82		50	6.1	12.3	124	
		5C	7.85		50	12.3	18.0	114	
Small / Air dried	63%:35%:02%	6A	7.84	7.80	50	18.0	24.5	130	126.00
		6B	7.78		50	24.5	30.9	128	
		6C	7.79		50	30.9	36.9	120	
		Check Std.3	9.42		50	36.9	42.9	120	
Large/ Air dried	63%:35%:02%	7A	7.78	7.80	50	0.0	6.0	120	120.67
		7B	7.82		50	6.0	12.1	122	
		7C	7.81		50	12.1	18.1	120	
		Blank 2	5		50	18.1	18.2	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 2]

Sample Date:	10/30/2002						Analyst:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.16		50	0.0	0.1	2	
		Check Std.1	9.45		50	0.1	6.0	118	
Small / Oven dried	73%:25%:02%	1A	6.58	7.29	50	6.0	10.1	82	100.00
		1B	7.67		50	10.1	15.5	108	
		1C	7.61		50	15.5	21.0	110	
Small / Oven dried	67%:30%:03%	2A	7.71	7.63	50	21.0	26.4	108	109.00
		2B	7.67		50	26.4	31.5	102	
		$2C_1$	7.57		50	31.5	36.9	108	
		2C2	7.58		50	36.9	42.8	118	
Small / Oven dried	62%:35%:03%	3A	7.67	7.66	50	0.0	5.5	110	108.00
		3B	7.64		50	5.5	10.8	106	
		3C	7.67		50	10.8	16.2	108	
		Check Std.2	9.62		50	16.2	22.0	116	
Small / Oven dried	63%:35%:02%	4A	7.64	7.67	50	22.0	27.6	112	112.67
		4B	7.72		50	27.6	33.4	116	
		4C	7.66		50	33.4	38.9	110	
Large/ Oven dried	63%:35%:02%	5A	7.86	7.88	50	38.9	44.4	110	120.00
		5B	7.89		50	0.0	6.3	126	
		5C	7.89		50	6.3	12.5	124	
Small / Air dried	63%:35%:02%	6A	7.77	7.78	50	12.5	18.7	124	125.33
		6B	7.77		50	18.7	25.0	126	
		6C	7.81		50	25.0	31.3	126	
Large/ Air dried	63%:35%:02%	$7A_1$	7.86	7.83	50	31.3	37.2	118	114.00
		$7A_2$	7.85		50	37.2	43.0	116	
		7B	7.78		50	0.0	5.9	118	
		7C	7.82		50	5.9	11.1	104	
		Check Std.3	9.68		50	11.1	16.6	110	
		Saltwater Blk	7.54		50	16.6	22.0	108	
		Blank 2	5.21		50	22.0	22.1	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions Dynamic Leaching Study [Day : 2]

Sample Date:	10/31/2002						Analyst:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	4.52		50	0.0	0.1	2	
		Check Std.1	10.20		50	0.1	6.4	126	
Small / Oven dried	73%:25%:02%	1A	8.26	8.28	50	6.4	12.3	118	116.00
		1B	8.31		50	12.3	18.0	114	
		1C	8.26		50	18.0	23.8	116	
Small / Oven dried	67%:30%:03%	$2A_1$	8.33	8.30	50	23.8	29.7	118	116.00
		$2A_2$	8.30		50	29.7	35.4	114	
		2B	8.33		50	35.4	41.2	116	
		2C	8.23		50	0.0	5.8	116	
Small / Oven dried	62%:35%:03%	3A	8.28	8.29	50	5.8	11.4	112	115.33
		3B	8.29		50	11.4	17.2	116	
		3C	8.31		50	17.2	23.1	118	
		Check Std.2	10.38		50	23.1	29.3	124	
Small / Oven dried	63%:35%:02%	4A	8.30	8.32	50	29.3	35.4	122	122.00
		4B	8.33		50	35.4	41.5	122	
		4C	8.32		50	41.5	47.6	122	
Large/ Oven dried	63%:35%:02%	5A	8.60	8.59	50	0.0	6.5	130	130.50
		5B	8.60		50	6.5	13.2	134	
		$5C_1$	8.58		50	13.2	19.6	128	
		$5C_2$	8.57		50	19.6	26.1	130	
Small / Air dried	63%:35%:02%	6A	8.49	8.50	50	26.1	32.6	130	129.33
		6B	8.48		50	32.6	39.0	128	
		6C	8.53		50	39.0	45.5	130	
		Check Std.3	10.38		50	0.0	6.3	126	
Large/ Air dried	63%:35%:02%	7A	8.52	8.52	50	6.3	12.7	128	121.33
		7B	8.50		50	12.7	18.4	114	
		7C	8.54		50	18.4	24.5	122	
		Blank 2	4.84		50	24.5	24.6	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 4]

Sample Date:		11/1/2002					Analyst:		Pradyot / Amy
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.13		50	0.0	0.1	2	
		Check Std.1	10.23		50	0.1	6.4	126	
Small / Oven dried	73%:25%:02%	1A	8.31	8.36	50	6.4	12.2	116	114.67
		1B	8.35		50	12.2	18.0	116	
		1C	8.42		50	18.0	23.6	112	
Small / Oven dried	67%:30%:03%	2A	8.40	8.39	50	23.6	29.6	120	118.00
		$2B_1$	8.38		50	29.6	35.5	118	
		$2B_2$	8.37		50	35.5	41.3	116	
		2C	8.39		50	0.0	5.9	118	
Small / Oven dried	62%:35%:03%	3A	8.43	8.40	50	5.9	11.8	118	118.67
		3B	8.40		50	11.8	17.7	118	
		3C	8.38		50	17.7	23.7	120	
		Check Std.2	10.31		50	23.7	30.0	126	
Small / Oven dried	63%:35%:02%	4A	8.36	8.38	50	30.0	36.1	122	118.67
		4B	8.38		50	36.1	41.9	116	
		4C	8.39		50	0.0	5.9	118	
Large/ Oven dried	63%:35%:02%	5A	8.61	8.64	50	5.9	12.2	126	127.50
		$5B_1$	8.66		50	12.2	18.8	132	
		$5B_2$	8.65		50	18.8	25.1	126	
		5C	8.62		50	25.1	31.4	126	
Small / Air dried	63%:35%:02%	6A	8.38	8.53	50	31.4	36.8	108	120.67
		6B	8.55		50	36.8	42.8	120	
		6C	8.67		50	0.0	6.7	134	
		Check Std.3	10.37		50	6.7	12.8	122	
Large/ Air dried	63%:35%:02%	7A	8.61	8.61	50	12.8	19.2	128	126.67
		7B	8.62		50	19.2	25.4	124	
		7C	8.61		50	25.4	31.8	128	
		Blank 2	5.64		50	31.8	31.9	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions Dynamic Leaching Study [Day : 5]

Sample Date:		11/2/2002					Analyst:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.65		50	0.0	0.1	2	
		Check Std.1	10.38		50	0.1	6.2	122	
Small / Oven dried	73%:25%:02%	1A	8.38	8.40	50	6.2	11.8	112	114.00
		1B	8.44		50	11.8	17.4	112	
		1C	8.37		50	17.4	23.3	118	
Small / Oven dried	67%:30%:03%	2A	8.45	8.44	50	23.3	28.6	106	113.50
		2B	8.44		50	28.6	34.4	116	
		$2C_1$	8.43		50	34.4	40.1	114	
		$2C_2$	8.42		50	0.0	5.9	118	
Small / Oven dried	62%:35%:03%	3A	8.46	8.44	50	5.9	12.0	122	120.67
		3B	8.45		50	12.0	17.9	118	
		3C	8.42		50	17.9	24.0	122	
		Check Std.2	10.30		50	24.0	30.2	124	
Small / Oven dried	63%:35%:02%	4A	8.45	8.46	50	30.2	36.3	122	122.67
		4B	8.47		50	36.3	42.5	124	
		4C	8.47		50	0.0	6.1	122	
Large/ Oven dried	63%:35%:02%	5A	8.64	8.66	50	6.1	12.4	126	124.00
		$5B_1$	8.68		50	12.4	18.5	122	
		$5B_2$	8.68		50	18.5	24.6	122	
		5C	8.65		50	24.6	30.9	126	
Small / Air dried	63%:35%:02%	6A	8.59	8.59	50	30.9	36.9	120	124.67
		6B	8.59		50	36.9	43.1	124	
		6C	8.60		50	0.0	6.5	130	
		Check Std.3	10.50		50	6.5	12.6	122	
Large/ Air dried	63%:35%:02%	7A	8.65	8.66	50	12.6	19.0	128	128.00
		7B	8.62		50	19.0	25.3	126	
		7C	8.71		50	25.3	31.8	130	
		Saltwater Blk	8.25		50	31.8	37.6	116	
		Blank 2	5.69		50	37.6	37.7	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 8]

Sample Date:		11/5/2002				Analyst:		Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.23		50	0.0	0.1	2	
		Check Std.1	10.10		50	0.1	6.6	130	
Small / Oven dried	73%:25%:02%	1A	8.14	8.16	50	6.6	12.2	112	113.33
		1B	8.18		50	12.2	17.7	110	
		1C	8.16		50	17.7	23.6	118	
Small / Oven dried	67%:30%:03%	2A	8.15	8.17	50	23.6	29.1	110	109.50
		2B	8.05		50	29.1	34.4	106	
		$2C_1$	8.22		50	34.4	39.9	110	
		$2C_2$	8.25		50	39.9	45.5	112	
Small / Oven dried	62%:35%:03%	3A	8.16	8.17	50	0.0	5.2	104	110.00
		3B	8.16		50	5.2	10.8	112	
		3C	8.19		50	10.8	16.5	114	
		Check Std.2	10.23		50	16.5	23.0	130	
Small / Oven dried	63%:35%:02%	4A	8.17	8.17	50	23.0	28.8	116	112.67
		4B	8.15		50	28.8	34.4	112	
		4C	8.18		50	34.4	39.9	110	
Large/ Oven dried	63%:35%:02%	5A	8.48	8.48	50	39.9	45.4	110	120.50
		$5B_1$	8.46		50	0.0	6.0	120	
		$5B_2$	8.48		50	6.0	12.4	128	
		5C	8.49		50	12.4	18.6	124	
Small / Air dried	63%:35%:02%	6A	8.50	8.51	50	18.6	25.9	146	133.33
		6B	8.52		50	25.9	32.0	122	
		6C	8.50		50	32.0	38.6	132	
Large/ Air dried	63%:35%:02%	7A	8.54	8.50	50	38.6	44.4	116	119.33
		7B	8.49		50	4.8	11.1	126	
		7C	8.47		50	11.1	16.9	116	
		Blank 2	5.28		50	16.9	17.0	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 11]

Sample Date:	11/8/2002					Analyst:		Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.06		50	0.0	0.1	2	
		Check Std.1	10.04		50	0.1	6.2	122	
Small / Oven dried	73%:25%:02%	1A	8.08	8.16	50	6.2	11.7	110	110.50
		1B	8.17		50	11.7	17.1	108	
		$1C_1$	8.18		50	17.1	22.6	110	
		$1C_2$	8.20		50	22.6	28.3	114	
Small / Oven dried	67%:30%:03%	2A	8.27	8.28	50	28.3	33.3	100	103.33
		2B	8.33		50	33.3	38.2	98	
		2C	8.25		50	38.2	43.8	112	
Small / Oven dried	62%:35%:03%	3A	8.23	8.22	50	0.0	5.5	110	110.00
		3B	8.24		50	5.5	11.1	112	
		3C	8.19		50	11.1	16.5	108	
		Check Std.2	10.15		50	16.5	23.2	134	
Small / Oven dried	63%:35%:02%	4A	8.20	8.18	50	23.2	28.4	104	106.67
		4B	8.22		50	28.4	34.2	116	
		4C	8.13		50	34.2	39.2	100	
Large/ Oven dried	63%:35%:02%	5A	8.47	8.49	50	39.2	45.3	122	120.50
		5B	8.50		50	0.0	5.8	116	
		$5C_1$	8.50		50	5.8	12.0	124	
		$5C_2$	8.49		50	12.0	18.0	120	
Small / Air dried	63%:35%:02%	6A	8.43	8.47	50	18.0	24.4	128	128.67
		6B	8.48		50	24.4	30.8	128	
		6C	8.50		50	30.8	37.3	130	
		Check Std.3	10.18		50	37.3	43.0	114	
Large/ Air dried	63%:35%:02%	7A	8.47	8.47	50	22.0	28.1	122	122.00
		7B	8.47		50	28.1	34.2	122	
		7C	8.46		50	34.2	40.3	122	
		Saltwater Blk	7.85		50	40.3	45.6	106	
		Blank 2	5.09		50	45.6	45.7	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 14]

Sample Date:	11/11/2002						Analyst:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.21		50	0.0	0.1	2	
		Check Std.1	10.31		50	0.1	6.0	118	
Small / Oven dried	73%:25%:02%	1A	8.24	8.27	50	6.0	11.2	104	104.50
		1B	8.26		50	11.2	16.4	104	
		$1C_1$	8.28		50	16.4	21.6	104	
		$1C_2$	8.29		50	21.6	26.9	106	
Small / Oven dried	67%:30%:03%	2A	8.30	8.31	50	26.9	32.1	104	103.33
		2B	8.31		50	32.1	37.3	104	
		2C	8.33		50	37.3	42.4	102	
Small / Oven dried	62%:35%:03%	3A	8.27	8.27	50	0.0	5.3	106	105.33
		3B	8.26		50	5.3	10.5	104	
		3C	8.29		50	10.5	15.8	106	
		Check Std.2	10.39		50	15.8	22.0	124	
Small / Oven dried	63%:35%:02%	4A	8.26	8.27	50	22.0	27.4	108	104.00
		4B	8.28		50	27.4	32.4	100	
		$4C_1$	8.26		50	32.4	37.6	104	
		$4C_2$	8.27		50	37.6	42.8	104	
Large/ Oven dried	63%:35%:02%	5A	8.53	8.55	50	0.0	5.2	104	106.67
		5B	8.56		50	5.2	10.5	106	
		5C	8.55		50	10.5	16.0	110	
Small / Air dried	63%:35%:02%	6A	8.49	8.48	50	16.0	21.9	118	118.00
		6B	8.46		50	21.9	27.7	116	
		6C	8.49		50	27.7	33.7	120	
		Check Std.3	10.20		50	33.7	39.5	116	
Large/ Air dried	63%:35%:02%	7A	8.52	8.53	50	39.5	44.9	108	113.33
		7B	8.55		50	0.0	5.9	118	
		7C	8.52		50	5.9	11.6	114	
		Saltwater Blk	7.92		50	11.6	16.7	102	
		Blank 2	5.23		50	16.7	16.8	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions Dynamic leaching Study [Day : 21]

Sample Date:		11/18/2002						Analyst:	Pradyot / Amy
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	4.96		50.0	0.0	0.1	2	
		Check Std.1	10.19		50.0	0.1	6.2	122	
Small / Oven dried	73%:25%:02%	1A	8.29	8.29	50.0	6.2	11.1	98	97.33
		1B	8.33		50.0	11.1	15.9	96	
		1C	8.24		50.0	15.9	20.8	98	
Small / Oven dried	67%:30%:03%	2A1	8.30	8.28	50.0	20.8	25.6	96	95.50
		2A2	8.30		50.0	25.6	30.7	102	
		2B	8.27		50.0	30.7	35.2	90	
		2C	8.24		50.0	35.2	39.9	94	
Small / Oven dried	62%:35%:03%	3A	8.28	8.27	50.0	39.9	44.3	88	98.67
		3B	8.24		50.0	0.0	5.1	102	
		3C	8.28		50.0	5.1	10.4	106	
		Check Std.2	10.20		50.0	10.4	16.5	122	
Small / Oven dried	63%:35%:02%	4A	8.31	8.31	50.0	16.5	21.7	104	101.33
		4B	8.31		50.0	21.7	26.5	96	
		4C	8.30		50.0	26.5	31.7	104	
Large/ Oven dried	63%:35%:02%	5A1	8.68	8.65	50.0	31.7	37.3	112	113.50
		5A2	8.67		50.0	37.3	43	114	
		5B	8.63		50.0	43.0	48.7	114	
		5C	8.61		50.0	0.0	5.7	114	
Small / Air dried	63%:35%:02%	6A	8.59	8.58	50.0	5.7	12	126	118.00
		6B	8.57		50.0	12.0	17.8	116	
		6C	8.59		50.0	17.8	23.4	112	
Large/ Air dried	63%:35%:02%	7A	8.62	8.62	50.0	23.4	29.2	116	116.67
		7B	8.63		50.0	29.2	35.2	120	
		7C	8.60		50.0	35.2	40.9	114	
		Saltwater Blk	7.88		50.0	40.9	46.1	104	
		Blank 2	4.98		50.0	46.1	46.2	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 28]

Sample Date:	11/25/2002						Analyst:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.56		50	0.0	0.1	2	
		Check Std.1	10.30		50	0.1	6.0	118	
Small / Oven dried	73%:25%:02%	1A	8.31	8.33	50	6.0	11.1	102	100.67
		1B	8.34		50	11.1	16.1	100	
		1C	8.35		50	16.1	21.1	100	
Small / Oven dried	67%:30%:03%	2A	8.37	8.35	50	21.1	25.8	94	96.67
		2B	8.34		50	25.8	30.7	98	
		2C	8.34		50	30.7	35.6	98	
Small / Oven dried	62%:35%:03%	$3A_1$	8.32	8.34	50	35.6	40.6	100	98.50
		$3A_2$	8.33		50	40.6	45.3	94	
		3B	8.33		50	0.0	5.0	100	
		3C	8.38		50	5.0	10.0	100	
		Check Std.2	10.17		50	10.0	16.3	126	
Small / Oven dried	63%:35%:02%	4A	8.35	8.33	50	16.3	21.5	104	103.33
		4B	8.34		50	21.5	26.7	104	
		4C	8.31		50	26.7	31.8	102	
Large/ Oven dried	63%:35%:02%	5A	8.61	8.65	50	31.8	37.4	112	112.50
		$5B_1$	8.66		50	37.4	43.1	114	
		$5B_2$	8.65		50	0.0	5.7	114	
		5C	8.69		50	5.7	11.2	110	
Small / Air dried	63%:35%:02%	6A	8.60	8.60	50	11.2	17.4	124	120.00
		6B	8.59		50	17.4	23.1	114	
		6C	8.60		50	23.1	29.2	122	
		Check Std.3	10.39		50	29.2	35.5	126	
Large/ Air dried	63%:35%:02%	7A	8.66	8.65	50	35.5	41.2	114	114.67
		7B	8.64		50	41.2	47.0	116	
		7C	8.65		50	0.0	5.7	114	
		Saltwater Blk	7.93		50	5.7	10.8	102	
		Blank 2	5.58		50	10.8	10.9	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions Dynamic Leaching Study [Day : 42]

Sample Date:	12/9/2002						Analyst:	Pradyot / Amy	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	5.54		50	0.0	0.1	2	
		Check Std. 1	10.25		50	0.1	6.1	120	
Small / Oven dried	73%:25%:02%	1A	8.19	8.20	50	6.1	10.9	96	112.67
		1B	8.21		50	10.9	16.2	106	
		1C	8.19		50	16.2	23.0	136	
Small / Oven dried	67%: 30%:03%	2A	8.15	8.18	50	23.0	27.9	98	115.50
		$2B_1$	8.20		50	27.9	33.9	120	
		$2B_2$	8.21		50	33.9	41.2	146	
		2C	8.17		50	41.2	46.1	98	
Small / Oven dried	62%:35%:03%	3A	8.25	8.22	50	0.0	5.8	116	115.33
		3B	8.21		50	5.8	12.0	124	
		3C	8.20		50	12.0	17.3	106	
		Check Std. 2	10.30		50	17.3	23.9	132	
Small / Oven dried	63%:35%:02%	4A	8.21	8.18	50	23.9	30.1	124	115.33
		4B	8.15		50	30.1	36.8	134	
		4C	8.17		50	36.8	41.2	88	
Large/ Oven dried	63%:35%:02%	$5A_1$	8.53	8.50	50	41.2	47.0	116	116.00
		$5A_2$	8.47		50	0.0	6.1	122	
		5B	8.48		50	6.1	12.3	124	
		5C	8.50		50	12.3	17.4	102	
Small / Air dried	63%:35%:02%	6A	8.45	8.48	50	17.4	24.1	134	124.00
		6B	8.51		50	24.1	30.1	120	
		6C	8.49		50	30.1	36.0	118	
		Check Std. 3	10.31		50	36.0	43.2	144	
Large/ Air dried	63%:35%:02%	7A	8.60	8.60	50	0.0	6.5	130	125.33
		7B	8.59		50	6.5	12.1	112	
		7C	8.62		50	12.1	18.8	134	
		Saltwater Blk	7.98		50	18.8	24.9	122	
		Blank 2	5.30		50	24.9	25.0	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 56]

Sample Date: 12/23/2002									Analyst: Pradyot / Will
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	4.98		50	0.0	0.1	2	
		Check Std. 1	10.12		50	0.1	6.2	122	
Small / Oven dried	73%:25%:02%	1A	8.43	8.38	50	6.2	10.9	94	92.67
		1B	8.38		50	10.9	15.6	94	
		1C	8.33		50	15.6	20.1	90	
Small / Oven dried	67%: 30%:03%	2A	8.38	8.40	50	20.1	24.5	88	90.00
		$2B_1$	8.46		50	24.5	29.1	92	
		$2B_2$	8.39		50	29.1	33.6	90	
		2C	8.38		50	33.6	38.1	90	
Small / Oven dried	62%:35%:03%	3A	8.35	8.32	50	38.1	42.9	96	92.00
		3B	8.27		50	0.0	4.3	86	
		3C	8.34		50	4.3	9.0	94	
		Check Std. 2	10.34		50	9.0	15.0	120	
Small / Oven dried	63%:35%:02%	4A	8.32	8.31	50	15.0	19.9	98	98.00
		4B	8.33		50	19.9	24.8	98	
		4C	8.29		50	24.8	29.7	98	
Large/ Oven dried	63%:35%:02%	5A	8.55	8.60	50	29.7	35.1	107.4	108.85
		$5B_1$	8.59		50	35.1	40.6	110	
		$5B_2$	8.60		50	40.6	46.0	108	
		5C	8.65		50	0.0	5.5	110	
Small / Air dried	63%:35%:02%	6A	8.52	8.59	50	5.5	11.3	116	118.67
		6B	8.58		50	11.3	17.2	118	
		6C	8.67		50	17.2	23.3	122	
		Check Std. 3	10.29		50	23.3	29.4	122	
Large/ Air dried	63%:35%:02%	7A	8.71	8.70	50	29.4	35.2	116	117.33
		7B	8.68		50	35.2	41.1	118	
		7C	8.70		50	41.1	47.0	118	
		Saltwater Blk	7.81		50	0.0	4.8	96	
		Blank 2	5.00		50	4.8	4.9	2	

Table C-1 (Cont.). Alkalinity and pH Recorded for 77-Day Dynamic Leaching Study.

pH and Alkalinity Analyses on the BEST FOUR PG Composite Briquette Compositions
Dynamic Leaching Study [Day : 77]

Sample Date:		1/13/2003					Analyst:	Pradyot / Will	
Briq. Size / Raw PG	PG:Class C Fly Ash:Portland Type II Cement	Sample ID	pH	Mean pH	Sample Vol. (ml)	Initial Vol. (ml)	Final Vol. (ml)	Alkalinity (mg/L $CaCO_3$)	Mean Alk. (mg/L $CaCO_3$)
		Blank 1	4.90		50	0.0	0.1	2	
		Check Std. 1	10.30		50	0.1	5.9	116	
Small / Oven dried	73%:25%:02%	1A	8.26	8.28	50	5.9	10.5	92	94.00
		1B	8.35		50	10.5	15.2	94	
		1C	8.24		50	15.2	20.0	96	
Small / Oven dried	67%: 30%:03%	2A	8.35	8.36	50	20.0	25.2	104	94.00
		$2B_1$	8.34		50	25.2	29.7	90	
		$2B_2$	8.34		50	29.7	34.4	94	
		2C	8.41		50	34.4	38.8	88	
Small / Oven dried	62%:35%:03%	3A	8.33	8.31	50	38.8	43.4	92	89.33
		3B	8.22		50	43.4	48.1	94	
		3C	8.38		50	0.0	4.1	82	
		Check Std. 2	10.28		50	4.1	10.4	126	
Small / Oven dried	63%:35%:02%	4A	8.45	8.40	50	10.4	15.1	94	98.67
		4B	8.41		50	15.1	20.2	102	
		4C	8.33		50	20.2	25.2	100	
Large/ Oven dried	63%:35%:02%	$5A_1$	8.54	8.57	50	25.2	30.4	104	105.00
		$5A_2$	8.56		50	30.4	35.6	104	
		5B	8.60		50	35.6	41.0	108	
		5C	8.59		50	41.0	46.2	104	
Small / Air dried	63%:35%:02%	6A	8.56	8.59	50	0.0	6.1	122	116.67
		6B	8.57		50	6.1	12.0	118	
		6C	8.64		50	12.0	17.5	110	
		Check Std. 3	8.62		50	17.5	22.3	96	
Large/ Air dried	63%:35%:02%	7A	8.60	8.35	50	22.3	27.8	110	175.33
		7B	8.60		50	27.8	33.2	108	
		7C	7.84		50	23.2	38.6	308	
		Saltwater Blk	10.39		50	38.6	44.9	126	
		Blank 2	5.20		50	44.9	45.0	2	

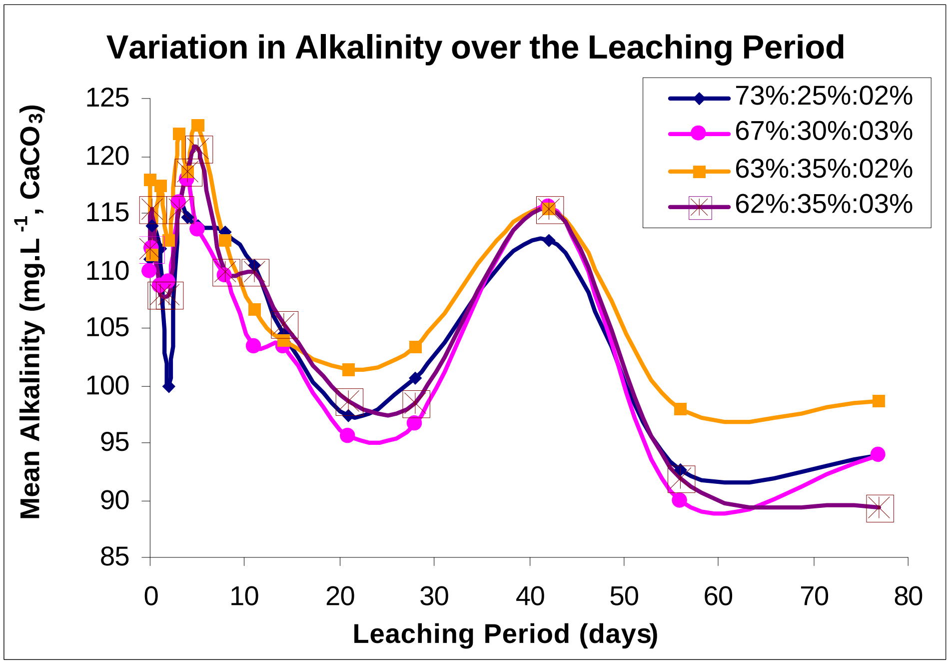

Figure C-1. Alkalinity Versus Time for the 77-Day Dynamic Leaching Period.

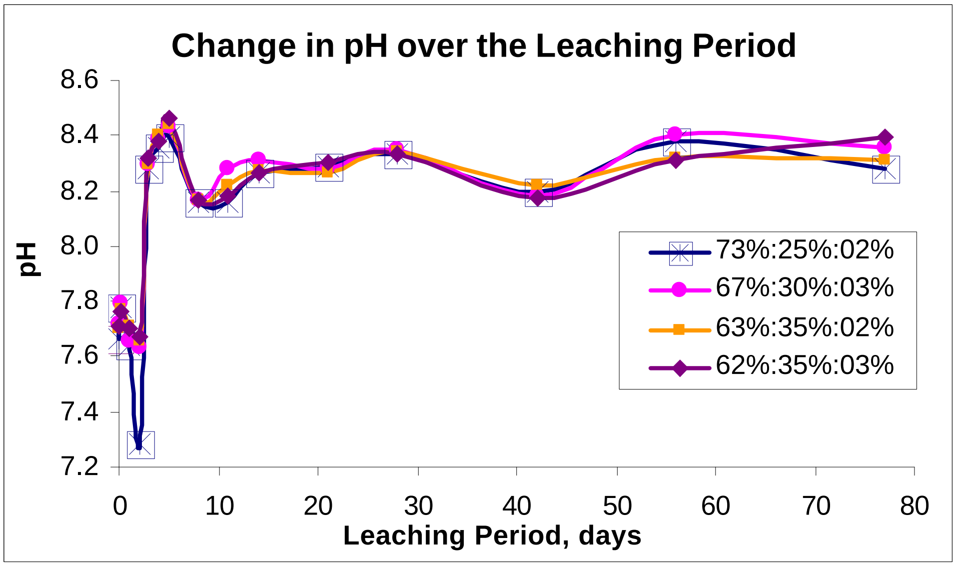

Figure C-2. pH Versus Time for the 77-Day Dynamic Leaching Period.

Table C-2. Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 0.08		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		411.0068	94.5316	45.6401	45.6401	1.5875
1B	73%:25%:02%	396.7167	91.2448	42.3534	42.3534	1.4732
1C		389.5729	89.6018	40.7103	40.7103	1.4160
2A		410.2237	94.3515	45.4600	45.4600	1.5812
2B	67%:30%:03%	410.2938	94.3676	45.4762	45.4762	1.5818
2C		410.0609	94.3140	45.4226	45.4226	1.5799
3A		412.6759	94.9155	46.0240	46.0240	1.6008
3B	62%:35%:03%	403.0699	92.7061	43.8147	43.8147	1.5240
3C		392.7213	90.3259	41.4345	41.4345	1.4412
4A		427.5584	98.3384	49.4470	49.4470	1.7199
4B	63%:35%:02%	429.0124	98.6729	49.7814	49.7814	1.7315
4C		420.4231	96.6973	47.8059	47.8059	1.6628
5A		468.3463	107.7196	58.8282	58.8282	2.0462
5B	63%:35%:02%	498.1588	114.5765	65.6851	65.6851	2.2847
5C		472.5789	108.6931	59.8017	59.8017	2.0801
6A		448.0057	103.0413	54.1499	54.1499	1.8835
6B	63%:35%:02%	440.0483	101.2111	52.3197	52.3197	1.8198
6C		457.5444	105.2352	56.3438	56.3438	1.9598
7A		472.2261	108.6120	59.7206	59.7206	2.0772
7B	63%:35%:02%	489.275	112.5333	63.6418	63.6418	2.2136
7C		488.8659	112.4392	63.5477	63.5477	2.2104

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 0.29		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		404.6422	93.0677	44.1763	89.8164	3.1240
1B	73%:25%:02%	436.5521	100.4070	51.5156	93.8690	3.2650
1C		429.2417	98.7256	49.8342	90.5445	3.1494
2A		391.7192	90.0954	41.2040	86.6640	3.0144
2B	67%:30%:03%	430.8872	99.1041	50.2126	95.6888	3.3283
2C		428.3028	98.5096	49.6182	95.0408	3.3058
3A		398.111	91.5655	42.6741	88.6981	3.0852
3B	62%:35%:03%	417.5278	96.0314	47.1400	90.9546	3.1636
3C		415.3558	95.5318	46.6404	88.0749	3.0635
4A		416.4544	95.7845	46.8931	96.3401	3.3510
4B	63%:35%:02%	421.5689	96.9608	48.0694	97.8509	3.4035
4C		440.6658	101.3531	52.4617	100.2676	3.4876
5A		477.1127	109.7359	60.8445	119.6727	4.1625
5B	63%:35%:02%	514.1001	118.2430	69.3516	135.0367	4.6969
5C		511.1911	117.5740	68.6825	128.4843	4.4690
6A		457.6283	105.2545	56.3631	110.5130	3.8439
6B	63%:35%:02%	469.6266	108.0141	59.1227	111.4424	3.8763
6C		484.7704	111.4972	62.6058	118.9496	4.1374
7A		484.6528	111.4701	62.5787	122.2993	4.2539
7B	63%:35%:02%	486.7333	111.9487	63.0572	126.6991	4.4069
7C		491.1676	112.9685	64.0771	127.6249	4.4391

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 1		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		452.6159	104.1017	55.2102	145.0267	5.0444
1B	73%:25%:02%	428.0397	98.4491	49.5577	143.4267	4.9888
1C		472.2406	108.6153	59.7239	150.2684	5.2267
2A		454.7667	104.5963	55.7049	142.3689	4.9520
2B	67%:30%:03%	471.9512	108.5488	59.6574	155.3461	5.4033
2C		432.5419	99.4846	50.5932	145.6340	5.0655
3A		436.5206	100.3997	51.5083	140.2065	4.8767
3B	62%:35%:03%	481.3244	110.7046	61.8132	152.7678	5.3137
3C		459.7187	105.7353	56.8439	144.9188	5.0407
4A		450.9206	103.7117	54.8203	151.1604	5.2578
4B	63%:35%:02%	493.2101	113.4383	64.5469	162.3978	5.6486
4C		488.7269	112.4072	63.5158	163.7834	5.6968
5A		600.9583	138.2204	89.3290	209.0017	7.2696
5B	63%:35%:02%	609.6776	140.2258	91.3344	226.3711	7.8738
5C		617.597	142.0473	93.1559	221.6401	7.7092
6A		585.0402	134.5592	85.6678	196.1808	6.8237
6B	63%:35%:02%	606.2703	139.4422	90.5507	201.9931	7.0258
6C		592.5836	136.2942	87.4028	206.3524	7.1775
7A		578.166	132.9782	84.0868	206.3861	7.1786
7B	63%:35%:02%	622.1672	143.0985	94.2070	220.9061	7.6837
7C		606.3826	139.4680	90.5766	218.2014	7.5896

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 2		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		477.1064	109.7345	60.8431	205.8697	7.1607
1B	73%:25%:02%	507.3331	116.6866	67.7952	211.2219	7.3468
1C		465.7864	107.1309	58.2395	208.5079	7.2524
2A		493.1834	113.4322	64.5408	206.9097	7.1969
2B	67%:30%:03%	486.5054	111.8962	63.0048	218.3510	7.5948
2C		409.713	94.2340	45.3426	190.9766	6.6427
3A		452.887	104.1640	55.2726	195.4790	6.7993
3B	62%:35%:03%	451.5275	103.8513	54.9599	207.7277	7.2253
3C		435.5107	100.1675	51.2760	196.1948	6.8242
4A		489.4791	112.5802	63.6888	214.8492	7.4730
4B	63%:35%:02%	494.9901	113.8477	64.9563	227.3541	7.9080
4C		459.383	105.6581	56.7667	220.5500	7.6713
5A		612.7529	140.9332	92.0417	301.0435	10.4711
5B	63%:35%:02%	697.3291	160.3857	111.4943	337.8654	11.7518
5C		709.8442	163.2642	114.3727	336.0129	11.6874
6A		572.9020	131.7675	82.8760	279.0568	9.7063
6B	63%:35%:02%	614.7328	141.3885	92.4971	294.4903	10.2431
6C		600.8865	138.2039	89.3125	295.6648	10.2840
7A		609.9011	140.2773	91.3858	297.7719	10.3573
7B	63%:35%:02%	664.6550	152.8707	103.9792	324.8853	11.3004
7C		673.7774	154.9688	106.0774	324.2788	11.2793

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 3		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		429.6344	98.8159	49.9245	255.7942	8.8972
1B	73%:25%:02%	438.718	100.9051	52.0137	263.2356	9.1560
1C		387.3683	89.0947	40.2033	248.7112	8.6508
2A		418.3072	96.2107	47.3192	254.2289	8.8427
2B	67%:30%:03%	440.7797	101.3793	52.4879	270.8389	9.4205
2C		409.2181	94.1202	45.2287	236.2053	8.2158
3A		411.9028	94.7376	45.8462	241.3253	8.3939
3B	62%:35%:03%	424.3603	97.6029	48.7114	256.4392	8.9196
3C		410.6648	94.4529	45.5615	241.7563	8.4089
4A		454.9704	104.6432	55.7518	270.6010	9.4122
4B	63%:35%:02%	468.4906	107.7528	58.8614	286.2155	9.9553
4C		515.1094	118.4752	69.5837	290.1338	10.0916
5A		557.0114	128.1126	79.2212	380.2647	13.2266
5B	63%:35%:02%	662.1493	152.2943	103.4029	441.2683	15.3485
5C		621.4368	142.9305	94.0390	430.0519	14.9583
6A		493.1862	113.4328	64.5414	343.5982	11.9512
6B	63%:35%:02%	498.2521	114.5980	65.7066	360.1968	12.5286
6C		515.2357	118.5042	69.6128	365.2776	12.7053
7A		645.5457	148.4755	99.5841	397.3560	13.8211
7B	63%:35%:02%	627.1951	144.2549	95.3635	420.2488	14.6173
7C		634.5027	145.9356	97.0442	421.3230	14.6547

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 4		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		425.1111	97.7756	48.8841	304.6783	10.5975
1B	73%:25%:02%	436.5952	100.4169	51.5255	314.7611	10.9482
1C		433.8171	99.7779	50.8865	299.5977	10.4208
2A		411.0001	94.5300	45.6386	299.8675	10.4302
2B	67%:30%:03%	427.5674	98.3405	49.4491	320.2879	11.1405
2C		466.2054	107.2272	58.3358	294.5412	10.2449
3A		404.49	93.0327	44.1413	285.4665	9.9293
3B	62%:35%:03%	419.1641	96.4077	47.5163	303.9555	10.5724
3C		405.5959	93.2871	44.3956	286.1519	9.9531
4A		453.7981	104.3736	55.4821	326.0831	11.3420
4B	63%:35%:02%	423.5474	97.4159	48.5245	334.7400	11.6431
4C		434.5842	99.9544	51.0629	341.1967	11.8677
5A		504.7776	116.0988	67.2074	447.4721	15.5642
5B	63%:35%:02%	604.1554	138.9557	90.0643	531.3326	18.4811
5C		596.456	137.1849	88.2935	518.3454	18.0294
6A		451.8366	103.9224	55.0310	398.6292	13.8654
6B	63%:35%:02%	519.6562	119.5209	70.6295	430.8263	14.9853
6C		560.2984	128.8686	79.9772	445.2548	15.4871
7A		500.9772	115.2248	66.3333	463.6893	16.1283
7B	63%:35%:02%	609.2321	140.1234	91.2320	511.4807	17.7906
7C		590.6589	135.8515	86.9601	508.2831	17.6794

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions			Calcium Leaching Study Data: Day 5			
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		441.3430	101.5089	52.6175	357.2958	12.4277
1B	73%:25%:02%	501.1897	115.2736	66.3822	381.1433	13.2572
1C		448.8205	103.2287	54.3373	353.9350	12.3108
2A		364.5191	83.8394	34.9480	334.8155	11.6458
2B	67%:30%:03%	416.4969	95.7943	46.9029	367.1908	12.7719
2C		478.7717	110.1175	61.2261	355.7672	12.3745
3A		405.6532	93.3002	44.4088	329.8754	11.4739
3B	62%:35%:03%	412.0038	94.7609	45.8695	349.8249	12.1678
3C		380.4500	87.5035	38.6121	324.7640	11.2961
4A		433.6335	99.7357	50.8443	376.9274	13.1105
4B	63%:35%:02%	469.7343	108.0389	59.1475	393.8874	13.7004
4C		470.4326	108.1995	59.3081	400.5048	13.9306
5A		479.8499	110.3655	61.4741	508.9461	17.7025
5B	63%:35%:02%	531.4227	122.2272	73.3358	604.6684	21.0319
5C		517.4730	119.0188	70.1274	588.4728	20.4686
6A		430.7744	99.0781	50.1867	448.8159	15.6110
6B	63%:35%:02%	494.5044	113.7360	64.8446	495.6709	17.2407
6C		510.2919	117.3671	68.4757	513.7306	17.8689
7A		484.8252	111.5098	62.6184	526.3077	18.3064
7B	63%:35%:02%	492.5790	113.2932	64.4017	575.8825	20.0307
7C		559.0776	128.5878	79.6964	587.9796	20.4515

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions		Calcium Leaching Study Data: Day 8				
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		495.1761	113.8905	64.9991	422.2949	14.6885
1B	73%:25%:02%	570.5216	131.2200	82.3285	463.4718	16.1208
1C		512.7011	117.9213	69.0298	422.9648	14.7118
2A		459.2027	105.6166	56.7252	391.5407	13.6188
2B	67%:30%:03%	541.878	124.6319	75.7405	442.9313	15.4063
2C		529.784	121.8503	72.9589	428.7261	14.9122
3A		458.7314	105.5082	56.6168	386.4922	13.4432
3B	62%:35%:03%	525.9943	120.9787	72.0873	421.9122	14.6752
3C		497.9717	114.5335	65.6421	390.4061	13.5793
4A		497.504	114.4259	65.5345	442.4619	15.3900
4B	63%:35%:02%	574.8534	132.2163	83.3249	477.2123	16.5987
4C		591.9920	136.1582	87.2667	487.7715	16.9660
5A		705.2765	162.2136	113.3222	622.2683	21.6441
5B	63%:35%:02%	705.3901	162.2397	113.3483	718.0167	24.9745
5C		689.2563	158.5289	109.6375	698.1103	24.2821
6A		643.7511	148.0628	99.1713	547.9873	19.0604
6B	63%:35%:02%	636.2550	146.3387	97.4472	593.1181	20.6302
6C		661.2803	152.0945	103.2030	616.9336	21.4586
7A		659.6716	151.7245	102.8330	629.1407	21.8832
7B	63%:35%:02%	673.9383	155.0058	106.1144	681.9969	23.7216
7C		685.6456	157.6985	108.8071	696.7866	24.2361

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 11		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		545.2806	125.4145	76.5231	498.8180	17.3502
1B	73%:25%:02%	503.0478	115.7010	66.8096	530.2814	18.4446
1C		516.1986	118.7257	69.8343	492.7991	17.1408
2A		534.585	122.9546	74.0631	465.6038	16.1949
2B	67%:30%:03%	520.4502	119.7035	70.8121	513.7435	17.8693
2C		488.6055	112.3793	63.4878	492.2140	17.1205
3A		513.406	118.0834	69.1920	455.6841	15.8499
3B	62%:35%:03%	571.5953	131.4669	82.5755	504.4877	17.5474
3C		526.6798	121.1364	72.2449	462.6510	16.0922
4A		550.9502	126.7185	77.8271	520.2890	18.0970
4B	63%:35%:02%	582.2499	133.9175	85.0261	562.2383	19.5561
4C		511.9285	117.7436	68.8521	556.6237	19.3608
5A		643.9615	148.1111	99.2197	721.4880	25.0952
5B	63%:35%:02%	630.4781	145.0100	96.1185	814.1353	28.3177
5C		655.0531	150.6622	101.7708	799.8811	27.8220
6A		587.0060	135.0114	86.1200	634.1072	22.0559
6B	63%:35%:02%	614.9441	141.4371	92.5457	685.6639	23.8492
6C		625.9006	143.9571	95.0657	711.9993	24.7652
7A		621.2161	142.8797	93.9883	723.1290	25.1523
7B	63%:35%:02%	683.7768	157.2687	108.3772	790.3741	27.4913
7C		662.7049	152.4221	103.5307	800.3173	27.8371

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 14		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		511.5265	117.6511	68.7597	567.5777	19.7418
1B	73%:25%:02%	544.9562	125.3399	76.4485	606.7299	21.1036
1C		522.3857	120.1487	71.2573	564.0563	19.6194
2A		485.3433	111.6290	62.7375	528.3414	18.3771
2B	67%:30%:03%	521.0495	119.8414	70.9500	584.6934	20.3372
2C		517.332	118.9864	70.0949	562.3089	19.5586
3A		464.0239	106.7255	57.8341	513.5182	17.8615
3B	62%:35%:03%	485.5869	111.6850	62.7936	567.2813	19.7315
3C		511.8173	117.7180	68.8266	531.4776	18.4862
4A		519.0863	119.3898	70.4984	590.7874	20.5491
4B	63%:35%:02%	551.0624	126.7444	77.8529	640.0913	22.2640
4C		542.6643	124.8128	75.9214	632.5450	22.0016
5A		567.6290	130.5547	81.6632	803.1513	27.9357
5B	63%:35%:02%	625.6505	143.8996	95.0082	909.1435	31.6224
5C		613.6350	141.1361	92.2446	892.1257	31.0305
6A		533.9139	122.8002	73.9088	708.0160	24.6266
6B	63%:35%:02%	558.7992	128.5238	79.6324	765.2963	26.6190
6C		573.2024	131.8366	82.9451	794.9444	27.6502
7A		559.2742	128.6331	79.7416	802.8707	27.9259
7B	63%:35%:02%	635.3303	146.1260	97.2345	887.6087	30.8733
7C		625.4609	143.8560	94.9646	895.2819	31.1402

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions			Calcium Leaching Study Data: Day 21			
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		597.8701	137.5101	88.6187	656.1964	22.8242
1B	73%:25%:02%	636.7594	146.4547	97.5632	704.2931	24.4972
1C		592.6679	136.3136	87.4222	651.4785	22.6601
2A		572.9313	131.7742	82.8828	611.2241	21.2600
2B	67%:30%:03%	604.7548	139.0936	90.2022	674.8956	23.4746
2C		550.1493	126.5343	77.6429	639.9518	22.2592
3A		544.5901	125.2557	76.3643	589.8825	20.5177
3B	62%:35%:03%	580.4284	133.4985	84.6071	651.8884	22.6744
3C		543.5194	125.0095	76.1180	607.5956	21.1338
4A		613.5949	141.1268	92.2354	683.0228	23.7573
4B	63%:35%:02%	649.5824	149.4040	100.5125	740.6038	25.7601
4C		594.2916	136.6871	87.7956	720.3407	25.0553
5A		699.3479	160.8500	111.9586	915.1099	31.8299
5B	63%:35%:02%	766.7439	176.3511	127.4597	1036.6031	36.0558
5C		742.6895	170.8186	121.9272	1014.0529	35.2714
6A		669.8188	154.0583	105.1669	813.1829	28.2846
6B	63%:35%:02%	704.0087	161.9220	113.0306	878.3268	30.5505
6C		709.7299	163.2379	114.3465	909.2909	31.6275
7A		677.7614	155.8851	106.9937	909.8644	31.6475
7B	63%:35%:02%	767.1537	176.4454	127.5539	1015.1626	35.3100
7C		730.4083	167.9939	119.1025	1014.3844	35.2829

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 28		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		566.2575	130.2392	81.3478	737.5442	25.6537
1B	73%:25%:02%	624.5999	143.6580	94.7666	799.0597	27.7934
1C		583.7287	134.2576	85.3662	736.8447	25.6294
2A		537.183	123.5521	74.6607	685.8848	23.8569
2B	67%:30%:03%	569.8626	131.0684	82.1770	757.0726	26.3330
2C		561.9338	129.2448	80.3534	720.3052	25.0541
3A		512.2434	117.8160	68.9246	658.8071	22.9150
3B	62%:35%:03%	576.131	132.5101	83.6187	735.5071	25.5829
3C		555.7237	127.8165	78.9250	686.5206	23.8790
4A		555.5041	127.7659	78.8745	761.8974	26.5008
4B	63%:35%:02%	611.0251	140.5358	91.6444	832.2481	28.9478
4C		580.9798	133.6254	84.7339	805.0746	28.0026
5A		651.0013	149.7303	100.8389	1015.9488	35.3373
5B	63%:35%:02%	692.9263	159.3730	110.4816	1147.0848	39.8986
5C		723.6568	166.4411	117.5496	1131.6025	39.3601
6A		600.8413	138.1935	89.3021	902.4850	31.3908
6B	63%:35%:02%	629.4985	144.7847	95.8932	974.2201	33.8859
6C		637.2769	146.5737	97.6823	1006.9732	35.0252
7A		625.5070	143.8666	94.9752	1004.8395	34.9509
7B	63%:35%:02%	701.9422	161.4467	112.5553	1127.7179	39.2250
7C		659.9257	151.7829	102.8915	1117.2759	38.8618

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 42		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		431.2189	99.1804	50.2889	787.8331	27.4029
1B	73%:25%:02%	435.1048	100.0741	51.1827	850.2424	29.5736
1C		470.3171	108.1729	59.2815	796.1262	27.6913
2A		465.3787	107.0371	58.1457	744.0305	25.8793
2B	67%:30%:03%	473.1300	108.8199	59.9285	817.0011	28.4174
2C		468.0535	107.6523	58.7609	779.0660	27.0979
3A		479.8177	110.3581	61.4667	720.2737	25.0530
3B	62%:35%:03%	465.3854	107.0386	58.1472	793.6543	27.6054
3C		476.9187	109.6913	60.7999	747.3205	25.9938
4A		541.0339	124.4378	75.5464	837.4437	29.1285
4B	63%:35%:02%	525.5887	120.8854	71.9940	904.2421	31.4519
4C		526.4699	121.0881	72.1966	877.2713	30.5138
5A		709.6628	163.2224	114.3310	1130.2798	39.3141
5B	63%:35%:02%	701.9003	161.4371	112.5457	1259.6304	43.8132
5C		719.5073	165.4867	116.5953	1248.1978	43.4156
6A		657.2323	151.1634	102.2720	1004.7570	34.9481
6B	63%:35%:02%	646.3708	148.6653	99.7739	1073.9939	37.3563
6C		647.7636	148.9856	100.0942	1107.0674	38.5067
7A		723.2803	166.3545	117.4630	1122.3026	39.0366
7B	63%:35%:02%	711.4396	163.6311	114.7397	1242.4576	43.2159
7C		696.0257	160.0859	111.1945	1228.4704	42.7294

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 56		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		599.9426	137.9868	89.0954	876.9285	30.5019
1B	73%:25%:02%	583.6140	134.2312	85.3398	935.5822	32.5420
1C		589.3023	135.5395	86.6481	882.7743	30.7052
2A		548.9706	126.2632	77.3718	821.4023	28.5705
2B	67%:30%:03%	568.4311	130.7392	81.8477	898.8488	31.2643
2C		558.5583	128.4684	79.5770	858.6430	29.8658
3A		541.6539	124.5804	75.6890	795.9627	27.6857
3B	62%:35%:03%	539.7594	124.1447	75.2532	868.9075	30.2229
3C		550.0097	126.5022	77.6108	824.9313	28.6933
4A		582.5972	133.9974	85.1059	922.5497	32.0887
4B	63%:35%:02%	559.5264	128.6911	79.7997	984.0418	34.2275
4C		548.5155	126.1586	77.2671	954.5384	33.2013
5A		668.9599	153.8608	104.9693	1235.2491	42.9652
5B	63%:35%:02%	678.7780	156.1189	107.2275	1366.8579	47.5429
5C		701.4293	161.3287	112.4373	1360.6351	47.3264
6A		603.1027	138.7136	89.8222	1094.5792	38.0723
6B	63%:35%:02%	607.2831	139.6751	90.7837	1164.7776	40.5140
6C		607.4696	139.7180	90.8266	1197.8940	41.6659
7A		694.3294	159.6958	110.8043	1233.1069	42.8907
7B	63%:35%:02%	709.6374	163.2166	114.3252	1356.7827	47.1924
7C		661.0637	152.0447	103.1532	1331.6236	46.3173

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

Table C-2 (Cont.). Calculation of Cumulative Calcium Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Calcium Leaching Study Data: Day 77		
ID	PG:Class C Fly Ash:Portland Type II Cement	Calcium Amount (mg/L)	Calcium Leached (mg)	Ca^{2+} Leached [Sample - Blank] (mg)	Cumulative Ca^{2+} (mg)	Cumulative Ca^{2+} Flux (mg/cm^2)
1A		633.2556	145.6488	96.7574	973.6859	33.8673
1B	73%:25%:02%	581.6206	133.7727	84.8813	1020.4635	35.4944
1C		555.1162	127.6767	78.7853	961.5597	33.4456
2A		600.1461	138.0336	89.1422	910.5445	31.6711
2B	67%:30%:03%	550.3504	126.5806	77.6892	976.5380	33.9665
2C		594.1403	136.6523	87.7609	946.4039	32.9184
3A		548.6312	126.1852	77.2938	873.2565	30.3741
3B	62%:35%:03%	530.5690	122.0309	73.1394	942.0470	32.7669
3C		535.4702	123.1581	74.2667	899.1981	31.2765
4A		629.2697	144.7320	95.8406	1018.3903	35.4223
4B	63%:35%:02%	655.2655	150.7111	101.8196	1085.8614	37.7691
4C		588.1479	135.2740	86.3826	1040.9210	36.2059
5A		789.0005	181.4701	132.5787	1367.8278	47.5766
5B	63%:35%:02%	756.3553	173.9617	125.0703	1491.9282	51.8932
5C		757.3153	174.1825	125.2911	1485.9262	51.6844
6A		671.1752	154.3703	105.4789	1200.0581	41.7411
6B	63%:35%:02%	670.3551	154.1817	105.2902	1270.0678	44.1763
6C		662.2412	152.3155	103.4241	1301.3180	45.2632
7A		740.7364	170.3694	121.4780	1354.5849	47.1160
7B	63%:35%:02%	733.4662	168.6972	119.8058	1476.5886	51.3596
7C		748.5589	172.1685	123.2771	1454.9007	50.6052

Specimen Volume (cm^3) =	9.03		Mean Ca^{2+} in BLK (mg) =	48.8914
Surface Area (cm^2) =	28.75			

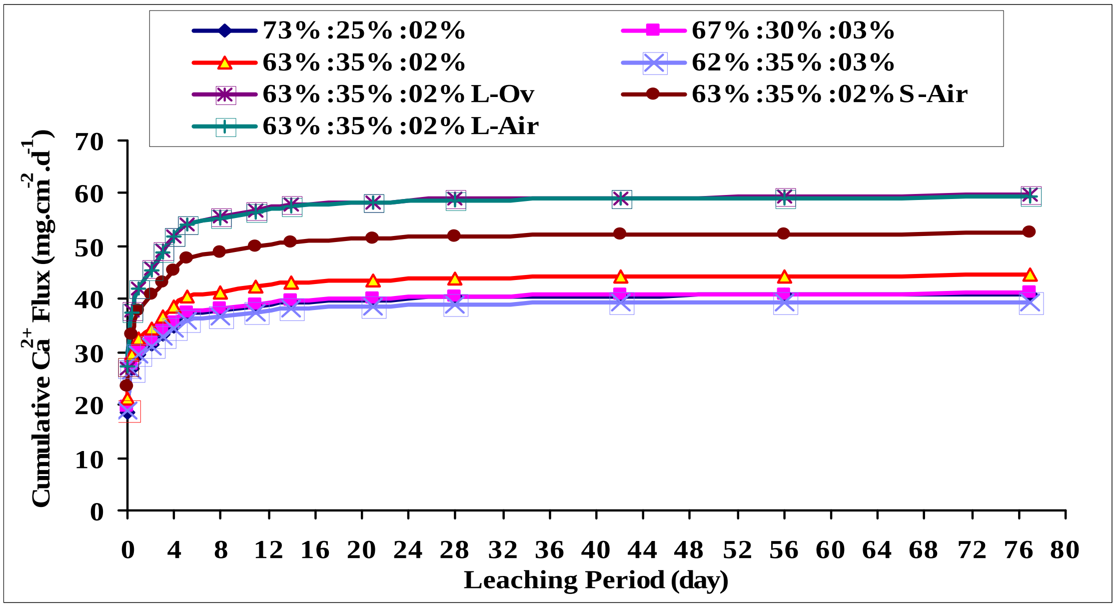

Figure C-3. Representative Flux of the Calcium Leaching Out During 77-Day Dynamic Leaching Test.

Table C-3. Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 0.08		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	1901.2378	437.2847	84.5347	84.5347	2.9403
1B		1882.6417	433.0076	80.2576	80.2576	2.7916
1C		1867.4338	429.5098	76.7598	76.7598	2.6699
2A	67%:30%:03%	1961.0001	451.0300	98.2800	98.2800	3.4184
2B		1979.3804	455.2575	102.5075	102.5075	3.5655
2C		1919.6723	441.5246	88.7746	88.7746	3.0878
3A	62%:35%:03%	1973.6505	453.9396	101.1896	101.1896	3.5196
3B		1830.4849	421.0115	68.2615	68.2615	2.3743
3C		1925.5369	442.8735	90.1235	90.1235	3.1347
4A	63%:35%:02%	2043.3307	469.9661	117.2161	117.2161	4.0771
4B		1981.5154	455.7485	102.9985	102.9985	3.5826
4C		1995.5736	458.9819	106.2319	106.2319	3.6950
5A	63%:35%:02%	2135.3218	491.1240	138.3740	138.3740	4.8130
5B		2153.8686	495.3898	142.6398	142.6398	4.9614
5C		2197.5126	505.4279	152.6779	152.6779	5.3105
6A	63%:35%:02%	2093.1728	481.4297	128.6797	128.6797	4.4758
6B		2039.0292	468.9767	116.2267	116.2267	4.0427
6C		2092.0234	481.1654	128.4154	128.4154	4.4666
7A	63%:35%:02%	2186.1269	502.8092	150.0592	150.0592	5.2195
7B		2157.6550	496.2606	143.5106	143.5106	4.9917
7C		2139.6368	492.1165	139.3665	139.3665	4.8475

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 0.29		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	1966.6683	452.3337	99.5837	184.1184	6.4041
1B		2001.1274	460.2593	107.5093	187.7669	6.5310
1C		1970.3204	453.1737	100.4237	177.1835	6.1629
2A	67%:30%:03%	1930.1592	443.9366	91.1866	189.4666	6.5901
2B		1916.6196	440.8225	88.0725	190.5800	6.6289
2C		1974.7122	454.1838	101.4338	190.2084	6.6159
3A	62%:35%:03%	1938.6968	445.9003	93.1503	194.3399	6.7596
3B		1928.8444	443.6342	90.8842	159.1457	5.5355
3C		1921.0276	441.8364	89.0864	179.2098	6.2334
4A	63%:35%:02%	2027.6135	466.3511	113.6011	230.8172	8.0284
4B		1933.1360	444.6213	91.8713	194.8698	6.7781
4C		1991.6347	458.0760	105.3260	211.5579	7.3585
5A	63%:35%:02%	2155.9110	495.8595	143.1095	281.4836	9.7907
5B		2193.9008	504.5972	151.8472	294.4870	10.2430
5C		2198.5633	505.6696	152.9196	305.5975	10.6295
6A	63%:35%:02%	2123.3684	488.3747	135.6247	264.3045	9.1932
6B		2094.5634	481.7496	128.9996	245.2263	8.5296
6C		2030.4934	467.0135	114.2635	242.6789	8.4410
7A	63%:35%:02%	2190.6783	503.8560	151.1060	301.1652	10.4753
7B		2125.4195	488.8465	136.0965	279.6071	9.7255
7C		2131.9297	490.3438	137.5938	276.9603	9.6334

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 1		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A		2108.1121	484.8658	132.1158	316.2342	10.9994
1B	73%:25%:02%	2077.7428	477.8808	125.1308	312.8977	10.8834
1C		1992.6482	458.3091	105.5591	282.7425	9.8345
2A		2090.7197	480.8655	128.1155	317.5822	11.0463
2B	67%:30%:03%	2074.3374	477.0976	124.3476	314.9276	10.9540
2C		1939.0359	445.9782	93.2282	283.4367	9.8587
3A		2056.0076	472.8817	120.1317	314.4716	10.9381
3B	62%:35%:03%	2095.4677	481.9576	129.2076	288.3533	10.0297
3C		2006.0628	461.3944	108.6444	287.8543	10.0123
4A		2133.8069	490.7756	138.0256	368.8428	12.8293
4B	63%:35%:02%	2115.6742	486.6051	133.8551	328.7249	11.4339
4C		2104.7532	484.0932	131.3432	342.9012	11.9270
5A		2428.9268	558.6532	205.9032	487.3867	16.9526
5B	63%:35%:02%	2434.3886	559.9094	207.1594	501.6464	17.4486
5C		2435.5143	560.1683	207.4183	513.0158	17.8440
6A		2460.2646	565.8609	213.1109	477.4153	16.6058
6B	63%:35%:02%	2435.2848	560.1155	207.3655	452.5918	15.7423
6C		2417.4262	556.0080	203.2580	445.9369	15.5108
7A		2378.7612	547.1151	194.3651	495.5303	17.2358
7B	63%:35%:02%	2462.0577	566.2733	213.5233	493.1304	17.1524
7C		2426.4002	558.0720	205.3220	482.2823	16.7750

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 2		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2072.0602	476.5738	123.8238	440.0580	15.3064
1B		2132.3328	490.4365	137.6865	450.5843	15.6725
1C		2055.6022	472.7885	120.0385	402.7811	14.0098
2A	67%:30%:03%	2104.3255	483.9949	131.2449	448.8270	15.6114
2B		2088.9830	480.4661	127.7161	442.6437	15.3963
2C		1870.9329	430.3146	77.5646	361.0012	12.5566
3A	62%:35%:03%	2042.1670	469.6984	116.9484	431.4200	15.0059
3B		1991.3097	458.0012	105.2512	393.6045	13.6906
3C		1983.6223	456.2331	103.4831	391.3374	13.6117
4A	63%:35%:02%	2163.9406	497.7063	144.9563	513.7991	17.8713
4B		2152.7555	495.1338	142.3838	471.1086	16.3864
4C		1999.3191	459.8434	107.0934	449.9945	15.6520
5A	63%:35%:02%	2507.7281	576.7775	224.0275	711.4142	24.7448
5B		2454.2880	564.4862	211.7362	713.3826	24.8133
5C		2548.4620	586.1463	233.3963	746.4120	25.9622
6A	63%:35%:02%	2369.8854	545.0736	192.3236	669.7390	23.2953
6B		2286.7642	525.9558	173.2058	625.7976	21.7669
6C		2426.6664	558.1333	205.3833	651.3202	22.6546
7A	63%:35%:02%	2401.6303	552.3750	199.6250	695.1552	24.1793
7B		2376.0627	546.4944	193.7444	686.8748	23.8913
7C		2367.0466	544.4207	191.6707	673.9531	23.4418

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 3		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2012.7960	462.9431	110.1931	550.2511	19.1392
1B		1988.0139	457.2432	104.4932	555.0775	19.3070
1C		1867.1628	429.4474	76.6974	479.4785	16.6775
2A	67%:30%:03%	1928.4847	443.5515	90.8015	539.6285	18.7697
2B		2005.4244	461.2476	108.4976	551.1413	19.1701
2C		1875.2898	431.3166	78.5666	439.5679	15.2893
3A	62%:35%:03%	1886.4529	433.8842	81.1342	512.5542	17.8280
3B		1926.6462	443.1286	90.3786	483.9832	16.8342
3C		1865.5718	429.0815	76.3315	467.6689	16.2667
4A	63%:35%:02%	2107.6464	484.7587	132.0087	645.8078	22.4629
4B		2049.3301	471.3459	118.5959	589.7046	20.5115
4C		1981.6865	455.7879	103.0379	553.0324	19.2359
5A	63%:35%:02%	2275.5697	523.3810	170.6310	882.0452	30.6798
5B		2383.0196	548.0945	195.3445	908.7271	31.6079
5C		2358.3894	542.4296	189.6796	936.0916	32.5597
6A	63%:35%:02%	2211.7377	508.6997	155.9497	825.6887	28.7196
6B		2102.6615	483.6121	130.8621	756.6597	26.3186
6C		2176.2059	500.5274	147.7774	799.0975	27.7947
7A	63%:35%:02%	2278.9300	524.1539	171.4039	866.5592	30.1412
7B		2267.0469	521.4208	168.6708	855.5456	29.7581
7C		2331.9532	536.3492	183.5992	857.5523	29.8279

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 4		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	1925.5392	442.8740	90.1240	640.3751	22.2739
1B		2013.3143	463.0623	110.3123	665.3897	23.1440
1C		1968.1077	452.6648	99.9148	579.3933	20.1528
2A	67%:30%:03%	1971.5923	453.4662	100.7162	640.3448	22.2729
2B		1916.3906	440.7698	88.0198	639.1612	22.2317
2C		1909.2012	439.1163	86.3663	525.9342	18.2934
3A	62%:35%:03%	1920.2750	441.6632	88.9132	601.4674	20.9206
3B		1922.6545	442.2105	89.4605	573.4437	19.9459
3C		1884.4889	433.4325	80.6825	548.3514	19.0731
4A	63%:35%:02%	2084.2075	479.3677	126.6177	772.4255	26.8670
4B		2081.1064	478.6545	125.9045	715.6090	24.8907
4C		1983.3266	456.1651	103.4151	656.4475	22.8330
5A	63%:35%:02%	2154.4562	495.5249	142.7749	1024.8201	35.6459
5B		2249.3679	517.3546	164.6046	1073.3317	37.3333
5C		2196.5461	505.2056	152.4556	1088.5472	37.8625
6A	63%:35%:02%	2040.5704	469.3312	116.5812	942.2699	32.7746
6B		2047.0874	470.8301	118.0801	874.7398	30.4257
6C		2105.3526	484.2311	131.4811	930.5786	32.3680
7A	63%:35%:02%	2181.6605	501.7819	149.0319	1015.5911	35.3249
7B		2231.1010	513.1532	160.4032	1015.9488	35.3374
7C		2183.6064	502.2295	149.4795	1007.0318	35.0272

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 5		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	1996.0141	459.0832	106.3332	746.7084	25.9725
1B		1981.5917	455.7661	103.0161	768.4058	26.7272
1C		1847.9160	425.0207	72.2707	651.6640	22.6666
2A	67%:30%:03%	1734.4587	398.9255	46.1755	686.5203	23.8790
2B		1963.0126	451.4929	98.7429	737.9040	25.6662
2C		1928.1612	443.4771	90.7271	616.6612	21.4491
3A	62%:35%:03%	1865.7356	429.1192	76.3692	677.8366	23.5769
3B		1855.1138	426.6762	73.9262	647.3699	22.5172
3C		1804.1338	414.9508	62.2008	610.5522	21.2366
4A	63%:35%:02%	2029.9864	466.8969	114.1469	886.5724	30.8373
4B		2051.1122	471.7558	119.0058	834.6148	29.0301
4C		1977.6096	454.8502	102.1002	758.5478	26.3843
5A	63%:35%:02%	2112.3983	485.8516	133.1016	1157.9217	40.2755
5B		2128.3842	489.5284	136.7784	1210.1101	42.0908
5C		2146.9440	493.7971	141.0471	1229.5943	42.7685
6A	63%:35%:02%	2002.6789	460.6161	107.8661	1050.1360	36.5265
6B		1983.9277	456.3034	103.5534	978.2932	34.0276
6C		2041.3359	469.5073	116.7573	1047.3359	36.4291
7A	63%:35%:02%	2168.8365	498.8324	146.0824	1161.6735	40.4060
7B		2183.2421	502.1457	149.3957	1165.3445	40.5337
7C		2142.8879	492.8642	140.1142	1147.1460	39.9007

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 8		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2156.2260	495.9320	143.1820	889.8903	30.9527
1B		2095.5880	481.9852	129.2352	897.6411	31.2223
1C		1980.6296	455.5448	102.7948	754.4588	26.2420
2A	67%:30%:03%	2001.2069	460.2776	107.5276	794.0479	27.6191
2B		2022.2862	465.1258	112.3758	850.2799	29.5750
2C		2025.7755	465.9284	113.1784	729.8396	25.3857
3A	62%:35%:03%	2017.2139	463.9592	111.2092	789.0458	27.4451
3B		1947.9596	448.0307	95.2807	742.6506	25.8313
3C		1950.5706	448.6312	95.8812	706.4334	24.5716
4A	63%:35%:02%	2158.9003	496.5471	143.7971	1030.3695	35.8389
4B		2139.5299	492.0919	139.3419	973.9567	33.8768
4C		2136.1274	491.3093	138.5593	897.1071	31.2037
5A	63%:35%:02%	2464.5753	566.8523	214.1023	1372.0240	47.7226
5B		2371.2691	545.3919	192.6419	1402.7520	48.7914
5C		2424.3218	557.5940	204.8440	1434.4383	49.8935
6A	63%:35%:02%	2357.6374	542.2566	189.5066	1239.6426	43.1180
6B		2318.6950	533.2999	180.5499	1158.8430	40.3076
6C		2441.0202	561.4346	208.6846	1256.0205	43.6877
7A	63%:35%:02%	2440.1708	561.2393	208.4893	1370.1627	47.6578
7B		2464.7846	566.9005	214.1505	1379.4950	47.9824
7C		2478.7112	570.1036	217.3536	1364.4995	47.4609

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 11		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2120.1563	487.6359	134.8859	1024.7763	35.6444
1B		2021.4914	464.9430	112.1930	1009.8341	35.1247
1C		1992.4126	458.2549	105.5049	859.9637	29.9118
2A	67%:30%:03%	2051.8436	471.9240	119.1740	913.2219	31.7642
2B		2027.8733	466.4109	113.6609	963.9407	33.5284
2C		1936.1903	445.3238	92.5738	822.4134	28.6057
3A	62%:35%:03%	1979.6797	455.3263	102.5763	891.6222	31.0129
3B		1961.6197	451.1725	98.4225	841.0731	29.2547
3C		1858.3071	427.4106	74.6606	781.0940	27.1685
4A	63%:35%:02%	2145.6803	493.5065	140.7565	1171.1259	40.7348
4B		2136.8963	491.4861	138.7361	1112.6929	38.7024
4C		1986.1039	456.8039	104.0539	1001.1610	34.8230
5A	63%:35%:02%	2246.6501	516.7295	163.9795	1536.0036	53.4262
5B		2247.4885	516.9224	164.1724	1566.9244	54.5017
5C		2246.8711	516.7804	164.0304	1598.4687	55.5989
6A	63%:35%:02%	2209.9925	508.2983	155.5483	1395.1909	48.5284
6B		2150.8462	494.6946	141.9446	1300.7877	45.2448
6C		2153.7329	495.3586	142.6086	1398.6291	48.6480
7A	63%:35%:02%	2276.7071	523.6426	170.8926	1541.0554	53.6019
7B		2305.2109	530.1985	177.4485	1556.9435	54.1546
7C		2260.0178	519.8041	167.0541	1531.5536	53.2714

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 14		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	1926.9910	443.2079	90.4579	1115.2342	38.7908
1B		1894.4974	435.7344	82.9844	1092.8185	38.0111
1C		1926.3549	443.0616	90.3116	950.2753	33.0531
2A	67%:30%:03%	1861.3950	428.1209	75.3709	988.5927	34.3858
2B		1901.1045	437.2540	84.5040	1048.4448	36.4676
2C		1825.8276	419.9403	67.1903	889.6037	30.9427
3A	62%:35%:03%	1807.7035	415.7718	63.0218	954.6440	33.2050
3B		1793.5455	412.5155	59.7655	900.8386	31.3335
3C		1808.4324	415.9395	63.1895	844.2835	29.3664
4A	63%:35%:02%	1971.1388	453.3619	100.6119	1271.7379	44.2344
4B		1925.4914	442.8630	90.1130	1202.8059	41.8367
4C		1881.7243	432.7966	80.0466	1081.2076	37.6072
5A	63%:35%:02%	2012.9318	462.9743	110.2243	1646.2279	57.2601
5B		2026.5209	466.0998	113.3498	1680.2742	58.4443
5C		2039.0271	468.9762	116.2262	1714.6949	59.6416
6A	63%:35%:02%	1988.8192	457.4284	104.6784	1499.8693	52.1694
6B		1944.6796	447.2763	94.5263	1395.3140	48.5327
6C		1916.7987	440.8637	88.1137	1486.7428	51.7128
7A	63%:35%:02%	1995.8861	459.0538	106.3038	1647.3592	57.2994
7B		2090.9353	480.9151	128.1651	1685.1086	58.6125
7C		2055.9652	472.8720	120.1220	1651.6756	57.4496

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 21		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2147.1986	493.8557	141.1057	1256.3399	43.6988
1B		2071.6929	476.4894	123.7394	1216.5579	42.3151
1C		1976.2106	454.5284	101.7784	1052.0537	36.5932
2A	67%:30%:03%	2006.4959	461.4941	108.7441	1097.3368	38.1682
2B		1921.6551	441.9807	89.2307	1137.6754	39.5713
2C		1859.7432	427.7409	74.9909	964.5946	33.5511
3A	62%:35%:03%	1941.0882	446.4503	93.7003	1048.3443	36.4641
3B		1899.5905	436.9058	84.1558	984.9944	34.2607
3C		1850.2523	425.5580	72.8080	917.0915	31.8988
4A	63%:35%:02%	2131.3996	490.2219	137.4719	1409.2098	49.0160
4B		2116.5717	486.8115	134.0615	1336.8674	46.4997
4C		1999.5341	459.8928	107.1428	1188.3504	41.3339
5A	63%:35%:02%	2360.2673	542.8615	190.1115	1836.3394	63.8727
5B		2356.8426	542.0738	189.3238	1869.5980	65.0295
5C		2297.8491	528.5053	175.7553	1890.4502	65.7548
6A	63%:35%:02%	2286.8336	525.9717	173.2217	1673.0910	58.1945
6B		2226.1637	512.0177	159.2677	1554.5816	54.0724
6C		2262.7972	520.4434	167.6934	1654.4362	57.5456
7A	63%:35%:02%	2335.6406	537.1973	184.4473	1831.8065	63.7150
7B		2385.4220	548.6471	195.8971	1881.0057	65.4263
7C		2327.5661	535.3402	182.5902	1834.2658	63.8006

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 28		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2022.2886	465.1264	112.3764	1368.7163	47.6075
1B		2021.1301	464.8599	112.1099	1328.6678	46.2145
1C		1925.7396	442.9201	90.1701	1142.2238	39.7295
2A	67%:30%:03%	1966.7281	452.3475	99.5975	1196.9343	41.6325
2B		1883.2068	433.1376	80.3876	1218.0630	42.3674
2C		1834.1346	421.8510	69.1010	1033.6956	35.9546
3A	62%:35%:03%	1885.8653	433.7490	80.9990	1129.3433	39.2815
3B		1882.9754	433.0843	80.3343	1065.3287	37.0549
3C		1858.2249	427.3917	74.6417	991.7332	34.4951
4A	63%:35%:02%	2022.2732	465.1228	112.3728	1521.5826	52.9246
4B		2014.9929	463.4484	110.6984	1447.5657	50.3501
4C		1939.5214	446.0899	93.3399	1281.6903	44.5805
5A	63%:35%:02%	2184.9448	502.5373	149.7873	1986.1267	69.0827
5B		2204.6254	507.0638	154.3138	2023.9118	70.3969
5C		2255.1169	518.6769	165.9269	2056.3771	71.5262
6A	63%:35%:02%	2115.0377	486.4587	133.7087	1806.7997	62.8452
6B		2082.4430	478.9619	126.2119	1680.7935	58.4624
6C		2029.6672	466.8235	114.0735	1768.5096	61.5134
7A	63%:35%:02%	2148.9625	494.2614	141.5114	1973.3179	68.6371
7B		2217.5873	510.0451	157.2951	2038.3007	70.8974
7C		2182.0681	501.8757	149.1257	1983.3915	68.9875

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 42		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	1776.6096	408.6202	55.8702	1424.5865	49.5508
1B		1783.9608	410.3110	57.5610	1386.2288	48.2167
1C		1801.4237	414.3275	61.5775	1203.8013	41.8713
2A	67%:30%:03%	1748.8603	402.2379	49.4879	1246.4221	43.3538
2B		1800.9999	414.2300	61.4800	1279.5430	44.5058
2C		1771.6508	407.4797	54.7297	1088.4253	37.8583
3A	62%:35%:03%	1779.0546	409.1826	56.4326	1185.7758	41.2444
3B		1763.0194	405.4945	52.7445	1118.0732	38.8895
3C		1779.0864	409.1899	56.4399	1048.1731	36.4582
4A	63%:35%:02%	2024.1470	465.5538	112.8038	1634.3864	56.8482
4B		1960.1686	450.8388	98.0888	1545.6545	53.7619
4C		1968.6519	452.7899	100.0399	1381.7303	48.0602
5A	63%:35%:02%	2334.6621	536.9723	184.2223	2170.3489	75.4904
5B		2301.9268	529.4432	176.6932	2200.6050	76.5428
5C		2347.9355	540.0252	187.2752	2243.6522	78.0401
6A	63%:35%:02%	2249.7244	517.4366	164.6866	1971.4863	68.5734
6B		2213.0974	509.0124	156.2624	1837.0559	63.8976
6C		2222.7829	511.2401	158.4901	1926.9997	67.0261
7A	63%:35%:02%	2353.0405	541.1993	188.4493	2161.7672	75.1919
7B		2376.2209	546.5308	193.7808	2232.0815	77.6376
7C		2318.9963	533.3692	180.6192	2164.0106	75.2699

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 56		
ID	PG:Class C Fly Ash:Portland Type II Cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2060.1123	473.8258	121.0758	1545.6623	53.7622
1B		2034.8857	468.0237	115.2737	1501.5025	52.2262
1C		2026.7249	466.1467	113.3967	1317.1980	45.8156
2A	67%:30%:03%	1901.6156	437.3716	84.6216	1331.0437	46.2972
2B		1984.5303	456.4420	103.6920	1383.2350	48.1125
2C		1979.7993	455.3538	102.6038	1191.0291	41.4271
3A	62%:35%:03%	1909.2058	439.1173	86.3673	1272.1432	44.2485
3B		1918.3728	441.2257	88.4757	1206.5489	41.9669
3C		1913.1821	440.0319	87.2819	1135.4550	39.4941
4A	63%:35%:02%	2083.7505	479.2626	126.5126	1760.8990	61.2487
4B		2075.5895	477.3856	124.6356	1670.2901	58.0970
4C		2061.5934	474.1665	121.4165	1503.1468	52.2834
5A	63%:35%:02%	2329.7200	535.8356	183.0856	2353.4345	81.8586
5B		2332.9655	536.5821	183.8321	2384.4370	82.9369
5C		2347.9495	540.0284	187.2784	2430.9306	84.5541
6A	63%:35%:02%	2166.2169	498.2299	145.4799	2116.9662	73.6336
6B		2137.3013	491.5793	138.8293	1975.8852	68.7264
6C		2147.7101	493.9733	141.2233	2068.2230	71.9382
7A	63%:35%:02%	2294.5490	527.7463	174.9963	2336.7635	81.2787
7B		2341.6315	538.5752	185.8252	2417.9068	84.1011
7C		2277.5289	523.8317	171.0817	2335.0923	81.2206

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

Table C-3 (Cont.). Calculation of Cumulative Sulfate Flux for 77-Day Dynamic Leaching Study.

Best Four PG Compositions				Sulfate Leaching Study Data: Day 77		
ID	PG:Class C Fly Ash:Portland Type II cement	Sulfate Amount (mg/L)	Sulfate Leached (mg)	SO_4^{2-} Leached [Sample - Blank] (mg)	Cumulative SO_4^{2-} (mg)	Cumulative SO_4^{2-} Flux (mg/cm^2)
1A	73%:25%:02%	2198.2563	505.5989	152.8489	1698.5112	59.0787
1B		2042.4448	469.7623	117.0123	1618.5148	56.2962
1C		2036.6301	468.4249	115.6749	1432.8729	49.8391
2A	67%:30%:03%	2061.1686	474.0688	121.3188	1452.3625	50.5170
2B		1929.4995	443.7849	91.0349	1474.2698	51.2790
2C		2054.1360	472.4513	119.7013	1310.7304	45.5906
3A	62%:35%:03%	1949.6600	448.4218	95.6718	1367.8150	47.5762
3B		1927.2506	443.2676	90.5176	1297.0666	45.1154
3C		1956.4131	449.9750	97.2250	1232.6800	42.8758
4A	63%:35%:02%	2176.5804	500.6135	147.8635	1908.7625	66.3917
4B		2283.8881	525.2943	172.5443	1842.8344	64.0986
4C		2105.5003	484.2651	131.5151	1634.6618	56.8578
5A	63%:35%:02%	2513.8324	578.1815	225.4315	2578.8660	89.6997
5B		2439.4022	561.0625	208.3125	2592.7495	90.1826
5C		2480.7973	570.5834	217.8334	2648.7640	92.1309
6A	63%:35%:02%	2332.2301	536.4129	183.6629	2300.6291	80.0219
6B		2233.9572	513.8102	161.0602	2136.9454	74.3285
6C		2286.3039	525.8499	173.0999	2241.3229	77.9591
7A	63%:35%:02%	2429.9588	558.8905	206.1405	2542.9040	88.4488
7B		2446.5649	562.7099	209.9599	2627.8667	91.4041
7C		2476.5198	569.5996	216.8496	2551.9419	88.7632

Specimen Volume (cm^3) =	9.03		Mean SO_4^{2-} in BLK (mg) =	352.75
Surface Area (cm^2) =	28.75			

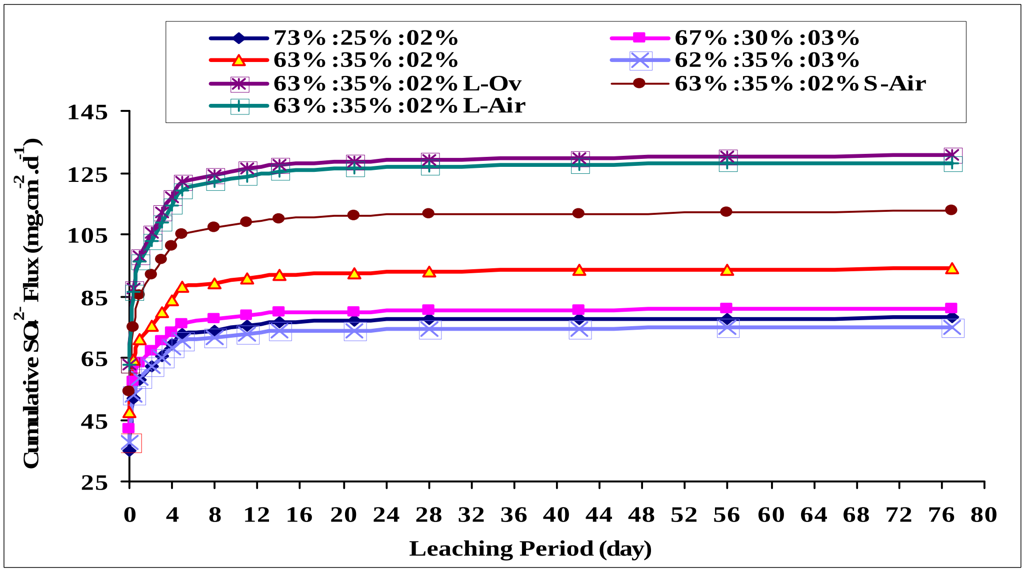

Figure C-4. Representative Flux of the Sulfate Leaching Out During 77-Day Dynamic Leaching Test.

Table C-4. Comparison of Effective Calcium and Sulfate Diffusion Coefficients for Four PG Composite Combinations Calculated Using Theoretical C_o Values.

Calcium Effective Diffusion Coefficients (Using Theoretical C_o)								
PG Composite	K_1 $(C_o$-$C_1)$ $mg\cdot cm^{-2}$	K_2 $(C_o$-$C_1)$ $mg\cdot cm^{-2} \cdot d^{-0.5}$	K_3 $(C_o$-$C_1)$ $mg\cdot cm^{-2} \cdot d^{-1}$	$C_{o,Theo.}$ (mg/cc)	C_1 (mg/cc)	K_2 (cm/day$^{0.5}$)	K_3 (cm/day)	D_e m^2/sec
73%:25%:02%	-0.79	6.52	-0.29	355.67	0.2746	0.0183	-0.0008	3.06E-13
67%:30%:03%	0	5.94	-0.25	326.44	0.2613	0.0182	-0.0008	3.02E-13
63%:35%:02%	-0.73	6.96	-0.31	306.95	0.2898	0.0187	-0.0008	4.68E-13
62%:35%:03%	0	5.72	-0.24	302.08	0.2513	0.0230	-0.0010	3.27E-13

Sulfate Effective Diffusion Coefficients (Using Theoretical C_o)								
PG Composite	K_1 $(C_o$-$C_1)$ $mg\cdot cm^{-2}$	K_2 $(C_o$-$C_1)$ $mg\cdot cm^{-2} \cdot d^{-0.5}$	K_3 $(C_o$-$C_1)$ $mg\cdot cm^{-2} \cdot d^{-1}$	$C_{o,Theo.}$ (mg/cc)	C_1 (mg/cc)	K_2 (cm/day$^{0.5}$)	K_3 (cm/day)	D_e m^2/sec
67%:30%:03%	0	11.425	-0.696	698.16	0.4165	0.0164	-0.0010	2.44E-13
63%:35%:02%	0	10.755	-0.670	685.98	0.5134	0.0157	-0.0010	2.24E-13
62%:35%:03%	0	13.617	-0.773	668.99	0.3848	0.0204	-0.0012	3.77E-13

FINAL FOUR Combinations			
Composite	SO_4^{2-} D_e m^2/sec	Ca^{2+} D_e m^2/sec	Ratio Sulfate D_e /Calcium D_e
73%:25%:03%	2.69E-13	3.06E-13	0.9
67%:30%:03%	2.44E-13	3.02E-13	0.8
63%:35%:02%	2.24E-13	4.68E-13	0.5
62%:35%:03%	3.77E-13	3.27E-13	1.2
Average	2.79E-13	3.51E-13	0.8

Table C-5. Comparison of Effective Calcium and Sulfate Diffusion Coefficients for PG Composite Combinations Calculated Using Experimental C_o Values.

Calcium Effective Diffusion Coefficients (Using Experimental C_o)								
PG Composite	K_1 (C_o-C_1) $mg \cdot cm^{-2}$	K_2 (C_o-C_1) $mg \cdot cm^{-2} \cdot d^{-0.5}$	K_3 (C_o-C_1) $mg \cdot cm^{-2} \cdot d^{-1}$	$C_{o,Expr.}$ (mg/cc)	C_1 (mg/cc)	K_2 (cm/day$^{0.5}$)	K_3 (cm/day)	D_e (m^2/sec)
73%:25%:02%	-0.79	6.52	-0.29	469.44	0.2746	0.0139	-0.0006	1.75E-13
67%:30%:03%	0.00	5.94	-0.25	473.36	0.2613	0.0126	-0.0005	1.44E-13
62%:35%:03%	0.00	5.72	-0.24	467.54	0.2513	0.0122	-0.0005	1.36E-13
63%:35%:02%	-0.73	6.96	-0.31	421.44	0.2898	0.0165	-0.0007	2.48E-13
63%:35%:02%	0.00	9.44	-0.43	317.71	0.3979	0.0297	-0.0014	8.04E-13
63%:35%:02%	0.00	8.22	-0.37	306.95	0.3483	0.0268	-0.0012	6.53E-13
63%:35%:02%	0.00	9.34	-0.43	317.71	0.3925	0.0294	-0.0013	7.88E-13
Sulfate Effective Diffusion Coefficients (Using Experimental C_o)								
PG Composite	K_1 (C_o-C_1) $mg \cdot cm^{-2}$	K_2 (C_o-C_1) $mg \cdot cm^{-2} \cdot d^{-0.5}$	K_3 (C_o-C_1) $mg \cdot cm^{-2} \cdot d^{-1}$	$C_{o,Expr.}$ (mg/cc)	C_1 (mg/cc)	K_2 (cm/day$^{0.5}$)	K_3 (cm/day)	D_e (m^2/sec)
73%:25%:02%	0	12.091	-0.689	670.88	0.4637	0.0172	-0.0010	2.96E-13
67%:30%:03%	0	11.425	-0.696	624.41	0.4165	0.0164	-0.0010	3.05E-13
62%:35%:03%	0	10.755	-0.670	609.43	0.3848	0.0157	-0.0010	3.25E-13
63%:35%:02%	0	13.617	-0.773	569.53	0.5134	0.0204	-0.0012	4.54E-13
63%:35%:02%	0	19.618	-1.108	697.98	0.7327	0.0281	-0.0016	7.20E-13
63%:35%:02%	0	17.179	-0.993	685.98	0.6348	0.0251	-0.0014	5.71E-13
63%:35%:02%	0	19.124	-1.058	697.98	0.7240	0.0274	-0.0015	6.84E-13

Appendix D

STANDARD PROCTOR COMPACTION TEST RESULTS

STANDARD PROCTOR COMPACTION TEST RESULTS

Table D-1. Results of Standard Proctor Compaction Test Conducted on Initial Nine Composites During Phase I Testing.

PG:Class C Fly Ash:Portland Type II Cement	Weight of Crushed Samples + Mold (kg)	Weight of Crushed Samples (kg)	Weight of Crushed Samples (gm)	Unit Weight* (gm/cm^3)	Moisture Content (%)	Maximum Dry Unit Weight of Compaction* (gm/cm^3)	Avg.	S.D. (n=2)
77%:20%:03%	5.5964	1.3536	1353.60	1.4355	8.0	1.3292	1.3198	0.0133
	5.5773	1.3345	1334.50	1.4152		1.3104		
73%:25%:02%	5.5882	1.3454	1345.40	1.4268	8.0	1.3211	1.3189	0.0032
	5.5836	1.3408	1340.80	1.4219		1.3166		
72%:25%:03%	5.5894	1.3466	1346.60	1.4281	8.0	1.3223	1.3214	0.0012
	5.5876	1.3448	1344.80	1.4262		1.3205		
69%:30%:01%	5.5728	1.3300	1330.00	1.4105	8.0	1.3060	1.2948	0.0158
	5.5500	1.3072	1307.20	1.3863		1.2836		
68%:30%:02%	5.5187	1.2759	1275.90	1.3531	8.0	1.2529	1.2550	0.0031
	5.5231	1.2803	1280.30	1.3578		1.2572		
67%:30%:03%	5.5618	1.3190	1319.00	1.3988	8.0	1.2952	1.2752	0.0283
	5.5210	1.2782	1278.20	1.3555		1.2551		
64%:35%:01%	5.5366	1.2938	1293.80	1.3721	8.0	1.2704	1.2703	0.0002
	5.5363	1.2935	1293.50	1.3718		1.2701		
63%:35%:02%	5.5366	1.2938	1293.80	1.3721	8.0	1.2704	1.2745	0.0058
	5.5449	1.3021	1302.10	1.3809		1.2786		
62%:35%:03%	5.5465	1.3037	1303.70	1.3826	8.0	1.2802	1.2713	0.0125
	5.5285	1.2857	1285.70	1.3635		1.2625		

* Volume of the Standard Mold = 942.951 cm^3

Weight of Std. Mold = 4.2538 kg

Table D-2. Results of Standard Proctor Compaction Test Conducted on Best Four Composite Combinations During Phase II Testing.

PG:Class C Fly Ash:Portland Type II Cement	Weight of Crushed Samples + Mold (kg)	Weight of Crushed Samples (kg)	Weight of Crushed Samples (gm)	Unit Weight* (gm/cm^3)	Moisture Content (%)	Maximum Dry Unit Weight of Compaction* (gm/cm^3)	Avg.	S.D. (n=2)
73%:25%:02%	5.6749	1.4211	1421.10	1.5071	4.0	1.4491	1.4333	0.0175
	5.6625	1.4087	1408.70	1.4939		1.4365		
	5.6409	1.3871	1387.10	1.4710		1.4144		
67%:30%:03%	5.6787	1.4249	1424.90	1.5111	4.0	1.4530	1.4633	0.0272
	5.6687	1.4149	1414.90	1.5005		1.4428		
	5.7191	1.4653	1465.30	1.5540		1.4942		
62%:35%:03%	5.7084	1.4546	1454.60	1.5426	4.0	1.4833	1.4795	0.0048
	5.6994	1.4456	1445.60	1.5331		1.4741		
	5.7063	1.4525	1452.50	1.5404		1.4811		
63%:35%:02%	5.7377	1.4839	1483.90	1.5737	4.0	1.5132	1.5281	0.0145
	5.7661	1.5123	1512.30	1.6038		1.5421		
	5.7534	1.4996	1499.60	1.5903		1.5292		

* Volume of the Standard Mold = 942.951 cm^3
Weight of the Standard Mold = 4.2538 kg

Appendix E

SPECIFIC GRAVITY TEST RESULTS

SPECIFIC GRAVITY TEST RESULTS

Table E-1. Results of Specific Gravity Analysis During Phase I Testing on Initial Nine Composite Briquette Combinations.

PG:Class C Fly Ash:Portland Type II Cement	Air Dry Wt. of Samples (gm)	Water Wt. of Samples (gm)	Specific Gravity (G_s)	Average Specific Gravity	Standard Deviation (n=3)
77%:20%:03%	498	272	2.2035	2.18	0.0195
	500	269	2.1645		
	498	270	2.1842		
73%:25%:03%	503	276	2.2159	2.22	0.0042
	498	274	2.2232		
	498	274	2.2232		
72%:25%:03%	497	266	2.1515	2.17	0.0125
	505	272	2.1674		
	494	267	2.1762		
69%:30%:01%	500	267	2.1459	2.16	0.0097
	498	268	2.1652		
	496	266	2.1565		
68%:30%:02%	499	270	2.1790	2.20	0.0255
	494	272	2.2252		
	500	271	2.1834		
67%:30%:03%	498	272	2.2035	2.21	0.0056
	491	269	2.2117		
	496	272	2.2143		
64%:35%:01%	501	274	2.2070	2.20	0.0038
	503	275	2.2061		
	495	270	2.2000		
63%:35%:02%	501	274	2.2070	2.21	0.0060
	494	271	2.2152		
	498	272	2.2035		
62%:35%:03%	503	279	2.2455	2.25	0.0096
	491	274	2.2627		
	492	273	2.2466		

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Table E-2. Results of Specific Gravity Analysis During Phase II Testing on PG Composite Briquettes (Final Four Combinations).

Sample ID	PG:Class C Fly Ash:Portland Type II Cement	Air Dry Wt. of Samples (gm)	Water Wt. of Samples (gm)	Specific Gravity (G_s)	Average Specific Gravity	Standard Deviation (n=3)
1A	73%:25%:02%	505.2	282.3	2.2665	2.24	0.0263
1B		497.3	274.2	2.2290		
1C		509.6	279.6	2.2157		
2A	67%:30%:03%	498.1	275.0	2.2326	2.24	0.0104
2B		507.3	281.8	2.2497		
2C		495.0	273.1	2.2307		
3A	62%:35%:03%	494.4	276.0	2.2637	2.26	0.0051
3B		504.1	280.4	2.2535		
3C		502.1	279.8	2.2587		
4A	63%:35%:02%	508.1	280.4	2.2314	2.21	0.0285
4B		506.4	279.1	2.2279		
4C		508.9	275.5	2.1804		
5A	63%:35%:02%	505.8	275.5	2.1963	2.16	0.0348
5B		506.5	268.4	2.1273		
5C		501.7	270.5	2.1700		
6A	63%:35%:02%	505.7	277.7	2.2180	2.18	0.0334
6B		502.6	272.1	2.1805		
6C		503.2	269.3	2.1513		
7A	63%:35%:02%	496.9	268.0	2.1708	2.18	0.0177
7B		502.3	273.5	2.1954		
7C		492.9	264.8	2.1609		

Appendix F

SIEVE ANALYSIS DATA RESULTS

SIEVE ANALYSIS DATA RESULTS

Table F-1. Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (77%:20%:03%)

Set 1: 1.1479 kg Set 2: 1.1296 kg **Avg. Total Wt. = 1.13875 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000 0.0000	0.00	0.00	0.00	100.0000
-	19.50	0.0000 0.0455	0.02	2.00	2.00	98.0004
-	12.70	0.6578 0.5792	0.62	54.36	56.36	43.6363
4	4.75	0.2296 0.2495	0.24	21.06	77.42	22.5806
10	2.00	0.0995 0.0985	0.10	8.70	86.12	13.8789
20	0.85	0.0670 0.0634	0.07	5.73	91.85	8.1480
40	0.43	0.0365 0.0345	0.04	3.12	94.97	5.0277
60	0.25	0.0218 0.0212	0.02	1.89	96.86	3.1379
140	0.11	0.0172 0.0171	0.02	1.51	98.37	1.6305
200	0.08	0.0051 0.0054	0.01	0.46	98.83	1.1690
PAN	-	0.0153 0.0112	0.01	-	-	-
	Sum of the Avg. Mass =		1.1377			
Percent Loss of Mass During Analysis:				0.00097	< ± 2% OK!	

Particle Dia (mm)	D_{30}	D_{60}	C_u	C_c
	8.5	15	7.50	1.63

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (73%:25%:02%)

Set 1: 1.1629 kg   Set 2: 1.1720 kg   **Avg. Total Wt. = 1.16745 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000 0.0000	0.00	0.00	0.00	100.0000
-	19.50	0.0675 0.1830	0.13	10.69	10.69	89.3077
-	12.70	0.6792 0.5761	0.63	53.58	64.27	35.7265
4	4.75	0.2398 0.2470	0.24	20.78	85.05	14.9479
10	2.00	0.0700 0.0676	0.07	5.87	90.93	9.0746
20	0.85	0.0422 0.0377	0.04	3.41	94.34	5.6642
40	0.43	0.0249 0.0266	0.03	2.20	96.53	3.4659
60	0.25	0.0162 0.0158	0.02	1.37	97.90	2.1001
140	0.11	0.0121 0.0118	0.01	1.02	98.92	1.0799
200	0.08	0.0019 0.0022	0.00	0.18	99.10	0.9049
PAN	-	0.0107 0.0105	0.01	-	-	-
	Sum of the Avg. Mass =		1.1714			
Percent Loss of Mass During Analysis:			-0.003383	< ± 2% OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	2.5	8	17	6.80	1.51

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (72%:25%:02%)

Set 1: 1.2852 kg   Set 2: 1.0975 kg   **Avg. Total Wt. = 1.19135 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000 0.0000	0.00	0.00	0.00	100.0000
-	19.50	0.1345 0.1532	0.1439	11.86	11.86	88.1351
-	12.70	0.6675 0.5065	0.5870	48.42	60.28	39.7187
4	4.75	0.2402 0.2417	0.2410	19.87	80.16	19.8449
10	2.00	0.0939 0.0873	0.0906	7.47	87.63	12.3722
20	0.85	0.0646 0.0617	0.0632	5.21	92.84	7.1635
40	0.43	0.0330 0.0328	0.0329	2.71	95.55	4.4499
60	0.25	0.0189 0.0198	0.0194	1.60	97.15	2.8538
140	0.11	0.0158 0.0163	0.0161	1.32	98.47	1.5300
200	0.08	0.0049 0.0044	0.0047	0.38	98.85	1.1465
PAN	-	0.0127 0.0150	0.0139	-	-	-
Sum of the Avg. Mass =			1.2124			
Percent Loss of Mass During Analysis:			-0.01763	< ± 2% OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	2	7	15	7.50	1.63

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (69%:30%:01%)

Set 1: 1.1519 kg Set 2: 1.1171 kg **Avg. Total Wt. = 1.1345 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000 0.0000	0.00	0.00	0.00	100.0000
-	19.50	0.0901 0.0703	0.08	7.07	7.07	92.9327
-	12.70	0.6203 0.6282	0.62	55.01	62.08	37.9230
4	4.75	0.2335 0.2225	0.23	20.09	82.17	17.8313
10	2.00	0.0829 0.0814	0.08	7.24	89.41	10.5922
20	0.85	0.0491 0.0466	0.05	4.22	93.62	6.3756
40	0.43	0.0252 0.0236	0.02	2.15	95.77	4.2254
60	0.25	0.0167 0.0153	0.02	1.41	97.18	2.8155
140	0.11	0.0135 0.0126	0.01	1.15	98.33	1.6655
200	0.08	0.0040 0.0033	0.00	0.32	98.66	1.3438
PAN	-	0.0156 0.0148	0.02	-	-	-
	Sum of the Avg. Mass =		1.1348			
	Percent Loss of Mass During Analysis:		-0.000220	< ± 2% OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	2.4	7	16	6.67	1.28

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (68%:30%:02%)

Set 1: 1.2512 kg   Set 2: 1.257 kg   **Avg. Total Wt. = 1.2541 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000 0.0000	0.00	0.00	0.00	100.0000
-	19.50	0.1907 0.2195	0.21	16.35	16.35	83.6548
-	12.70	0.6588 0.6262	0.64	51.20	67.55	32.4514
4	4.75	0.2405 0.2308	0.24	18.78	86.33	13.6715
10	2.00	0.0715 0.0785	0.08	5.98	92.31	7.6945
20	0.85	0.0400 0.0442	0.04	3.36	95.66	4.3393
40	0.43	0.0193 0.0231	0.02	1.69	97.35	2.6498
60	0.25	0.0111 0.0136	0.01	0.98	98.33	1.6656
140	0.11	0.0091 0.0120	0.01	0.84	99.18	0.8248
200	0.08	0.0022 0.0039	0.00	0.24	99.42	0.5818
PAN	-	0.0089 0.0057	0.01	-	-	-
	Sum of the Avg. Mass =		1.2548			
	Percent Loss of Mass During Analysis:		-0.000558	< ± 2%. OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	3	8.0	17	5.67	1.25

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (67%:30%:03%)

Set 1: 1.1544 kg Set 2: 1.1202 kg **Avg. Total Wt. = 1.1373 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000 0.0000	0.00	0.00	0.00	100.0000
-	19.50	0.1568 0.1652	0.16	14.14	14.14	85.8648
-	12.70	0.5779 0.5558	0.57	49.77	63.90	36.0975
4	4.75	0.2272 0.2106	0.22	19.22	83.12	16.8788
10	2.00	0.0830 0.0798	0.08	7.15	90.27	9.7322
20	0.85	0.0485 0.0464	0.05	4.17	94.43	5.5663
40	0.43	0.0243 0.0235	0.02	2.10	96.53	3.4680
60	0.25	0.0141 0.0139	0.01	1.23	97.76	2.2388
140	0.11	0.0110 0.0117	0.01	1.00	98.76	1.2423
200	0.08	0.0030 0.0030	0.00	0.26	99.02	0.9789
PAN	-	0.0104 0.0118	0.01	-	-	-
	Sum of the Avg. Mass =		1.1390			
	Percent Loss of Mass During Analysis:		-0.001451	< ± 2% OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	2.8	7.9	16	5.71	1.39

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During the Phase I Testing.

Sieve Analysis Test Results (64%:35%:01%)

Set 1: 1.2678 kg Set 2: 1.2706 kg **Avg. Total Wt. = 1.2692 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000	0.00	0.00	0.00	100.0000
		0.0000				
-	19.50	0.2264	0.21	16.53	16.53	83.4698
		0.1935				
-	12.70	0.5900	0.59	46.63	63.16	36.8396
		0.5945				
4	4.75	0.2501	0.26	20.64	83.80	16.1995
		0.2742				
10	2.00	0.0836	0.09	6.82	90.62	9.3812
		0.0896				
20	0.85	0.0523	0.05	4.24	94.86	5.1374
		0.0555				
40	0.43	0.0258	0.03	2.02	96.88	3.1218
		0.0254				
60	0.25	0.0148	0.01	1.15	98.02	1.9762
		0.0143				
140	0.11	0.0120	0.01	0.93	98.95	1.0472
		0.0116				
200	0.08	0.0034	0.00	0.28	99.23	0.7716
		0.0036				
PAN	-	0.0101	0.01	-	-	-
		0.0095				
	Sum of the Avg. Mass =		1.2701			
	Percent Loss of Mass During Analysis:		-0.000709	< ± 2% OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	2.9	8.0	16	5.52	1.38

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (63%:35%:02%)

Set 1: 1.2668 kg Set 2: 1.2816 kg **Avg. Total Wt. = 1.2742 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000 0.0000	0.00	0.00	0.00	100.0000
-	19.50	0.2370 0.1899	0.21	16.74	16.74	83.2588
-	12.70	0.6362 0.6850	0.66	51.81	68.55	31.4471
4	4.75	0.2302 0.2307	0.23	18.07	86.63	13.3725
10	2.00	0.0711 0.0779	0.07	5.84	92.47	7.5294
20	0.85	0.0422 0.0442	0.04	3.39	95.86	4.1412
40	0.43	0.0203 0.0216	0.02	1.64	97.50	2.4980
60	0.25	0.0113 0.0118	0.01	0.91	98.41	1.5922
140	0.11	0.0089 0.0097	0.01	0.73	99.14	0.8627
200	0.08	0.0023 0.0020	0.00	0.17	99.31	0.6941
PAN	-	0.0084 0.0092	0.01	-	-	-
	Sum of the Avg. Mass =		1.2750			
	Percent Loss of Mass During Analysis:		-0.000589	< ± 2% OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	3	8.0	17	5.67	1.25

Table F-1 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase I Testing.

Sieve Analysis Test Results (62%:35%:02%)

Set 1: 1.1234 kg   Set 2: 1.2754 kg   **Avg. Total Wt. = 1.1994 kg**

Sieve No.	Sieve Opening (mm)	Mass of Sample Retained on Each Sieve, W_n (kg)	Avg. Mass of Sample Retained on Each Sieve, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	Percent Finer, 100-$SUMR_n$
-	25.40	0.0000	0.00	0.00	0.00	100.0000
		0.0000				
-	19.50	0.4518	0.32	26.98	26.98	73.0210
		0.1971				
-	12.70	0.3157	0.49	40.94	67.92	32.0805
		0.6690				
4	4.75	0.2021	0.21	17.67	85.59	14.4104
		0.2229				
10	2.00	0.0620	0.07	5.95	91.54	8.4567
		0.0812				
20	0.85	0.0406	0.04	3.64	95.19	4.8146
		0.0470				
40	0.43	0.0241	0.02	2.00	97.19	2.8106
		0.0241				
60	0.25	0.0131	0.01	1.11	98.30	1.6963
		0.0137				
140	0.11	0.0096	0.01	0.81	99.11	0.8856
		0.0099				
200	0.08	0.0023	0.00	0.19	99.30	0.6985
		0.0022				
PAN	-	0.0084	0.01	-	-	-
		0.0084				
	Sum of the Avg. Mass =		1.2026			
	Percent Loss of Mass During Analysis:		-0.002668	< ± 2% OK!		

Particle Dia (mm)	D_{10}	D_{30}	D_{60}	C_u	C_c
	3	8.5	18	6.00	1.34

Table F-2. Results of Sieve Analysis Conducted Subsequent to Compaction During Phase II Testing.

Sieve Analysis Test Results (73%:25%:02%)						
Sieve No.	Sieve Opening (mm)	Mass Retained, W_n (kg)	Avg. Mass Retained, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	% Finer, 100-$SUMR_n$
1"	25.40	0.0000	0.00	0.32	0.00	100.0000
		0.0000				
		0.0135				
3/4"	19.50	0.3409	0.27	19.51	19.51	80.4946
		0.2968				
		0.1841				
1/2"	12.70	0.6350	0.67	47.84	67.35	32.6521
		0.6195				
		0.7612				
3/8"	9.51	0.0869	0.09	6.43	73.77	26.2271
		0.1054				
		0.0784				
4	4.75	0.1301	0.13	9.30	83.08	16.9230
		0.1416				
		0.1203				
10	2.00	0.1053	0.10	7.38	90.45	9.5462
		0.1076				
		0.0979				
18	1.00	0.0448	0.05	3.40	93.86	6.1426
		0.0502				
		0.0484				
20	0.85	0.0076	0.01	0.56	94.42	5.5848
		0.0079				
		0.0080				
40	0.43	0.0266	0.03	2.01	96.43	3.5745
		0.0297				
		0.0284				
60	0.25	0.0166	0.02	1.24	97.67	2.3308
		0.0182				
		0.0176				
140	0.11	0.0143	0.02	1.09	98.76	1.2366
		0.0164				
		0.0154				
200	0.08	0.0041	0.00	0.30	99.06	0.9375
		0.0044				
		0.0041				
PAN	-	0.0080	0.01	0.62	-	-
		0.0092				
		0.0088				
	Sum of the Avg. Mass =		1.4044			
	Percent Loss of Mass During Analysis:		-0.202964	< ± 2% OK!		

Table F-2 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase II Testing.

Sieve Analysis Test Results (67%:30%:03%)						
Sieve No.	Sieve Opening (mm)	Mass Retained, W_n (kg)	Avg. Mass Retained, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	% Finer, 100-$SUMR_n$
1"	25.40	0.0000 0.0000 0.0000	0.00	0.00	0.00	100.0000
3/4"	19.50	0.3632 0.3284 0.3516	0.35	24.24	24.24	75.7570
1/2"	12.70	0.5886 0.6365 0.6424	0.62	43.40	67.64	32.3581
3/8"	9.51	0.1028 0.0813 0.0814	0.09	6.17	73.81	26.1881
4	4.75	0.1404 0.1181 0.1353	0.13	9.15	82.96	17.0366
10	2.00	0.1038 0.1108 0.1129	0.11	7.61	90.57	9.4258
18	1.00	0.0484 0.0520 0.0543	0.05	3.60	94.17	5.8307
20	0.85	0.0078 0.0085 0.0087	0.01	0.58	94.75	5.2497
40	0.43	0.0268 0.0299 0.0307	0.03	2.03	96.78	3.2186
60	0.25	0.0165 0.0184 0.0185	0.02	1.24	98.02	1.9776
140	0.11	0.0144 0.0163 0.0160	0.02	1.09	99.11	0.8924
200	0.08	0.0036 0.0043 0.0040	0.00	0.28	99.38	0.6158
PAN	-	0.0085 0.0092 0.0088	0.01	0.62	-	-
	Sum of the Avg. Mass =		1.4344			
	Percent Loss of Mass During Analysis:		-0.228632	< ± 2% OK!		

Table F-2 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase II Testing.

Sieve Analysis Test Results (63%:35%:02%)						
Sieve No.	Sieve Opening (mm)	Mass Retained, W_n (kg)	Avg. Mass Retained, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	% Finer, 100-$SUMR_n$
1"	25.40	0.0000 0.0000 0.0000	0.00	0.00	0.00	100.0000
3/4"	19.50	0.2469 0.2106 0.2707	0.24	16.20	16.20	83.8001
1/2"	12.70	0.7001 0.6939 0.7068	0.70	46.74	62.94	37.0648
3/8"	9.51	0.0717 0.1108 0.0990	0.09	6.26	69.20	30.8024
4	4.75	0.1393 0.1776 0.1148	0.14	9.60	78.80	21.1986
10	2.00	0.1398 0.1404 0.1285	0.14	9.09	87.89	12.1065
18	1.00	0.0637 0.0631 0.0607	0.06	4.17	92.06	7.9353
20	0.85	0.0103 0.0098 0.0110	0.01	0.69	92.76	7.2434
40	0.43	0.0392 0.0372 0.0389	0.04	2.57	95.32	4.6784
60	0.25	0.0249 0.0239 0.0282	0.03	1.71	97.03	2.9655
140	0.11	0.0234 0.0220 0.0222	0.02	1.50	98.54	1.4616
200	0.08	0.0073 0.0078 0.0068	0.01	0.49	99.03	0.9744
PAN	-	0.0153 0.0134 0.0151	0.01	0.97	-	-
	Sum of the Avg. Mass =		1.4984			
	Percent Loss of Mass During Analysis:		-0.283453	< ± 2% OK!		

Table F-2 (Cont.). Results of Sieve Analysis Conducted Subsequent to Compaction During Phase II Testing.

Sieve Analysis Test Results (62%:35%:03%)						
Sieve No.	Sieve Opening (mm)	Mass Retained, W_n (kg)	Avg. Mass Retained, W_n (kg)	Percent of Mass Retained on Each Sieve, R_n	Cumulative Percent Retained, $SUMR_n$	% Finer, $100\text{-}SUMR_n$
1"	25.40	0.0000	0.00	0.00	0.00	100.0000
		0.0000				
		0.0000				
3/4"	19.50	0.3072	0.35	23.83	23.83	76.1702
		0.3629				
		0.3659				
1/2"	12.70	0.6426	0.61	41.97	65.80	34.2013
		0.6056				
		0.5764				
3/8"	9.51	0.0781	0.08	5.57	71.37	28.6325
		0.0905				
		0.0735				
4	4.75	0.1398	0.14	9.47	80.84	19.1581
		0.1268				
		0.1453				
10	2.00	0.1317	0.13	8.76	89.60	10.3991
		0.1192				
		0.1299				
18	1.00	0.0611	0.06	4.07	93.67	6.3278
		0.0545				
		0.0614				
20	0.85	0.0092	0.01	0.60	94.27	5.7274
		0.0083				
		0.0086				
40	0.43	0.0327	0.03	2.22	96.49	3.5124
		0.0294				
		0.0342				
60	0.25	0.0192	0.02	1.32	97.81	2.1898
		0.0177				
		0.0206				
140	0.11	0.0168	0.02	1.17	98.98	1.0236
		0.0156				
		0.0183				
200	0.08	0.0047	0.00	0.31	99.29	0.7131
		0.0041				
		0.0047				
PAN	-	0.0099	0.01	0.71	-	-
		0.0094				
		0.0117				
	Sum of the Avg. Mass =		1.4492			
	Percent Loss of Mass During Analysis:		-0.241309	< ± 2% OK!		

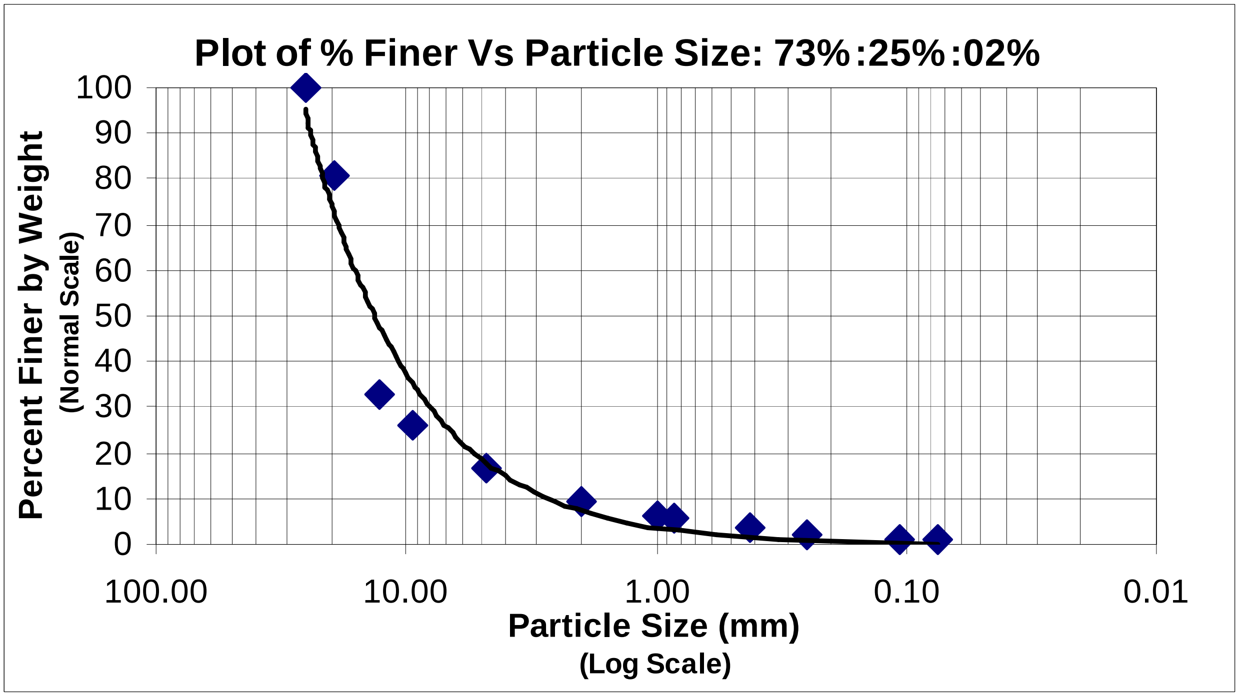


Figure F-1. Plot of Particle Size Versus Percent Finer by Weight for Determination of Particle Gradation.

Particle Dia.	mm
D_{10}	3
D_{30}	8
D_{60}	17
C_u	5.67
C_c	1.25

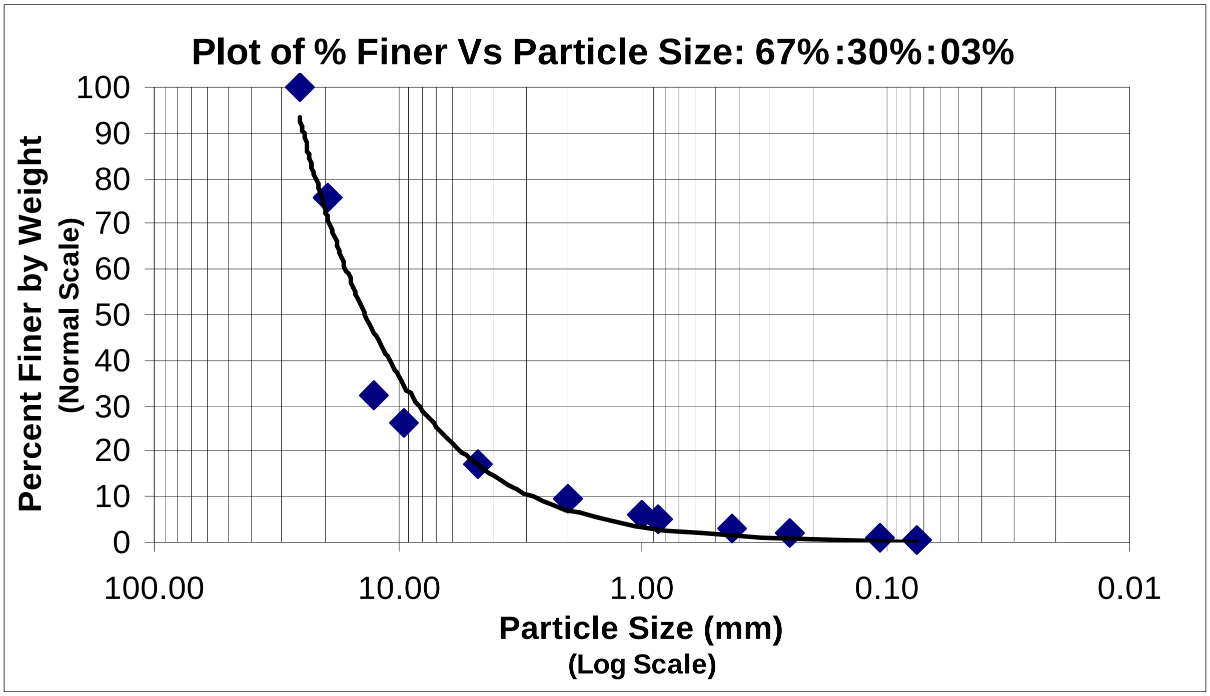


Figure F-2. Plot of Particle Size Versus Percent Finer by Weight for Determination of Particle Gradation.

Particle Dia.	mm
D_{10}	3
D_{30}	8
D_{60}	18
C_u	6.00
C_c	1.19

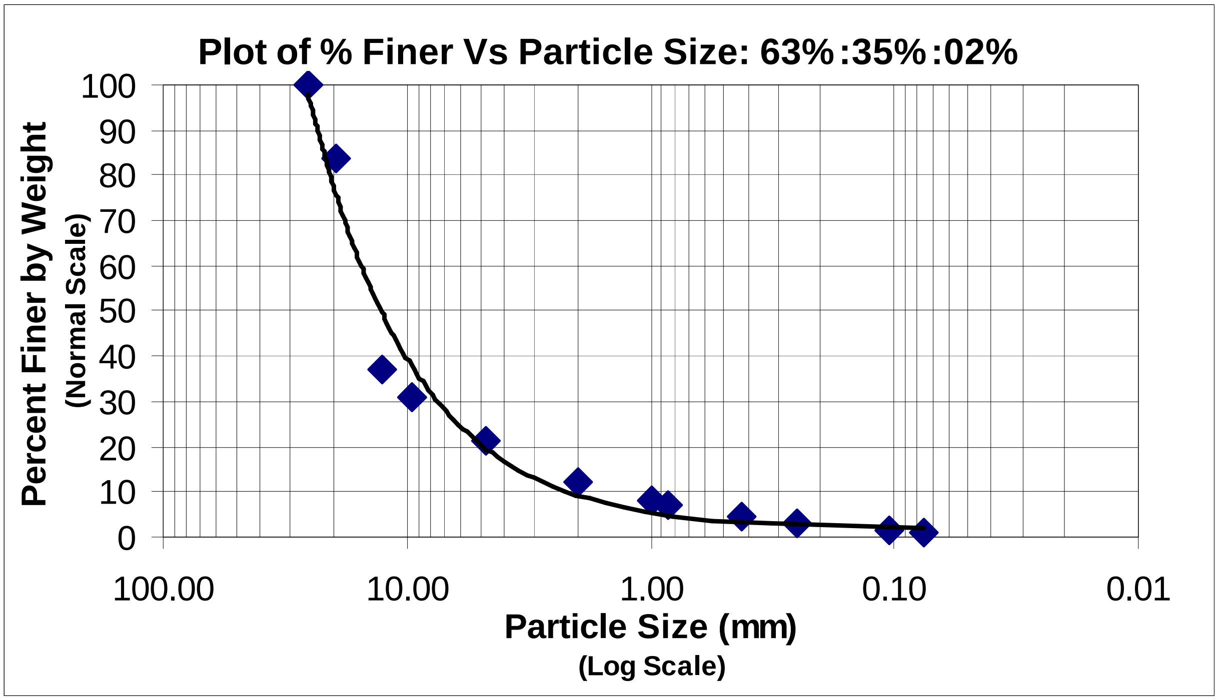


Figure F-3. Plot of Particle Size Versus Percent Finer by Weight for Determination of Particle Gradation.

Particle Dia.	mm
D_{10}	2.5
D_{30}	7.5
D_{60}	16.5
C_u	6.60
C_c	1.36

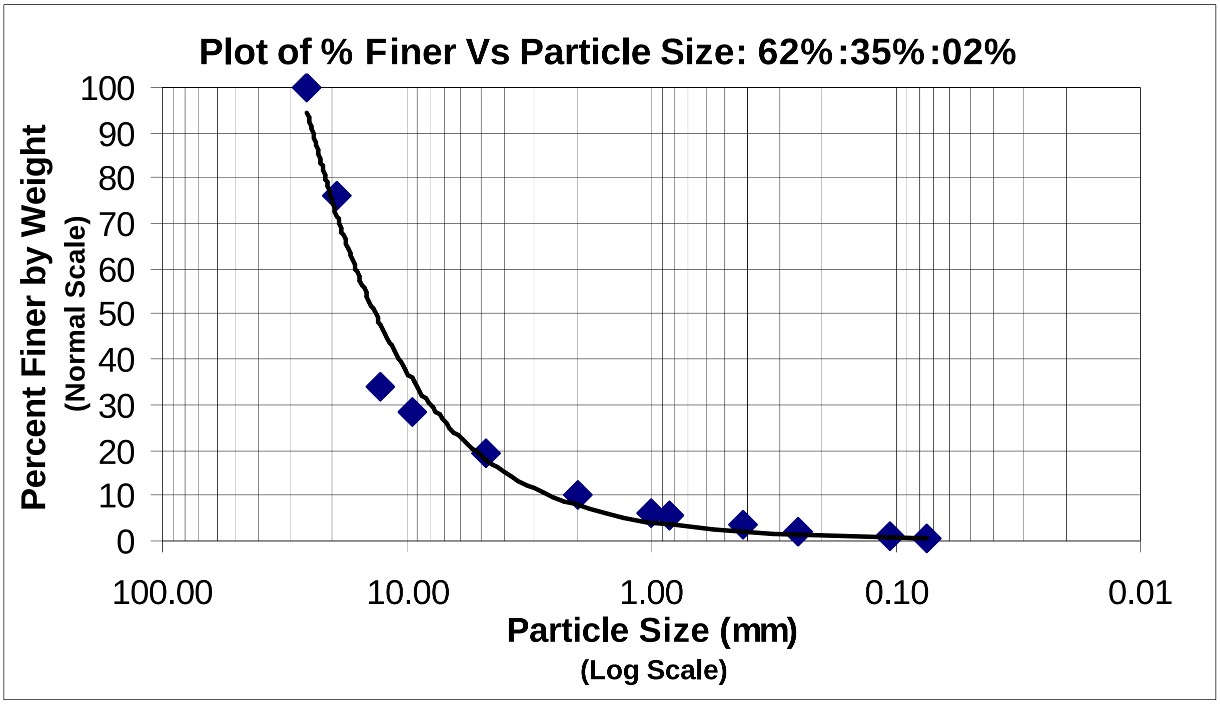


Figure F-4. Plot of Particle Size Versus Percent Finer by Weight for Determination of Particle Gradation.

Particle Dia.	mm
D_{10}	2.8
D_{30}	8
D_{60}	16
C_u	5.71
C_c	1.43

Appendix G

SURFACE HARDNESS TEST RESULTS

SURFACE HARDNESS TEST RESULTS

Table G-1. Results of Surface Hardness Tests on Control PG Briquettes, Phase I Testing.

Surface Hardness Test Results on Control PG Briquettes (Initial Nine Combinations)			
PG:Class C Fly Ash:Portland Type II Cement	Mean Surface Hardness (mm^{-1})	Average Surface Hardness (mm^{-1})	Standard Deviation (n=3)
77%:20%:03%	41.27	39.06	2.73
	36.00		
	39.91		
73%:25%:03%	56.67	53.33	2.90
	51.94		
	51.39		
72%:25%:03%	41.39	44.64	5.99
	40.97		
	51.55		
69%:30%:01%	43.15	39.44	3.73
	35.69		
	39.48		
68%:30%:02%	44.51	45.86	2.39
	48.61		
	44.44		
67%:30%:03%	45.99	44.97	10.31
	54.72		
	34.19		
64%:35%:01%	65.00	39.81	21.81
	27.50		
	26.94		
63%:35%:02%	52.38	55.99	6.24
	52.38		
	63.19		
62%:35%:03%	35.83	45.09	17.25
	34.44		
	65.00		

Table G-2. Results of Surface Hardness Tests on Leached PG Briquettes, Phase I Testing.

Surface Hardness Test Results on Leached PG Briquettes (Initial Nine Combinations)			
PG:Class C Fly Ash:Portland Type II Cement	Mean Surface Hardness (mm^{-1})	Average Surface Hardness (mm^{-1})	Standard Deviation (n=3)
77%:20%:03%	10.43	10.07	1.96
	7.96		
	11.82		
73%:25%:03%	31.44	29.34	11.03
	17.40		
	39.17		
72%:25%:03%	17.77	25.38	8.98
	23.09		
	35.28		
69%:30%:01%	38.06	47.20	8.10
	50.07		
	53.47		
68%:30%:02%	63.06	47.79	19.67
	54.72		
	25.60		
67%:30%:03%	58.33	57.13	2.58
	58.89		
	54.17		
64%:35%:01%	33.24	29.30	8.27
	34.86		
	19.79		
63%:35%:02%	25.23	20.79	5.51
	22.51		
	14.62		
62%:35%:03%	29.72	34.50	14.73
	51.02		
	22.75		

Table G-3. Results of Surface Hardness Tests on Control PG Briquettes, Phase II Testing.

Surface Hardness Test Results on Control PG Briquettes (Best FOUR Combinations)				
Sample ID	PG:Class C Fly Ash:Portland Type II Cement	Mean Surface Hardness (mm^{-1})	Average Surface Hardness (mm^{-1})	Standard Deviation (n=3)
1A	73%:25%:02%	67.2222	73.33	6.7358
1B		72.2222		
1C		80.5556		
2A	67%:30%:03%	88.8889	89.35	10.4244
2B		79.1667		
2C		100.0000		
3A	62%:35%:03%	66.6667	74.07	6.9906
3B		75.0000		
3C		80.5556		
4A	63%:35%:02%	91.6667	87.04	5.7824
4B		88.8889		
4C		80.5556		
5A	63%:35%:02%	88.8889	81.48	8.4863
5B		83.3333		
5C		72.2222		
6A	63%:35%:02%	80.5556	76.85	5.2582
6B		79.1667		
6C		70.8333		
7A	63%:35%:02%	80.5556	68.98	11.1400
7B		58.3333		
7C		68.0556		

Table G-4. Results of Surface Hardness Tests on Leached PG Briquettes, Phase II Testing.

Surface Hardness Test Results on Leached PG Briquettes (Best FOUR Combinations)				
Sample ID	PG:Class C Fly Ash:Portland Type II Cement	Mean Surface Hardness (mm^{-1})	Average Surface Hardness (mm^{-1})	Standard Deviation (n=3)
1A	73%:25%:02%	15.3042	17.09	4.1417
1B		21.8254		
1C		14.1414		
2A	67%:30%:03%	25.0000	24.64	7.2648
2B		17.1970		
2C		31.7130		
3A	62%:35%:03%	54.7222	45.19	13.5125
3B		51.1111		
3C		29.7222		
4A	63%:35%:02%	16.5419	12.20	4.7757
4B		7.0854		
4C		12.9765		
5A	63%:35%:02%	14.3773	17.71	7.3141
5B		26.0985		
5C		12.6583		
6A	63%:35%:02%	20.8654	20.66	3.3613
6B		23.9087		
6C		17.1958		
7A	63%:35%:02%	16.1895	15.52	2.5077
7B		12.7519		
7C		17.6335		

Appendix H

DRY AND WET WEIGHT STUDY RESULTS

DRY AND WET WEIGHT STUDY RESULTS

Table H-1. Porosity Analysis for Control Briquettes During Phase I Testing.

Porosity – (Wet / Dry Weights Study) of Control PG Briquettes (Initial NINE Combinations)								
PG:Class C Fly Ash:Portland Type II Cement	Wet Weight (gm)	Dry Weight (gm)	Difference: Dry&Wet Weights (gm)	Avg.	Avg. Briquette Vol.(cm^3)	Porosity (%)	Mean Porosity (%)	Std. Dev. (n=3)
77%:20%:03%	16.77	15.45	1.32	1.24	8.50	15.52	14.55	0.84
	15.70	14.51	1.19			14.02		
	15.49	14.29	1.20			14.12		
73%:25%:03%	16.91	15.74	1.17	1.16	8.50	13.80	13.68	0.45
	16.92	15.80	1.12			13.19		
	16.88	15.69	1.19			14.05		
72%:25%:03%	15.87	14.66	1.22	1.21	8.50	14.31	14.25	0.30
	15.86	14.63	1.23			14.53		
	15.61	14.43	1.18			13.93		
69%:30%:01%	13.69	12.45	1.24	1.21	8.50	14.64	14.29	0.31
	14.18	12.98	1.20			14.15		
	13.94	12.75	1.20			14.07		
68%:30%:02%	14.37	13.25	1.12	1.17	8.50	13.14	13.73	0.52
	15.69	14.50	1.19			14.01		
	15.63	14.44	1.19			14.05		
67%:30%:03%	16.24	15.01	1.24	1.22	8.50	14.55	14.40	0.13
	16.42	15.21	1.22			14.32		
	16.09	14.87	1.22			14.34		
64%:35%:01%	15.87	14.73	1.13	1.16	8.50	13.35	13.69	0.94
	16.10	14.85	1.25			14.76		
	16.10	15.00	1.10			12.97		
63%:35%:02%	15.33	14.15	1.18	1.14	8.50	13.83	13.41	0.36
	14.62	13.50	1.12			13.17		
	15.02	13.90	1.12			13.23		
62%:35%:03%	15.72	14.60	1.12	1.12	8.50	13.14	13.18	0.30
	15.03	13.88	1.15			13.50		
	15.01	13.92	1.10			12.91		

Table H-2. Porosity Analysis for Leached Briquettes During Phase I Testing.

Porosity – (Wet / Dry Weights Study) of Leached PG Briquettes (Initial NINE Combinations)								
PG:Class C Fly Ash:Portland Type II Cement	Wet Weight (gm)	Dry Weight (gm)	Difference: Dry&Wet Weights (gm)	Avg.	Avg. Briquette Vol.(cm^3)	Porosity (%)	Mean Porosity (%)	Std. Dev. (n=3)
77%:20%:03%	14.15	12.25	1.90	1.86	8.50	22.35	21.83	1.01
	13.85	12.09	1.76			20.66		
	15.26	13.35	1.91			22.47		
73%:25%:03%	16.53	15.07	1.46	1.54	8.50	17.22	18.15	1.02
	16.11	14.47	1.63			19.23		
	16.25	14.72	1.53			18.01		
72%:25%:03%	13.93	12.24	1.69	1.67	8.50	19.93	19.69	0.62
	15.16	13.45	1.71			20.16		
	13.75	12.13	1.61			18.99		
69%:30%:01%	12.63	10.97	1.66	1.62	8.50	19.47	19.09	0.73
	13.15	11.49	1.66			19.54		
	13.30	11.75	1.55			18.25		
68%:30%:02%	14.64	13.20	1.44	1.47	8.50	16.99	17.35	0.34
	14.71	13.24	1.48			17.37		
	14.64	13.14	1.50			17.67		
67%:30%:03%	14.96	13.49	1.46	1.49	8.50	17.21	17.47	0.66
	14.83	13.39	1.44			16.98		
	15.45	13.90	1.55			18.23		
64%:35%:01%	13.78	12.47	1.31	1.38	8.50	15.43	16.21	1.27
	14.80	13.48	1.32			15.53		
	15.37	13.86	1.50			17.68		
63%:35%:02%	14.37	12.95	1.42	1.35	8.50	16.72	15.86	1.03
	13.81	12.44	1.37			16.15		
	13.83	12.57	1.25			14.72		
62%:35%:03%	14.20	12.90	1.30	1.30	8.50	15.31	15.29	0.35
	14.42	13.15	1.27			14.93		
	14.76	13.43	1.33			15.64		

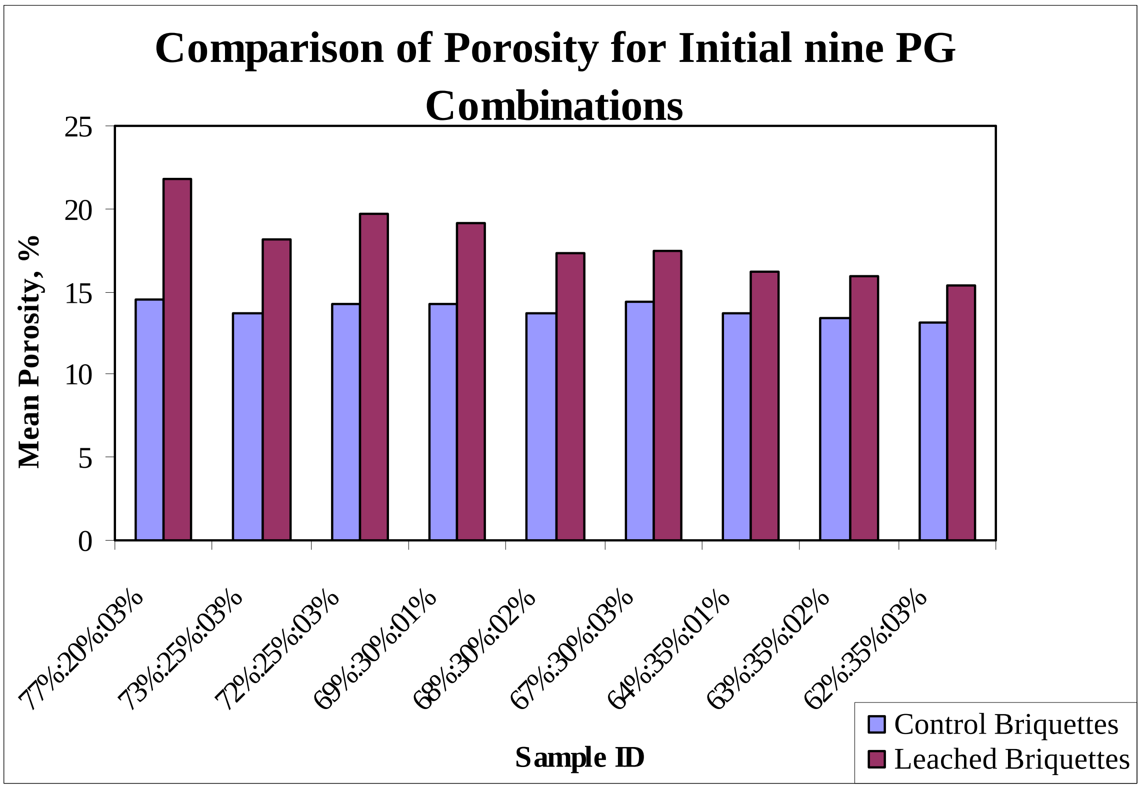


Figure H-1. Comparison of the Porosities of Control and Leached Briquettes During Phase I Testing.

Table H-3. Porosity Analysis for Control Briquettes During Phase II Testing.

Porosity – (Wet / Dry Weights Study) of Control PG Briquettes (Best Four Combinations)								
PG:Class C Fly Ash:Portland Type II Cement	Wet Weight (gm)	Dry Weight (gm)	Difference: Dry&Wet Weights (gm)	Avg.	Avg. Briquette Vol.(cm^3)	Porosity (%)	Mean Porosity (%)	Std. Dev. (n=3)
73%:25%:03%	20.66	19.82	0.84	0.86	9.03	9.31	9.52	1.40
	19.77	18.78	0.99			11.01		
	17.39	16.65	0.74			8.24		
67%:30%:03%	20.72	19.87	0.85	0.90	9.03	9.39	9.97	0.58
	20.31	19.36	0.95			10.55		
	20.78	19.88	0.90			9.97		
63%:35%:02%	18.98	18.00	0.97	1.0	9.03	10.79	11.07	0.31
	19.37	18.34	1.03			11.41		
	19.27	18.28	1.00			11.02		
62%:35%:03%	20.49	19.56	0.93	0.88	9.03	10.28	9.77	0.55
	20.51	19.68	0.83			9.19		
	22.87	21.98	0.89			9.84		
63%:35%:02%	73.32	69.14	4.11	3.96	31.33	13.12	12.63	0.88
	74.79	71.07	3.64			11.62		
	73.07	68.91	4.12			13.15		
63%:35%:02%	19.31	18.36	0.89	0.98	9.03	9.86	10.87	0.95
	19.23	18.22	0.99			10.99		
	19.19	18.13	1.06			11.75		
63%:35%:02%	70.79	67.05	3.68	3.62	31.33	11.73	11.56	0.72
	74.42	70.60	3.82			12.19		
	71.88	68.39	3.38			10.78		

Table H-4. Porosity Analysis for Leached Briquettes During Phase II Testing.

Porosity – (Wet / Dry Weights Study) of <u>Leached</u> PG Briquettes (Best Four Combinations)								
PG:Class C Fly Ash:Portland Type II Cement	Wet Weight (gm)	Dry Weight (gm)	Difference: Dry&Wet Weights (gm)	Avg.	Avg. Briquette Vol.(cm^3)	Porosity (%)	Mean Porosity (%)	Std. Dev. (n=3)
73%:25%:03%	16.98	15.72	1.26	1.28	9.03	13.93	14.20	0.23
	18.37	17.07	1.30			14.35		
	16.83	15.54	1.29			14.32		
67%:30%:03%	19.60	18.52	1.08	1.11	9.03	12.00	12.28	0.33
	17.32	16.22	1.10			12.19		
	19.95	18.81	1.14			12.64		
63%:35%:02%	18.22	16.67	1.55	1.56	9.03	17.17	17.25	0.13
	17.65	16.07	1.57			17.39		
	17.92	16.37	1.55			17.18		
62%:35%:03%	19.90	18.80	1.10	1.08	9.03	12.14	11.99	0.28
	19.80	18.74	1.05			11.67		
	20.01	18.91	1.10			12.17		
63%:35%:02%	69.44	64.17	5.27	5.38	31.33	16.82	17.17	0.52
	77.53	72.23	5.30			16.92		
	69.74	64.18	5.57			17.77		
63%:35%:02%	18.40	16.75	1.65	1.63	9.03	18.26	18.04	0.30
	18.20	16.60	1.60			17.69		
	18.85	17.21	1.64			18.18		
63%:35%:02%	70.40	65.03	5.37	5.12	31.33	17.14	16.35	0.73
	65.47	60.39	5.07			16.20		
	68.05	63.13	4.92			15.71		

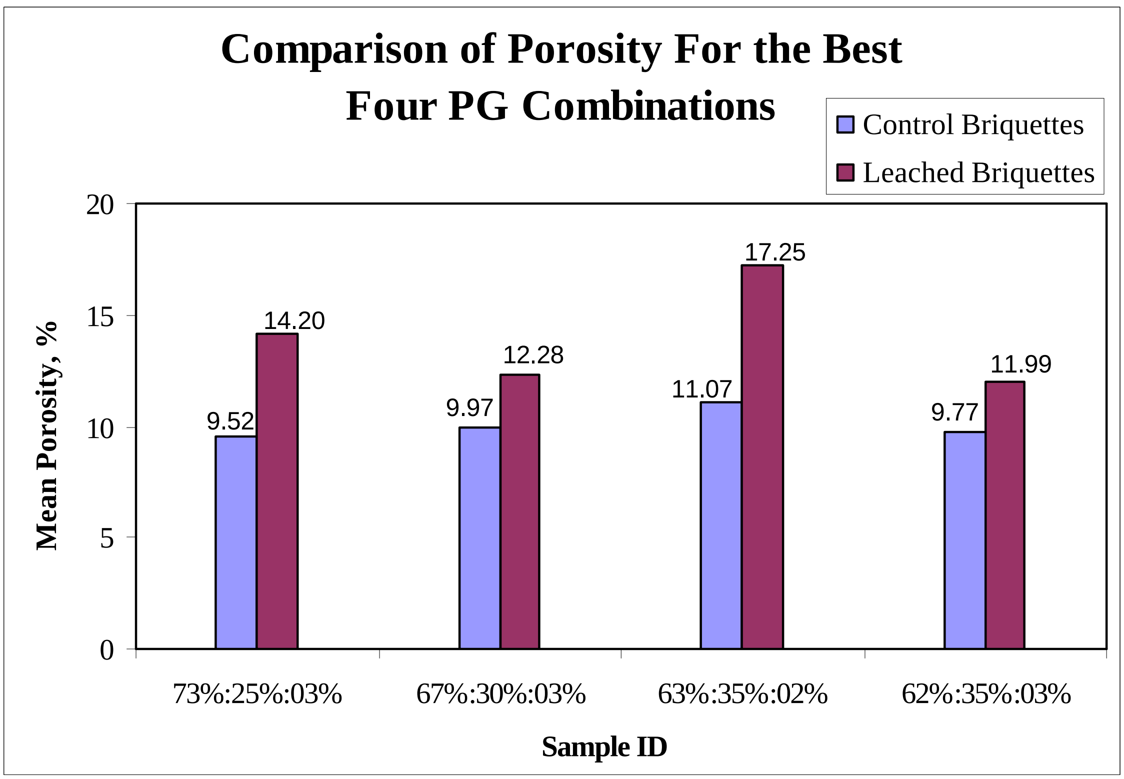


Figure H-2. Plot Comparing the Porosities of Control and Leached Briquettes During Phase I Testing.

Appendix I

METAL TCLP RESULTS

METAL TCLP RESULTS

Table I-1. Results of TCLP Analysis for Raw Materials.

Metal	Lower Detection Limits, ppm	EPA Regulatory Limits, ppm [a]	Typical Trace Element Conc. in PG, ppm [b]	Raw PG	Oven-Dried PG	Class C Fly Ash	Portland Type II Cement
Al	0.5			2.76	2.8	2.26	2.24
As	0.05	5.0	1.0 - 5.0	[c] -	-	-	-
Ba	0.05			-	-	-	-
Cd	0.075	1.0	0.3 - 0.4	-	-	-	-
Ca	10			730.6	702.54	1431.34	2200
Cu	0.05	130.0	N/A	0.12	0.14	0.12	0.12
Fe	1	30.0	N/A	0.38	0.58	0.54	0.34
Pb	0.25	5.0	2.0 - 10.0	-	-	-	-
Mg	5			9.26	9.3	287.14	8.64
Mn	0.525			-	-	0.36	-
Mo	0.05			0.06	0.04	0.08	0.14
Ni	0.1			0.08	0.1	0.14	-
P	5			19.3	19.14	-	-
K	18.75			54.98	53.04	30.32	114.2
Se	0.25	1.0	1.0	-	-	-	-
Na	5			1154	1129.34	73.64	53.94
S	5			747.94	718.14	231.34	70.4
Zn	0.25	500.0	N/A	0.44	0.42	0.26	0.76

Table I-2. Results of TCLP Analysis for Briquettes, Phase II Testing.

Metal	Detection Limits, ppm	EPA Limits, ppm [a]	Typical Trace Element Conc. in PG, ppm [b]	PG Composite 73%:25%:2%	PG Composite 67%:30%:3%	PG Composite 63%:35%:2%	PG Composite 62%:35%:3%
Al	0.5			20.06	12.66	43.98	7.89
As	0.05	5.0	1.0 - 5.0	0.24	0.22	0.18	0.16
Ba	0.05			7.76	11.04	11.70	13.52
Cd	0.075	1.0	0.3 - 0.4	0.16	0.12	0.10	0.14
Ca	10			1626.00	3140.00	2006.00	3352.00
Cu	0.05	130.0	N/A	0.19	0.20	0.32	0.13
Fe	1	30.0	N/A	0.30	0.58	0.74	0.44
Pb	0.25	5.0	2.0 - 10.0	0.16	0.28	0.16	0.20
Mg	5			129.60	267.70	224.20	322.00
Mn	0.525			0.77	1.26	1.23	1.32
Mo	0.05			0.06	0.11	0.04	0.13
Ni	0.1			0.22	0.46	0.35	0.47
P	5			0.02	0.02	0.02	0.02
K	18.75			31.12	53.10	32.91	54.61
Se	0.25	1.0	1.0	0.32	0.30	0.14	0.17
Na	5			67.03	119.50	93.42	129.40
S	5			336.80	600.40	470.50	652.00
Zn	0.25	500.0	N/A	1.31	1.71	2.23	2.13

Appendix J

RADIUM LEACHING STUDY DATA

RADIUM LEACHING STUDY DATA

Table J-1. Ra^{226} Measurements for the Four PG Composite Compositions for the 28-Day Time Period During the 77-Day Dynamic Leaching Test.

Radium Leaching Study Data: Day 0.08					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.34	0.0782	0.0782	0.00272
2A	67%:30%:03%	0.31	0.0713	0.0713	0.00248
3A	62%:35%:03%	0.40	0.0920	0.0920	0.00320
4A	63%:35%:02%	0.12	0.0276	0.0276	0.00096
Radium Leaching Study Data: Day 0.29					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.28	0.0644	0.1426	0.00496
2A	67%:30%:03%	0.33	0.0759	0.1472	0.00512
3A	62%:35%:03%	0.30	0.069	0.1610	0.00560
4A	63%:35%:02%	0.50	0.115	0.1426	0.00496
Radium Leaching Study Data: Day 1					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.35	0.0805	0.2231	0.00776
2A	67%:30%:03%	0.37	0.0851	0.2323	0.00808
3A	62%:35%:03%	0.48	0.1104	0.2714	0.00944
4A	63%:35%:02%	0.37	0.0851	0.2277	0.00792

Table J-1 (Cont.). Ra^{226} Measurements for the Four PG Composite Compositions for the 28-Day Time Period During the 77-Day Dynamic Leaching Test.

Radium Leaching Study Data: Day 2					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.32	0.0736	0.2967	0.01032
2A	67%:30%:03%	0.89	0.2047	0.4370	0.01520
3A	62%:35%:03%	0.62	0.1426	0.4140	0.01440
4A	63%:35%:02%	0.44	0.1012	0.3289	0.01144

Radium Leaching Study Data: Day 3					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.27	0.0621	0.3588	0.01248
2A	67%:30%:03%	0.64	0.1472	0.5842	0.02032
3A	62%:35%:03%	0.12	0.0276	0.4416	0.01536
4A	63%:35%:02%	0.48	0.1104	0.4393	0.01528

Radium Leaching Study Data: Day 4					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.55	0.1265	0.4853	0.01688
2A	67%:30%:03%	0.18	0.0414	0.6256	0.02176
3A	62%:35%:03%	0.32	0.0736	0.5152	0.01792
4A	63%:35%:02%	0.62	0.1426	0.5819	0.02024

Radium Leaching Study Data: Day 5					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.43	0.0989	0.5842	0.02032
2A	67%:30%:03%	0.41	0.0943	0.7199	0.02504
3A	62%:35%:03%	0.31	0.0713	0.5865	0.02040
4A	63%:35%:02%	0.27	0.0621	0.6440	0.02240

Table J-1 (Cont.). Ra^{226} Measurements for the Four PG Composite Compositions for the 28-Day Time Period During the 77-Day Dynamic Leaching Test.

Radium Leaching Study Data: Day 8					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.29	0.0667	0.6509	0.02264
2A	67%:30%:03%	0.19	0.0437	0.7636	0.02656
3A	62%:35%:03%	0.30	0.069	0.6555	0.02280
4A	63%:35%:02%	0.34	0.0782	0.7222	0.02512

Radium Leaching Study Data: Day 11					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.62	0.1426	0.7935	0.02760
2A	67%:30%:03%	0.36	0.0828	0.8464	0.02944
3A	62%:35%:03%	0.27	0.0621	0.7176	0.02496
4A	63%:35%:02%	0.51	0.1173	0.8395	0.02920

Radium Leaching Study Data: Day 14					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.37	0.0851	0.8786	0.03056
2A	67%:30%:03%	0.31	0.0713	0.9177	0.03192
3A	62%:35%:03%	0.22	0.0506	0.7682	0.02672
4A	63%:35%:02%	0.24	0.0552	0.8947	0.03112

Radium Leaching Study Data: Day 21					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.48	0.1104	0.9890	0.03440
2A	67%:30%:03%	0.24	0.0552	0.9729	0.03384
3A	62%:35%:03%	0.49	0.1127	0.8809	0.03064
4A	63%:35%:02%	0.79	0.1817	1.0764	0.03744

Table J-1 (Cont.). Ra^{226} Measurements for the Four PG Composite Compositions for the 28-Day Time Period During the 77-Day Dynamic Leaching Test.

Radium Leaching Study Data: Day 28					
No.	PG:Class C Fly Ash:Portland Type II Cement	Radium Amount (pCi/L)	Ra^{226} Leached (pCi)	Cumulative Release [Ra^{226} Leached] (pCi)	Cumulative Ra^{226} Flux (pCi/cm^2)
1A	73%:25%:02%	0.37	0.0851	1.0741	0.03736
2A	67%:30%:03%	0.41	0.0943	1.0672	0.03712
3A	62%:35%:03%	0.66	0.1518	1.0327	0.03592
4A	63%:35%:02%	0.35	0.0805	1.1569	0.04024

ID	PG:Class C Fly Ash: Portland Type II Cement	Dry Wt. (gm)	PG	Fly Ash	Cement	Initial Ra^{226} (Co, pCi/cm^3)	Total Available Ra^{226} for Leaching (pCi)	Cumul. Ra^{226} Release (pCi)	% Ra^{226} Release
1A	73%:25%:02%	18.69	13.64	4.67	0.37	56.234	507.8	1.074	0.212
2A	67%:30%:03%	19.90	12.51	5.60	0.56	51.612	466.1	1.067	0.229
3A	62%:35%:03%	20.64	11.58	6.54	0.56	47.761	431.3	1.033	0.239
4A	63%:35%:02%	18.48	11.77	6.54	0.37	48.531	438.2	1.157	0.264
	Average	19.43	12.37	5.84	0.47	51.034	460.8	1.083	0.236

Average Volume of Briquette = 9.03 cm^3
Density = 2.15$g.cm^{-3}$
Water Content in the composite briquette = 4 %
Average Radium Concentration in Raw PG = 37.24 pCi/gm

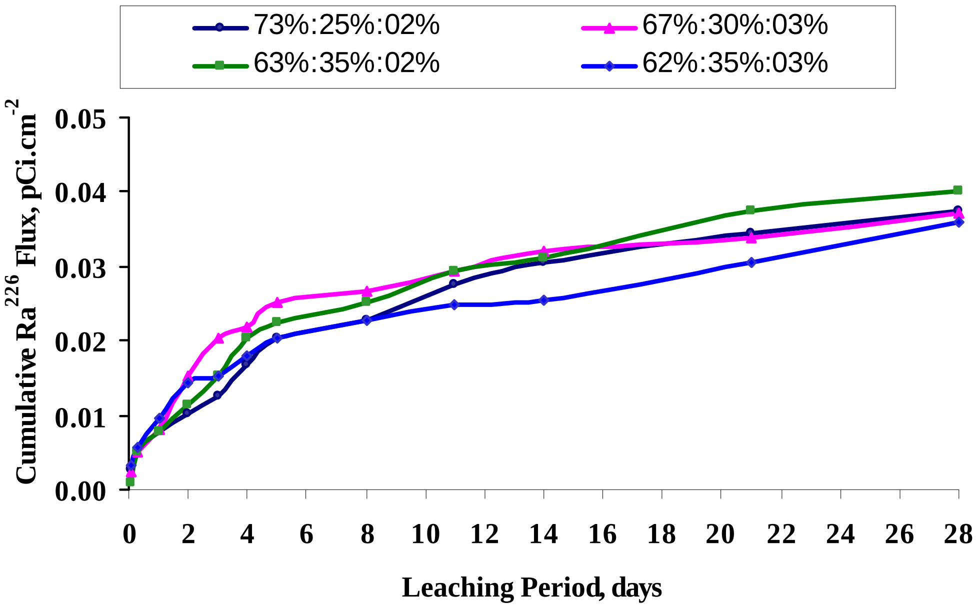


Figure J-1. Cumulative Flux Rate of Radium Versus Leaching Period.

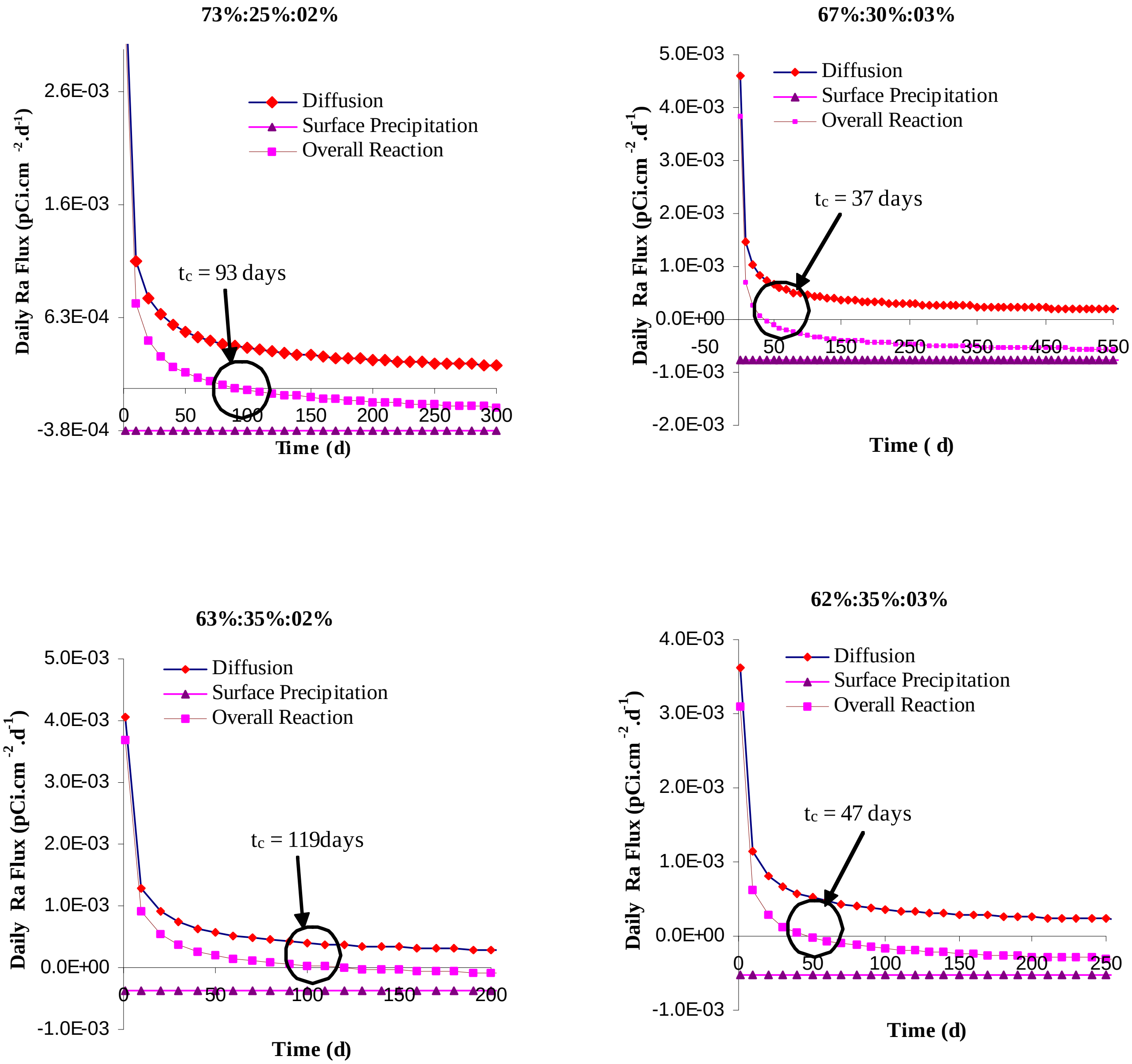


Figure J-2. Calculation of t_c for Ra^{226} for Selected Four PG Composites from the 28-Day Dynamic Leaching Data.

Appendix K

METALS DYNAMIC LEACHING STUDY DATA

METALS DYNAMIC STUDY DATA

Table K-1. Cu^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Cu^{2+} Amount (mg/L)	Cu^{2+} Leached (mg)	Daily Cu^{2+} (mg/cm^2)	Cumulative Cu^{2+} Flux (mg/cm^2)
Copper Leaching Study Data: Day 0.08					
1	73%:25%:02%	0.16	0.0368	0.0013	0.0013
2		0.12	0.0276	0.0010	0.0010
3		0.08	0.0184	0.0006	0.0006
4	67%:30%:03%	0.27	0.0621	0.0022	0.0022
5		0.12	0.0276	0.0010	0.0010
6		0.13	0.0299	0.0010	0.0010
7	63%:35%:02%	0.29	0.0667	0.0023	0.0023
8		0.12	0.0276	0.0010	0.0010
9		0.19	0.0437	0.0015	0.0015
10	62%:35%:03%	0.28	0.0644	0.0022	0.0022
11		0.12	0.0276	0.0010	0.0010
12		0.22	0.0506	0.0018	0.0018
Copper Leaching Study Data: Day 0.29					
1	73%:25%:02%	0.32	0.0736	0.0026	0.0038
2		0.12	0.0276	0.0010	0.0019
3		0.12	0.0276	0.0010	0.0016
4	67%:30%:03%	0.11	0.0253	0.0009	0.0030
5		0.12	0.0276	0.0010	0.0019
6		0.12	0.0276	0.0010	0.0020
7	63%:35%:02%	0.12	0.0276	0.0010	0.0033
8		0.21	0.0483	0.0017	0.0026
9		0.00	0.0000	0.0000	0.0015
10	62%:35%:03%	0.16	0.0368	0.0013	0.0035
11		0.12	0.0276	0.0010	0.0019
12		0.12	0.0276	0.0010	0.0027
Copper Leaching Study Data: Day 1					
1	73%:25%:02%	0.21	0.0483	0.0017	0.0055
2		0.18	0.0414	0.0014	0.0034
3		0.07	0.0161	0.0006	0.0022
4	67%:30%:03%	0.16	0.0368	0.0013	0.0043
5		0.12	0.0276	0.0010	0.0029
6		0.10	0.0230	0.0008	0.0028
7	63%:35%:02%	0.11	0.0253	0.0009	0.0042
8		0.15	0.0345	0.0012	0.0038
9		0.21	0.0483	0.0017	0.0032
10	62%:35%:03%	0.15	0.0345	0.0012	0.0047
11		0.17	0.0391	0.0014	0.0033
12		0.04	0.0092	0.0003	0.0030

Table K-1 (Cont.). Cu^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Cu^{2+} Amount (mg/L)	Cu^{2+} Leached (mg)	Cumulative Cu^{2+} (mg/cm^2)	Cumulative Cu^{2+} Flux (mg/cm^2)
Copper Leaching Study Data: Day 2					
1	73%:25%:02%	0.04	0.0092	0.0003	0.0058
2		0.10	0.0230	0.0008	0.0042
3		0.12	0.0276	0.0010	0.0031
4	67%:30%:03%	0.12	0.0276	0.0010	0.0053
5		0.18	0.0414	0.0014	0.0043
6		0.12	0.0276	0.0010	0.0038
7	63%:35%:02%	0.21	0.0483	0.0017	0.0058
8		0.24	0.0552	0.0019	0.0058
9		0.17	0.0391	0.0014	0.0046
10	62%:35%:03%	0.14	0.0322	0.0011	0.0058
11		0.12	0.0276	0.0010	0.0042
12		0.10	0.0230	0.0008	0.0038
Copper Leaching Study Data: Day 3					
1	73%:25%:02%	0.02	0.0046	0.0002	0.0060
2		0.05	0.0115	0.0004	0.0046
3		0.10	0.0230	0.0008	0.0039
4	67%:30%:03%	0.05	0.0115	0.0004	0.0057
5		0.08	0.0184	0.0006	0.0050
6		0.12	0.0276	0.0010	0.0047
7	63%:35%:02%	0.02	0.0046	0.0002	0.0060
8		0.14	0.0322	0.0011	0.0069
9		0.15	0.0345	0.0012	0.0058
10	62%:35%:03%	0.11	0.0253	0.0009	0.0067
11		0.00	0.0000	0.0000	0.0042
12		0.13	0.0299	0.0010	0.0049
Copper Leaching Study Data: Day 4					
1	73%:25%:02%	0.06	0.0138	0.0005	0.0065
2		0.12	0.0276	0.0010	0.0055
3		0.20	0.0460	0.0016	0.0055
4	67%:30%:03%	0.03	0.0069	0.0002	0.0059
5		0.12	0.0276	0.0010	0.0059
6		0.17	0.0391	0.0014	0.0061
7	63%:35%:02%	0.12	0.0276	0.0010	0.0070
8		0.12	0.0276	0.0010	0.0078
9		0.20	0.0460	0.0016	0.0074
10	62%:35%:03%	0.26	0.0598	0.0021	0.0088
11		0.12	0.0276	0.0010	0.0052
12		0.25	0.0575	0.0020	0.0069

Table K-1 (Cont.). Cu^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Cu^{2+} Amount (mg/L)	Cu^{2+} Leached (mg)	Cumulative Cu^{2+} (mg/cm^2)	Cumulative Cu^{2+} Flux (mg/cm^2)
Copper Leaching Study Data: Day 5					
1	73%:25%:02%	0.13	0.0299	0.0010	0.0075
2		0.19	0.0437	0.0015	0.0070
3		0.09	0.0207	0.0007	0.0062
4	67%:30%:03%	0.22	0.0506	0.0018	0.0077
5		0.22	0.0506	0.0018	0.0077
6		0.32	0.0736	0.0026	0.0086
7	63%:35%:02%	0.33	0.0759	0.0026	0.0096
8		0.25	0.0575	0.0020	0.0098
9		0.25	0.0575	0.0020	0.0094
10	62%:35%:03%	0.40	0.0920	0.0032	0.0120
11		0.41	0.0943	0.0033	0.0085
12		0.12	0.0276	0.0010	0.0078
Copper Leaching Study Data: Day 8					
1	73%:25%:02%	0.46	0.1058	0.0037	0.0112
2		0.54	0.1242	0.0043	0.0114
3		0.12	0.0276	0.0010	0.0072
4	67%:30%:03%	0.16	0.0368	0.0013	0.0090
5		0.13	0.0299	0.0010	0.0087
6		0.12	0.0276	0.0010	0.0096
7	63%:35%:02%	0.21	0.0483	0.0017	0.0113
8		0.22	0.0506	0.0018	0.0116
9		0.12	0.0276	0.0010	0.0103
10	62%:35%:03%	0.29	0.0667	0.0023	0.0143
11		0.25	0.0575	0.0020	0.0105
12		0.03	0.0069	0.0002	0.0081
Copper Leaching Study Data: Day 11					
1	73%:25%:02%	0.31	0.0713	0.0025	0.0137
2		0.39	0.0897	0.0031	0.0145
3		0.06	0.0138	0.0005	0.0077
4	67%:30%:03%	0.27	0.0621	0.0022	0.0111
5		0.20	0.0460	0.0016	0.0103
6		0.27	0.0621	0.0022	0.0118
7	63%:35%:02%	0.31	0.0713	0.0025	0.0138
8		0.22	0.0506	0.0018	0.0134
9		0.36	0.0828	0.0029	0.0132
10	62%:35%:03%	0.26	0.0598	0.0021	0.0164
11		0.05	0.0115	0.0004	0.0109
12		0.31	0.0713	0.0025	0.0106

Table K-1 (Cont.). Cu^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Cu^{2+} Amount (mg/L)	Cu^{2+} Leached (mg)	Daily Cu^{2+} (mg/cm^2)	Cumulative Cu^{2+} Flux (mg/cm^2)
Copper Leaching Study Data: Day 14					
1	73%:25%:02%	0.16	0.0368	0.0013	0.0150
2		0.20	0.0460	0.0016	0.0161
3		0.28	0.0644	0.0022	0.0099
4	67%:30%:03%	0.16	0.0368	0.0013	0.0124
5		0.12	0.0276	0.0010	0.0113
6		0.32	0.0736	0.0026	0.0143
7	63%:35%:02%	0.58	0.1334	0.0046	0.0184
8		0.12	0.0276	0.0010	0.0143
9		0.50	0.1150	0.0040	0.0172
10	62%:35%:03%	0.13	0.0299	0.0010	0.0174
11		0.11	0.0253	0.0009	0.0118
12		0.18	0.0414	0.0014	0.0120
Copper Leaching Study Data: Day 21					
1	73%:25%:02%	0.24	0.0552	0.0019	0.0169
2		0.15	0.0345	0.0012	0.0173
3		0.30	0.0690	0.0024	0.0123
4	67%:30%:03%	0.15	0.0345	0.0012	0.0136
5		0.12	0.0276	0.0010	0.0122
6		0.34	0.0782	0.0027	0.0170
7	63%:35%:02%	0.12	0.0276	0.0010	0.0194
8		0.12	0.0276	0.0010	0.0153
9		0.45	0.1035	0.0036	0.0208
10	62%:35%:03%	0.13	0.0299	0.0010	0.0185
11		0.11	0.0253	0.0009	0.0126
12		0.53	0.1219	0.0042	0.0162
Copper Leaching Study Data: Day 28					
1	73%:25%:02%	0.14	0.0322	0.0011	0.0180
2		0.12	0.0276	0.0010	0.0182
3		0.70	0.1610	0.0056	0.0179
4	67%:30%:03%	0.27	0.0621	0.0022	0.0158
5		0.21	0.0483	0.0017	0.0139
6		0.53	0.1219	0.0042	0.0213
7	63%:35%:02%	0.02	0.0046	0.0002	0.0195
8		0.25	0.0575	0.0020	0.0173
9		0.39	0.0897	0.0031	0.0239
10	62%:35%:03%	0.02	0.0046	0.0002	0.0186
11		0.15	0.0345	0.0012	0.0138
12		0.12	0.0276	0.0010	0.0172

Table K-1 (Cont.). Cu^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Cu^{2+} Amount (mg/L)	Cu^{2+} Leached (mg)	Daily Cu^{2+} (mg/cm^2)	Cumulative Cu^{2+} Flux (mg/cm^2)
Copper Leaching Study Data: Day 42					
1	73%:25%:02%	0.08	0.0184	0.0006	0.0186
2		0.08	0.0184	0.0006	0.0189
3		0.06	0.0138	0.0005	0.0184
4	67%:30%:03%	0.00	0.0000	0.0000	0.0158
5		0.00	0.0000	0.0000	0.0139
6		0.11	0.0253	0.0009	0.0222
7	63%:35%:02%	0.07	0.0161	0.0006	0.0201
8		0.07	0.0161	0.0006	0.0178
9		0.06	0.0138	0.0005	0.0254
10	62%:35%:03%	0.04	0.0092	0.0003	0.0190
11		0.27	0.0621	0.0022	0.0170
12		0.28	0.0644	0.0022	0.0194
Copper Leaching Study Data: Day 56					
1	73%:25%:02%	0.35	0.0805	0.0028	0.0214
2		0.40	0.0920	0.0032	0.0221
3		0.52	0.1196	0.0042	0.0226
4	67%:30%:03%	0.13	0.0299	0.0010	0.0168
5		0.16	0.0368	0.0013	0.0152
6		0.20	0.0460	0.0016	0.0238
7	63%:35%:02%	0.20	0.0460	0.0016	0.0217
8		0.08	0.0184	0.0006	0.0185
9		0.15	0.0345	0.0012	0.0266
10	62%:35%:03%	0.12	0.0276	0.0010	0.0199
11		0.12	0.0276	0.0010	0.0179
12		0.15	0.0345	0.0012	0.0206
Copper Leaching Study Data: Day 77					
1	73%:25%:02%	0.26	0.0598	0.0021	0.0235
2		0.17	0.0391	0.0014	0.0234
3		0.14	0.0322	0.0011	0.0237
4	67%:30%:03%	0.08	0.0184	0.0006	0.0174
5		0.12	0.0276	0.0010	0.0162
6		0.13	0.0299	0.0010	0.0248
7	63%:35%:02%	0.17	0.0391	0.0014	0.0230
8		0.19	0.0437	0.0015	0.0200
9		0.23	0.0529	0.0018	0.0284
10	62%:35%:03%	0.06	0.0138	0.0005	0.0204
11		0.09	0.0207	0.0007	0.0186
12		0.12	0.0276	0.0010	0.0216

Table K-2. Cr^{3+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Cr^{2+} Amount (mg/L)	Cr^{2+} Leached (mg)	Daily Cr^{2+} (mg/cm^2)	Cumulative Cr^{2+} Flux (mg/cm^2)
Chromium Leaching Study Data: Day 0.08					
1	73%:25%:02%	0.07	0.0161	0.0006	0.0006
2		0.03	0.0069	0.0002	0.0002
3		0.06	0.0138	0.0005	0.0005
4	67%:30%:03%	0.08	0.0184	0.0006	0.0006
5		0.04	0.0092	0.0003	0.0003
6		0.07	0.0161	0.0006	0.0006
7	63%:35%:02%	0.08	0.0184	0.0006	0.0006
8		0.04	0.0092	0.0003	0.0003
9		0.07	0.0161	0.0006	0.0006
10	62%:35%:03%	0.07	0.0161	0.0006	0.0006
11		0.03	0.0069	0.0002	0.0002
12		0.07	0.0161	0.0006	0.0006
Chromium Leaching Study Data: Day 0.29					
1	73%:25%:02%	0.08	0.0184	0.0006	0.0012
2		0.04	0.0092	0.0003	0.0006
3		0.06	0.0138	0.0005	0.0010
4	67%:30%:03%	0.06	0.0138	0.0005	0.0011
5		0.05	0.0115	0.0004	0.0007
6		0.05	0.0115	0.0004	0.0010
7	63%:35%:02%	0.06	0.0138	0.0005	0.0011
8		0.09	0.0207	0.0007	0.0010
9		0.04	0.0092	0.0003	0.0009
10	62%:35%:03%	0.05	0.0115	0.0004	0.0010
11		0.06	0.0138	0.0005	0.0007
12		0.04	0.0092	0.0003	0.0009
Chromium Leaching Study Data: Day 1					
1	73%:25%:02%	0.07	0.0161	0.0006	0.0018
2		0.08	0.0184	0.0006	0.0012
3		0.06	0.0138	0.0005	0.0014
4	67%:30%:03%	0.07	0.0161	0.0006	0.0017
5		0.07	0.0161	0.0006	0.0013
6		0.06	0.0138	0.0005	0.0014
7	63%:35%:02%	0.07	0.0161	0.0006	0.0017
8		0.08	0.0184	0.0006	0.0017
9		0.11	0.0253	0.0009	0.0018
10	62%:35%:03%	0.06	0.0138	0.0005	0.0014
11		0.06	0.0138	0.0005	0.0012
12		0.05	0.0115	0.0004	0.0013

Table K-2 (Cont.). Cr^{3+} Measurements on the Four PG Composite Compositions.

Chromium Leaching Study Data: Day 2					
ID	PG Composite	Cr^{2+} Amount (mg/L)	Cr^{2+} Leached (mg)	Daily Cr^{2+} (mg/cm^2)	Cumulative Cr^{2+} Flux (mg/cm^2)
1	73%:25%:02%	0.05	0.0115	0.0004	0.0022
2		0.10	0.0230	0.0008	0.0020
3		0.06	0.0138	0.0005	0.0019
4	67%:30%:03%	0.06	0.0138	0.0005	0.0022
5		0.00	0.0000	0.0000	0.0013
6		0.05	0.0115	0.0004	0.0018
7	63%:35%:02%	0.07	0.0161	0.0006	0.0022
8		0.09	0.0207	0.0007	0.0024
9		0.07	0.0161	0.0006	0.0023
10	62%:35%:03%	0.06	0.0138	0.0005	0.0019
11		0.05	0.0115	0.0004	0.0016
12		0.05	0.0115	0.0004	0.0017
Chromium Leaching Study Data: Day 3					
1	73%:25%:02%	0.05	0.0115	0.0004	0.0026
2		0.06	0.0138	0.0005	0.0025
3		0.08	0.0184	0.0006	0.0026
4	67%:30%:03%	0.06	0.0138	0.0005	0.0026
5		0.07	0.0161	0.0006	0.0018
6		0.07	0.0161	0.0006	0.0024
7	63%:35%:02%	0.05	0.0115	0.0004	0.0026
8		0.10	0.0230	0.0008	0.0032
9		0.07	0.0161	0.0006	0.0029
10	62%:35%:03%	0.05	0.0115	0.0004	0.0023
11		0.03	0.0069	0.0002	0.0018
12		0.06	0.0138	0.0005	0.0022
Chromium Leaching Study Data: Day 4					
1	73%:25%:02%	0.05	0.0115	0.0004	0.0030
2		0.04	0.0092	0.0003	0.0028
3		0.07	0.0161	0.0006	0.0031
4	67%:30%:03%	0.05	0.0115	0.0004	0.0030
5		0.04	0.0092	0.0003	0.0022
6		0.06	0.0138	0.0005	0.0029
7	63%:35%:02%	0.06	0.0138	0.0005	0.0031
8		0.04	0.0092	0.0003	0.0035
9		0.10	0.0230	0.0008	0.0037
10	62%:35%:03%	0.07	0.0161	0.0006	0.0029
11		0.04	0.0092	0.0003	0.0022
12		0.07	0.0161	0.0006	0.0027

Table K-2 (Cont.). Cr^{3+} Measurements on the Four PG Composite Compositions.

Chromium Leaching Study Data: Day 5					
ID	PG Composite	Cr^{2+} Amount (mg/L)	Cr^{2+} Leached (mg)	Cumulative Cr^{2+} (mg/cm^2)	Cumulative Cr^{2+} Flux (mg/cm^2)
1	73%:25%:02%	0.06	0.0138	0.0005	0.0034
2		0.08	0.0184	0.0006	0.0034
3		0.05	0.0115	0.0004	0.0035
4	67%:30%:03%	0.07	0.0161	0.0006	0.0036
5		0.08	0.0184	0.0006	0.0028
6		0.07	0.0161	0.0006	0.0034
7	63%:35%:02%	0.09	0.0207	0.0007	0.0038
8		0.08	0.0184	0.0006	0.0042
9		0.06	0.0138	0.0005	0.0042
10	62%:35%:03%	0.08	0.0184	0.0006	0.0035
11		0.08	0.0184	0.0006	0.0028
12		0.05	0.0115	0.0004	0.0031
Chromium Leaching Study Data: Day 8					
1	73%:25%:02%	0.11	0.0253	0.0009	0.0043
2		0.12	0.0276	0.0010	0.0044
3		0.05	0.0115	0.0004	0.0039
4	67%:30%:03%	0.08	0.0184	0.0006	0.0042
5		0.10	0.0230	0.0008	0.0036
6		0.06	0.0138	0.0005	0.0039
7	63%:35%:02%	0.09	0.0207	0.0007	0.0046
8		0.09	0.0207	0.0007	0.0049
9		0.05	0.0115	0.0004	0.0046
10	62%:35%:03%	0.08	0.0184	0.0006	0.0042
11		0.08	0.0184	0.0006	0.0034
12		0.04	0.0092	0.0003	0.0034
Chromium Leaching Study Data: Day 11					
1	73%:25%:02%	0.08	0.0184	0.0006	0.0050
2		0.10	0.0230	0.0008	0.0052
3		0.06	0.0138	0.0005	0.0044
4	67%:30%:03%	0.09	0.0207	0.0007	0.0050
5		0.06	0.0138	0.0005	0.0041
6		0.11	0.0253	0.0009	0.0048
7	63%:35%:02%	0.09	0.0207	0.0007	0.0053
8		0.08	0.0184	0.0006	0.0055
9		0.10	0.0230	0.0008	0.0054
10	62%:35%:03%	0.07	0.0161	0.0006	0.0047
11		0.10	0.0230	0.0008	0.0042
12		0.08	0.0184	0.0006	0.0041

Table K-2 (Cont.). Cr^{3+} Measurements on the Four PG Composite Compositions.

Chromium Leaching Study Data: Day 14					
ID	PG Composite	Cr^{2+} Amount (mg/L)	Cr^{2+} Leached (mg)	Daily Cr^{2+} (mg/cm^2)	Cumulative Cr^{2+} Flux (mg/cm^2)
1	73%:25%:02%	0.07	0.0161	0.0006	0.0055
2		0.10	0.0230	0.0008	0.0060
3		0.08	0.0184	0.0006	0.0050
4	67%:30%:03%	0.07	0.0161	0.0006	0.0055
5		0.07	0.0161	0.0006	0.0046
6		0.08	0.0184	0.0006	0.0054
7	63%:35%:02%	0.11	0.0253	0.0009	0.0062
8		0.07	0.0161	0.0006	0.0061
9		0.09	0.0207	0.0007	0.0061
10	62%:35%:03%	0.05	0.0115	0.0004	0.0051
11		0.07	0.0161	0.0006	0.0048
12		0.06	0.0138	0.0005	0.0046
Chromium Leaching Study Data: Day 21					
1	73%:25%:02%	0.07	0.0161	0.0006	0.0061
2		0.10	0.0230	0.0008	0.0068
3		0.11	0.0253	0.0009	0.0059
4	67%:30%:03%	0.07	0.0161	0.0006	0.0061
5		0.09	0.0207	0.0007	0.0054
6		0.09	0.0207	0.0007	0.0062
7	63%:35%:02%	0.07	0.0161	0.0006	0.0067
8		0.09	0.0207	0.0007	0.0068
9		0.10	0.0230	0.0008	0.0069
10	62%:35%:03%	0.05	0.0115	0.0004	0.0055
11		0.10	0.0230	0.0008	0.0056
12		0.10	0.0230	0.0008	0.0054
Chromium Leaching Study Data: Day 28					
1	73%:25%:02%	0.07	0.0161	0.0006	0.0066
2		0.10	0.0230	0.0008	0.0076
3		0.12	0.0276	0.0010	0.0069
4	67%:30%:03%	0.08	0.0184	0.0006	0.0067
5		0.11	0.0253	0.0009	0.0062
6		0.10	0.0230	0.0008	0.0070
7	63%:35%:02%	0.05	0.0115	0.0004	0.0071
8		0.12	0.0276	0.0010	0.0078
9		0.09	0.0207	0.0007	0.0076
10	62%:35%:03%	0.04	0.0092	0.0003	0.0058
11		0.09	0.0207	0.0007	0.0063
12		0.06	0.0138	0.0005	0.0058

Table K-2 (Cont.). Cr^{3+} Measurements on the Four PG Composite Compositions.

Chromium Leaching Study Data: Day 42					
ID	PG Composite	Cr^{2+} Amount (mg/L)	Cr^{2+} Leached (mg)	Daily Cr^{2+} (mg/cm^2)	Cumulative Cr^{2+} Flux (mg/cm^2)
1	73%:25%:02%	0.07	0.0161	0.0006	0.0072
2		0.07	0.0161	0.0006	0.00816
3		0.06	0.0138	0.0005	0.00736
4	67%:30%:03%	0.06	0.0138	0.0005	0.0072
5		0.06	0.0138	0.0005	0.00672
6		0.08	0.0184	0.0006	0.0076
7	63%:35%:02%	0.07	0.0161	0.0006	0.00768
8		0.07	0.0161	0.0006	0.00832
9		0.07	0.0161	0.0006	0.00816
10	62%:35%:03%	0.06	0.0138	0.0005	0.00632
11		0.06	0.0138	0.0005	0.0068
12		0.08	0.0184	0.0006	0.00648
Chromium Leaching Study Data: Day 56					
1	73%:25%:02%	0.10	0.0230	0.0008	0.008
2		0.11	0.0253	0.0009	0.00904
3		0.12	0.0276	0.0010	0.00832
4	67%:30%:03%	0.07	0.0161	0.0006	0.00776
5		0.07	0.0161	0.0006	0.00728
6		0.08	0.0184	0.0006	0.00824
7	63%:35%:02%	0.07	0.0161	0.0006	0.00824
8		0.06	0.0138	0.0005	0.0088
9		0.07	0.0161	0.0006	0.00872
10	62%:35%:03%	0.06	0.0138	0.0005	0.0068
11		0.06	0.0138	0.0005	0.00728
12		0.06	0.0138	0.0005	0.00696
Chromium Leaching Study Data: Day 77					
1	73%:25%:02%	0.08	0.0184	0.0006	0.00864
2		0.07	0.0161	0.0006	0.0096
3		0.06	0.0138	0.0005	0.0088
4	67%:30%:03%	0.07	0.0161	0.0006	0.00832
5		0.07	0.0161	0.0006	0.00784
6		0.08	0.0184	0.0006	0.00888
7	63%:35%:02%	0.09	0.0207	0.0007	0.00896
8		0.09	0.0207	0.0007	0.00952
9		0.11	0.0253	0.0009	0.0096
10	62%:35%:03%	0.05	0.0115	0.0004	0.0072
11		0.05	0.0115	0.0004	0.00768
12		0.06	0.0138	0.0005	0.00744

Table K-3. Zn^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Zn^{2+} Amount (mg/L)	Zn^{2+} Leached (mg)	Daily Zn^{2+} (mg/cm^2)	Cumulative Zn^{2+} Flux (mg/cm^2)
Zinc Leaching Study Data: Day 0.08					
1	73%:25%:02%	0.05	0.0115	0.0004	0.0004
2		0.03	0.0069	0.0002	0.0002
3		0.04	0.0092	0.0003	0.0003
4	67%:30%:03%	0.06	0.0138	0.0005	0.0005
5		0.02	0.0046	0.0002	0.0002
6		0.05	0.0115	0.0004	0.0004
7	63%:35%:02%	0.06	0.0138	0.0005	0.0005
8		0.01	0.0023	0.0001	0.0001
9		0.07	0.0161	0.0006	0.0006
10	62%:35%:03%	0.06	0.0138	0.0005	0.0005
11		0.01	0.0023	0.0001	0.0001
12		0.06	0.0138	0.0005	0.0005
Zinc Leaching Study Data: Day 0.29					
1	73%:25%:02%	0.06	0.0138	0.0005	0.0009
2		0.02	0.0046	0.0002	0.0004
3		0.02	0.0046	0.0002	0.0005
4	67%:30%:03%	0.04	0.0092	0.0003	0.0008
5		0.02	0.0046	0.0002	0.0003
6		0.04	0.0092	0.0003	0.0007
7	63%:35%:02%	0.03	0.0069	0.0002	0.0007
8		0.05	0.0115	0.0004	0.0005
9		0.05	0.0115	0.0004	0.0010
10	62%:35%:03%	0.03	0.0069	0.0002	0.0007
11		0.04	0.0092	0.0003	0.0004
12		0.03	0.0069	0.0002	0.0007
Zinc Leaching Study Data: Day 1					
1	73%:25%:02%	0.05	0.0115	0.0004	0.0013
2		0.04	0.0092	0.0003	0.0007
3		0.04	0.0092	0.0003	0.0008
4	67%:30%:03%	0.04	0.0092	0.0003	0.0011
5		0.05	0.0115	0.0004	0.0007
6		0.04	0.0092	0.0003	0.0010
7	63%:35%:02%	0.02	0.0046	0.0002	0.0009
8		0.05	0.0115	0.0004	0.0009
9		0.05	0.0115	0.0004	0.0014
10	62%:35%:03%	0.01	0.0023	0.0001	0.0008
11		0.04	0.0092	0.0003	0.0007
12		0.04	0.0092	0.0003	0.0010

Table K-3 (Cont.). Zn^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Zn^{2+} Amount (mg/L)	Zn^{2+} Leached (mg)	Cumulative Zn^{2+} (mg/cm^2)	Cumulative Zn^{2+} Flux (mg/cm^2)
Zn Leaching Study Data: Day 2					
1	73%:25%:02%	0.02	0.0046	0.0002	0.0014
2		0.05	0.0115	0.0004	0.0011
3		0.03	0.0069	0.0002	0.0010
4	67%:30%:03%	0.02	0.0046	0.0002	0.0013
5		0.07	0.0161	0.0006	0.0013
6		0.02	0.0046	0.0002	0.0012
7	63%:35%:02%	0.02	0.0046	0.0002	0.0010
8		0.04	0.0092	0.0003	0.0012
9		0.05	0.0115	0.0004	0.0018
10	62%:35%:03%	0.03	0.0069	0.0002	0.0010
11		0.03	0.0069	0.0002	0.0010
12		0.05	0.0115	0.0004	0.0014
Zinc Leaching Study Data: Day 3					
1	73%:25%:02%	0.02	0.0046	0.0002	0.0016
2		0.03	0.0069	0.0002	0.0014
3		0.04	0.0092	0.0003	0.0014
4	67%:30%:03%	0.02	0.0046	0.0002	0.0014
5		0.03	0.0069	0.0002	0.0015
6		0.05	0.0115	0.0004	0.0016
7	63%:35%:02%	0.02	0.0046	0.0002	0.0012
8		0.04	0.0092	0.0003	0.0015
9		0.03	0.0069	0.0002	0.0020
10	62%:35%:03%	0.04	0.0092	0.0003	0.0014
11		0.01	0.0023	0.0001	0.0010
12		0.05	0.0115	0.0004	0.0018
Zinc Leaching Study Data: Day 4					
1	73%:25%:02%	0.03	0.0069	0.0002	0.0018
2		0.01	0.0023	0.0001	0.0014
3		0.06	0.0138	0.0005	0.0018
4	67%:30%:03%	0.02	0.0046	0.0002	0.0016
5		0.01	0.0023	0.0001	0.0016
6		0.06	0.0138	0.0005	0.0021
7	63%:35%:02%	0.02	0.0046	0.0002	0.0014
8		0.06	0.0138	0.0005	0.0020
9		0.08	0.0184	0.0006	0.0026
10	62%:35%:03%	0.02	0.0046	0.0002	0.0015
11		0.04	0.0092	0.0003	0.0014
12		0.07	0.0161	0.0006	0.0024

Table K-3 (Cont.). Zn^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Zn^{2+} Amount (mg/L)	Zn^{2+} Leached (mg)	Cumulative Zn^{2+} (mg/cm^2)	Cumulative Zn^{2+} Flux (mg/cm^2)
Zinc Leaching Study Data: Day 5					
1	73%:25%:02%	0.04	0.0092	0.0003	0.0022
2		0.04	0.0092	0.0003	0.0018
3		0.04	0.0092	0.0003	0.0022
4	67%:30%:03%	0.05	0.0115	0.0004	0.0020
5		0.06	0.0138	0.0005	0.0021
6		0.06	0.0138	0.0005	0.0026
7	63%:35%:02%	0.05	0.0115	0.0004	0.0018
8		0.06	0.0138	0.0005	0.0025
9		0.06	0.0138	0.0005	0.0031
10	62%:35%:03%	0.06	0.0138	0.0005	0.0020
11		0.08	0.0184	0.0006	0.0020
12		0.03	0.0069	0.0002	0.0026
Zinc Leaching Study Data: Day 8					
1	73%:25%:02%	0.07	0.0161	0.0006	0.0027
2		0.09	0.0207	0.0007	0.0025
3		0.03	0.0069	0.0002	0.0024
4	67%:30%:03%	0.03	0.0069	0.0002	0.0022
5		0.06	0.0138	0.0005	0.0026
6		0.01	0.0023	0.0001	0.0026
7	63%:35%:02%	0.05	0.0115	0.0004	0.0022
8		0.07	0.0161	0.0006	0.0030
9		0.03	0.0069	0.0002	0.0034
10	62%:35%:03%	0.05	0.0115	0.0004	0.0024
11		0.08	0.0184	0.0006	0.0026
12		0.04	0.0092	0.0003	0.0030
Zinc Leaching Study Data: Day 11					
1	73%:25%:02%	0.04	0.0092	0.0003	0.0030
2		0.09	0.0207	0.0007	0.0032
3		0.07	0.0161	0.0006	0.0030
4	67%:30%:03%	0.05	0.0115	0.0004	0.0026
5		0.12	0.0276	0.0010	0.0035
6		0.06	0.0138	0.0005	0.0031
7	63%:35%:02%	0.05	0.0115	0.0004	0.0026
8		0.06	0.0138	0.0005	0.0035
9		0.06	0.0138	0.0005	0.0038
10	62%:35%:03%	0.05	0.0115	0.0004	0.0028
11		0.08	0.0184	0.0006	0.0033
12		0.05	0.0115	0.0004	0.0034

Table K-3 (Cont.). Zn^{2+} Measurements on the Four PG Composite Compositions.

Zinc Leaching Study Data: Day 14					
ID	PG Composite	Zn^{2+} Amount (mg/L)	Zn^{2+} Leached (mg)	Cumulative Zn^{2+} (mg/cm^2)	Cumulative Zn^{2+} Flux (mg/cm^2)
1	73%:25%:02%	0.06	0.0138	0.0005	0.0035
2		0.04	0.0092	0.0003	0.0035
3		0.06	0.0138	0.0005	0.0034
4	67%:30%:03%	0.03	0.0069	0.0002	0.0029
5		0.02	0.0046	0.0002	0.0037
6		0.05	0.0115	0.0004	0.0035
7	63%:35%:02%	0.08	0.0184	0.0006	0.0032
8		0.03	0.0069	0.0002	0.0038
9		0.07	0.0161	0.0006	0.0044
10	62%:35%:03%	0.04	0.0092	0.0003	0.0031
11		0.04	0.0092	0.0003	0.0036
12		0.06	0.0138	0.0005	0.0038
Zinc Leaching Study Data: Day 21					
1	73%:25%:02%	0.04	0.0092	0.0003	0.0038
2		0.04	0.0092	0.0003	0.0038
3		0.07	0.0161	0.0006	0.0040
4	67%:30%:03%	0.03	0.0069	0.0002	0.0031
5		0.04	0.0092	0.0003	0.0040
6		0.06	0.0138	0.0005	0.0040
7	63%:35%:02%	0.04	0.0092	0.0003	0.0035
8		0.05	0.0115	0.0004	0.0042
9		0.07	0.0161	0.0006	0.0050
10	62%:35%:03%	0.04	0.0092	0.0003	0.0034
11		0.04	0.0092	0.0003	0.0039
12		0.09	0.0207	0.0007	0.0046
Zinc Leaching Study Data: Day 28					
1	73%:25%:02%	0.03	0.0069	0.0002	0.0041
2		0.04	0.0092	0.0003	0.0042
3		0.09	0.0207	0.0007	0.0047
4	67%:30%:03%	0.05	0.0115	0.0004	0.0035
5		0.05	0.0115	0.0004	0.0044
6		0.08	0.0184	0.0006	0.0046
7	63%:35%:02%	0.02	0.0046	0.0002	0.0037
8		0.05	0.0115	0.0004	0.0046
9		0.06	0.0138	0.0005	0.0054
10	62%:35%:03%	0.02	0.0046	0.0002	0.0036
11		0.04	0.0092	0.0003	0.0042
12		0.01	0.0023	0.0001	0.0046

Table K-3 (Cont.). Zn^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Zn^{2+} Amount (mg/L)	Zn^{2+} Leached (mg)	Cumulative Zn^{2+} (mg/cm^2)	Cumulative Zn^{2+} Flux (mg/cm^2)
Zinc Leaching Study Data: Day 42					
1	73%:25%:02%	0.05	0.0115	0.0004	0.0045
2		0.03	0.0069	0.0002	0.0044
3		0.02	0.0046	0.0002	0.0049
4	67%:30%:03%	0.03	0.0069	0.0002	0.0038
5		0.03	0.0069	0.0002	0.0046
6		0.04	0.0092	0.0003	0.0049
7	63%:35%:02%	0.03	0.0069	0.0002	0.0039
8		0.03	0.0069	0.0002	0.0048
9		0.06	0.0138	0.0005	0.0059
10	62%:35%:03%	0.03	0.0069	0.0002	0.0038
11		0.09	0.0207	0.0007	0.0050
12		0.08	0.0184	0.0006	0.0053
Zinc Leaching Study Data: Day 56					
1	73%:25%:02%	0.07	0.0161	0.0006	0.0050
2		0.08	0.0184	0.0006	0.0050
3		0.09	0.0207	0.0007	0.0056
4	67%:30%:03%	0.03	0.0069	0.0002	0.0040
5		0.03	0.0069	0.0002	0.0049
6		0.06	0.0138	0.0005	0.0054
7	63%:35%:02%	0.04	0.0092	0.0003	0.0042
8		0.03	0.0069	0.0002	0.0050
9		0.04	0.0092	0.0003	0.0062
10	62%:35%:03%	0.04	0.0092	0.0003	0.0042
11		0.05	0.0115	0.0004	0.0054
12		0.03	0.0069	0.0002	0.0055
Zinc Leaching Study Data: Day 77					
1	73%:25%:02%	0.06	0.0138	0.0005	0.0055
2		0.05	0.0115	0.0004	0.0054
3		0.03	0.0069	0.0002	0.0058
4	67%:30%:03%	0.05	0.0115	0.0004	0.0044
5		0.04	0.0092	0.0003	0.0052
6		0.05	0.0115	0.0004	0.0058
7	63%:35%:02%	0.06	0.0138	0.0005	0.0047
8		0.05	0.0115	0.0004	0.0054
9		0.06	0.0138	0.0005	0.0067
10	62%:35%:03%	0.02	0.0046	0.0002	0.0043
11		0.03	0.0069	0.0002	0.0056
12		0.04	0.0092	0.0003	0.0058

Table K-4. Fe^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Fe^{2+} Amount (mg/L)	Fe^{2+} Leached (mg)	Cumulative Fe^{2+} (mg/cm^2)	Cumulative Fe^{2+} Flux (mg/cm^2)
Iron Leaching Study Data: Day 0.08					
1	73%:25%:02%	0.79	0.1817	0.0063	0.0063
2		1.08	0.2484	0.0086	0.0086
3		1.30	0.2990	0.0104	0.0104
4	67%:30%:03%	0.87	0.2001	0.0070	0.0070
5		1.18	0.2714	0.0094	0.0094
6		1.42	0.3266	0.0114	0.0114
7	63%:35%:02%	0.79	0.1817	0.0063	0.0063
8		1.15	0.2645	0.0092	0.0092
9		1.29	0.2967	0.0103	0.0103
10	62%:35%:03%	0.80	0.1840	0.0064	0.0064
11		1.14	0.2622	0.0091	0.0091
12		1.32	0.3036	0.0106	0.0106
Iron Leaching Study Data: Day 0.29					
1	73%:25%:02%	0.91	0.2093	0.0073	0.0136
2		1.01	0.2323	0.0081	0.0167
3		1.07	0.2461	0.0086	0.0190
4	67%:30%:03%	0.80	0.1840	0.0064	0.0134
5		1.22	0.2806	0.0098	0.0192
6		1.06	0.2438	0.0085	0.0198
7	63%:35%:02%	0.75	0.1725	0.0060	0.0123
8		1.27	0.2921	0.0102	0.0194
9		0.96	0.2208	0.0077	0.0180
10	62%:35%:03%	0.65	0.1495	0.0052	0.0116
11		1.22	0.2806	0.0098	0.0189
12		1.03	0.2369	0.0082	0.0188
Iron Leaching Study Data: Day 1					
1	73%:25%:02%	0.64	0.1472	0.0051	0.0187
2		1.20	0.2760	0.0096	0.0263
3		1.09	0.2507	0.0087	0.0277
4	67%:30%:03%	0.71	0.1633	0.0057	0.0190
5		1.11	0.2553	0.0089	0.0281
6		1.08	0.2484	0.0086	0.0285
7	63%:35%:02%	0.61	0.1403	0.0049	0.0172
8		1.32	0.3036	0.0106	0.0299
9		1.23	0.2829	0.0098	0.0278
10	62%:35%:03%	0.67	0.1541	0.0054	0.0170
11		1.20	0.2760	0.0096	0.0285
12		1.17	0.2691	0.0094	0.0282

Table K-4 (Cont.). Fe^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Fe^{2+} Amount (mg/L)	Fe^{2+} Leached (mg)	Cumulative Fe^{2+} (mg/cm^2)	Cumulative Fe^{2+} Flux (mg/cm^2)
Iron Leaching Study Data: Day 2					
1	73%:25%:02%	0.54	0.1242	0.0043	0.0230
2		1.31	0.3013	0.0105	0.0368
3		1.20	0.2760	0.0096	0.0373
4	67%:30%:03%	0.50	0.1150	0.0040	0.0230
5		1.29	0.2967	0.0103	0.0384
6		1.19	0.2737	0.0095	0.0380
7	63%:35%:02%	0.61	0.1403	0.0049	0.0221
8		1.42	0.3266	0.0114	0.0413
9		1.25	0.2875	0.0100	0.0378
10	62%:35%:03%	0.88	0.2024	0.0070	0.0240
11		1.40	0.3220	0.0112	0.0397
12		1.17	0.2691	0.0094	0.0375
Iron Leaching Study Data: Day 3					
1	73%:25%:02%	0.84	0.1932	0.0067	0.0298
2		1.17	0.2691	0.0094	0.0462
3		1.18	0.2714	0.0094	0.0467
4	67%:30%:03%	0.95	0.2185	0.0076	0.0306
5		1.25	0.2875	0.0100	0.0484
6		1.28	0.2944	0.0102	0.0482
7	63%:35%:02%	0.89	0.2047	0.0071	0.0292
8		0.75	0.1725	0.0060	0.0473
9		1.25	0.2875	0.0100	0.0478
10	62%:35%:03%	0.88	0.2024	0.0070	0.0310
11		0.00	0.0000	0.0000	0.0397
12		1.22	0.2806	0.0098	0.0473
Iron Leaching Study Data: Day 4					
1	73%:25%:02%	0.78	0.1794	0.0062	0.0360
2		0.74	0.1702	0.0059	0.0521
3		1.14	0.2622	0.0091	0.0558
4	67%:30%:03%	0.77	0.1771	0.0062	0.0368
5		0.75	0.1725	0.0060	0.0544
6		1.19	0.2737	0.0095	0.0578
7	63%:35%:02%	0.74	0.1702	0.0059	0.0351
8		0.80	0.1840	0.0064	0.0537
9		1.22	0.2806	0.0098	0.0576
10	62%:35%:03%	0.70	0.1610	0.0056	0.0366
11		0.86	0.1978	0.0069	0.0466
12		1.33	0.3059	0.0106	0.0579

Table K-4 (Cont.). Fe^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Fe^{2+} Amount (mg/L)	Fe^{2+} Leached (mg)	Daily Fe^{2+} (mg/cm^2)	Cumulative Fe^{2+} Flux (mg/cm^2)
Iron Leaching Study Data: Day 5					
1	73%:25%:02%	0.76	0.1748	0.0061	0.0421
2		1.44	0.3312	0.0115	0.0636
3		1.00	0.2300	0.0080	0.0638
4	67%:30%:03%	0.88	0.2024	0.0070	0.0438
5		1.43	0.3289	0.0114	0.0658
6		1.01	0.2323	0.0081	0.0658
7	63%:35%:02%	0.92	0.2116	0.0074	0.0425
8		1.25	0.2875	0.0100	0.0637
9		0.93	0.2139	0.0074	0.0650
10	62%:35%:03%	0.96	0.2208	0.0077	0.0443
11		1.47	0.3381	0.0118	0.0583
12		0.83	0.1909	0.0066	0.0646
Iron Leaching Study Data: Day 8					
1	73%:25%:02%	0.98	0.2254	0.0078	0.0499
2		1.76	0.4048	0.0141	0.0777
3		0.98	0.2254	0.0078	0.0717
4	67%:30%:03%	0.87	0.2001	0.0070	0.0508
5		1.16	0.2668	0.0093	0.0751
6		1.00	0.2300	0.0080	0.0738
7	63%:35%:02%	0.95	0.2185	0.0076	0.0501
8		1.48	0.3404	0.0118	0.0755
9		0.85	0.1955	0.0068	0.0718
10	62%:35%:03%	0.91	0.2093	0.0073	0.0516
11		1.36	0.3128	0.0109	0.0692
12		0.81	0.1863	0.0065	0.0710
Iron Leaching Study Data: Day 11					
1	73%:25%:02%	0.85	0.1955	0.0068	0.0567
2		1.42	0.3266	0.0114	0.0890
3		1.19	0.2737	0.0095	0.0812
4	67%:30%:03%	0.85	0.1955	0.0068	0.0576
5		1.35	0.3105	0.0108	0.0859
6		1.18	0.2714	0.0094	0.0833
7	63%:35%:02%	0.89	0.2047	0.0071	0.0572
8		1.31	0.3013	0.0105	0.0860
9		1.27	0.2921	0.0102	0.0820
10	62%:35%:03%	0.85	0.1955	0.0068	0.0584
11		0.88	0.2024	0.0070	0.0762
12		1.32	0.3036	0.0106	0.0816

Table K-4 (Cont.). Fe^{2+} Measurements on the Four PG Composite Compositions.

Iron Leaching Study Data: Day 14					
ID	PG Composite	Fe^{2+} Amount (mg/L)	Fe^{2+} Leached (mg)	Cumulative Fe^{2+} (mg/cm^2)	Cumulative Fe^{2+} Flux (mg/cm^2)
1	73%:25%:02%	0.85	0.1955	0.0068	0.0635
2		0.92	0.2116	0.0074	0.0964
3		1.26	0.2898	0.0101	0.0913
4	67%:30%:03%	0.90	0.2070	0.0072	0.0648
5		0.81	0.1863	0.0065	0.0924
6		1.18	0.2714	0.0094	0.0927
7	63%:35%:02%	1.15	0.2645	0.0092	0.0664
8		0.88	0.2024	0.0070	0.0930
9		1.09	0.2507	0.0087	0.0907
10	62%:35%:03%	0.94	0.2162	0.0075	0.0659
11		0.91	0.2093	0.0073	0.0835
12		1.10	0.2530	0.0088	0.0904
Iron Leaching Study Data: Day 21					
1	73%:25%:02%	0.82	0.1886	0.0066	0.0701
2		0.84	0.1932	0.0067	0.1031
3		1.38	0.3174	0.0110	0.1023
4	67%:30%:03%	0.80	0.1840	0.0064	0.0712
5		1.10	0.2530	0.0088	0.1012
6		1.55	0.3565	0.0124	0.1051
7	63%:35%:02%	0.90	0.2070	0.0072	0.0736
8		1.05	0.2415	0.0084	0.1014
9		1.54	0.3542	0.0123	0.1030
10	62%:35%:03%	1.00	0.2300	0.0080	0.0739
11		1.21	0.2783	0.0097	0.0932
12		1.44	0.3312	0.0115	0.1019
Iron Leaching Study Data: Day 28					
1	73%:25%:02%	1.12	0.2576	0.0090	0.0790
2		1.21	0.2783	0.0097	0.1128
3		1.54	0.3542	0.0123	0.1146
4	67%:30%:03%	1.12	0.2576	0.0090	0.0802
5		1.09	0.2507	0.0087	0.1099
6		1.47	0.3381	0.0118	0.1169
7	63%:35%:02%	0.64	0.1472	0.0051	0.0787
8		1.14	0.2622	0.0091	0.1106
9		1.34	0.3082	0.0107	0.1138
10	62%:35%:03%	0.88	0.2024	0.0070	0.0810
11		1.14	0.2622	0.0091	0.1023
12		1.01	0.2323	0.0081	0.1100

Table K-4 (Cont.). Fe^{2+} Measurements on the Four PG Composite Compositions.

ID	PG Composite	Fe^{2+} Amount (mg/L)	Fe^{2+} Leached (mg)	Cumulative Fe^{2+} (mg/cm^2)	Cumulative Fe^{2+} Flux (mg/cm^2)
Iron Leaching Study Data: Day 42					
1	73%:25%:02%	1.01	0.2323	0.0081	0.0871
2		0.97	0.2231	0.0078	0.1206
3		1.11	0.2553	0.0089	0.1235
4	67%:30%:03%	0.80	0.1840	0.0064	0.0866
5		0.76	0.1748	0.0061	0.1160
6		1.00	0.2300	0.0080	0.1249
7	63%:35%:02%	0.95	0.2185	0.0076	0.0863
8		0.90	0.2070	0.0072	0.1178
9		0.90	0.2070	0.0072	0.1210
10	62%:35%:03%	0.87	0.2001	0.0070	0.0879
11		0.97	0.2231	0.0078	0.1101
12		1.03	0.2369	0.0082	0.1182
Iron Leaching Study Data: Day 56					
1	73%:25%:02%	1.17	0.2691	0.0094	0.0965
2		1.24	0.2852	0.0099	0.1306
3		1.40	0.3220	0.0112	0.1347
4	67%:30%:03%	0.95	0.2185	0.0076	0.0942
5		1.01	0.2323	0.0081	0.1241
6		1.02	0.2346	0.0082	0.1330
7	63%:35%:02%	1.04	0.2392	0.0083	0.0946
8		0.94	0.2162	0.0075	0.1253
9		0.96	0.2208	0.0077	0.1286
10	62%:35%:03%	0.93	0.2139	0.0074	0.0954
11		1.16	0.2668	0.0093	0.1194
12		0.98	0.2254	0.0078	0.1261
Iron Leaching Study Data: Day 77					
1	73%:25%:02%	1.24	0.2852	0.0099	0.1064
2		1.06	0.2438	0.0085	0.1390
3		1.15	0.2645	0.0092	0.1439
4	67%:30%:03%	1.10	0.2530	0.0088	0.1030
5		1.13	0.2599	0.0090	0.1331
6		1.17	0.2691	0.0094	0.1424
7	63%:35%:02%	1.28	0.2944	0.0102	0.1049
8		1.25	0.2875	0.0100	0.1353
9		1.49	0.3427	0.0119	0.1406
10	62%:35%:03%	0.86	0.1978	0.0069	0.1022
11		0.85	0.1955	0.0068	0.1262
12		0.98	0.2254	0.0078	0.1339

Table K-5. Effective Metal Diffusion Coefficients for Copper for the Four PG Composite Combinations Calculated Using Experimental C_o Values.

Composite Combination	$K_2(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-0.5}$)	$K_3(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-1}$)	C_0 ($mg \cdot cm^{-3}$)	C_1 ($mg \cdot cm^{-3}$)	D_e ($cm^2 \cdot d^{-1}$)	D_e ($m^2 \cdot s^{-1}$)	t_c Days
73%:25%:03%	0.00370	0.00	0.043	1.96E-04	5.869E-03	6.79E-12	245
67%:30%:03%	0.00390	0.00	0.034	1.62E-04	1.043E-02	1.21E-11	123
63%:35%:02%	0.00457	-2.60E-04	0.047	1.68E-04	7.480E-03	8.66E-12	78
62%:35%:03%	0.00504	0.00	0.060	1.98E-04	5.579E-03	6.46E-12	98

Table K-6. Effective Metal Diffusion Coefficients for Zinc for the Four PG Composite Combinations Calculated Using Experimental C_o Values.

Composite Combination	$K_2(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-0.5}$)	$K_3(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-1}$)	C_0 ($mg \cdot cm^{-3}$)	C_1 ($mg \cdot cm^{-3}$)	D_e ($cm^2 \cdot d^{-1}$)	D_e ($m^2 \cdot s^{-1}$)	t_c Days
73%:25%:03%	0.00103	-4.32E-05	0.151	4.67E-05	3.657E-05	4.23E-14	145
67%:30%:03%	0.00105	-5.43E-05	0.159	4.27E-05	3.427E-05	3.97E-14	100
63%:35%:02%	0.00108	-5.39E-05	0.108	4.38E-05	7.861E-05	9.10E-14	108
62%:35%:03%	0.00118	-6.29E-05	0.168	4.69E-05	3.877E-05	4.49E-14	89

Table K-7. Effective Metal Diffusion Coefficients for Chromium for the Four PG Composite Combinations Calculated Using Experimental C_o Values.

Composite Combination	$K_2(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-0.5}$)	$K_3(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-1}$)	C_0 ($mg \cdot cm^{-3}$)	C_1 ($mg \cdot cm^{-3}$)	D_e ($cm^2 \cdot d^{-1}$)	D_e ($m^2 \cdot s^{-1}$)	t_c Days
73%:25%:03%	0.00169	-7.42E-05	0.052	7.51E-05	8.321E-04	9.63E-13	135
67%:30%:03%	0.00160	-7.22E-05	0.047	6.96E-05	9.130E-04	1.06E-12	130
63%:35%:02%	0.00194	-7.62E-05	0.045	6.20E-05	1.464E-03	1.69E-12	168
62%:35%:03%	0.00152	-1.02E-04	0.060	7.80E-05	5.054E-04	5.85E-13	61

Table K-8. Effective Metal Diffusion Coefficients for Iron for the Four PG Composite Combinations Calculated Using Experimental C_o Values.

Composite Combination	$K_2(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-0.5}$)	$K_3(C_0 - C_1)$ ($mg \cdot cm^{-2} \cdot d^{-1}$)	C_0 ($mg \cdot cm^{-3}$)	C_1 ($mg \cdot cm^{-3}$)	D_e ($cm^2 \cdot d^{-1}$)	D_e ($m^2 \cdot s^{-1}$)	t_c Days
73%:25%:03%	0.02694	-1.42E-03	27.155	1.08E-03	7.732E-07	8.95E-16	98
67%:30%:03%	0.02768	-1.57E-03	27.559	1.05E-03	7.925E-07	9.17E-16	80
63%:35%:02%	0.02653	-1.49E-03	26.339	1.01E-03	7.970E-07	9.22E-16	79
62%:35%:03%	0.02730	-1.52E-03	29.206	1.06E-03	6.864E-07	7.94E-16	92

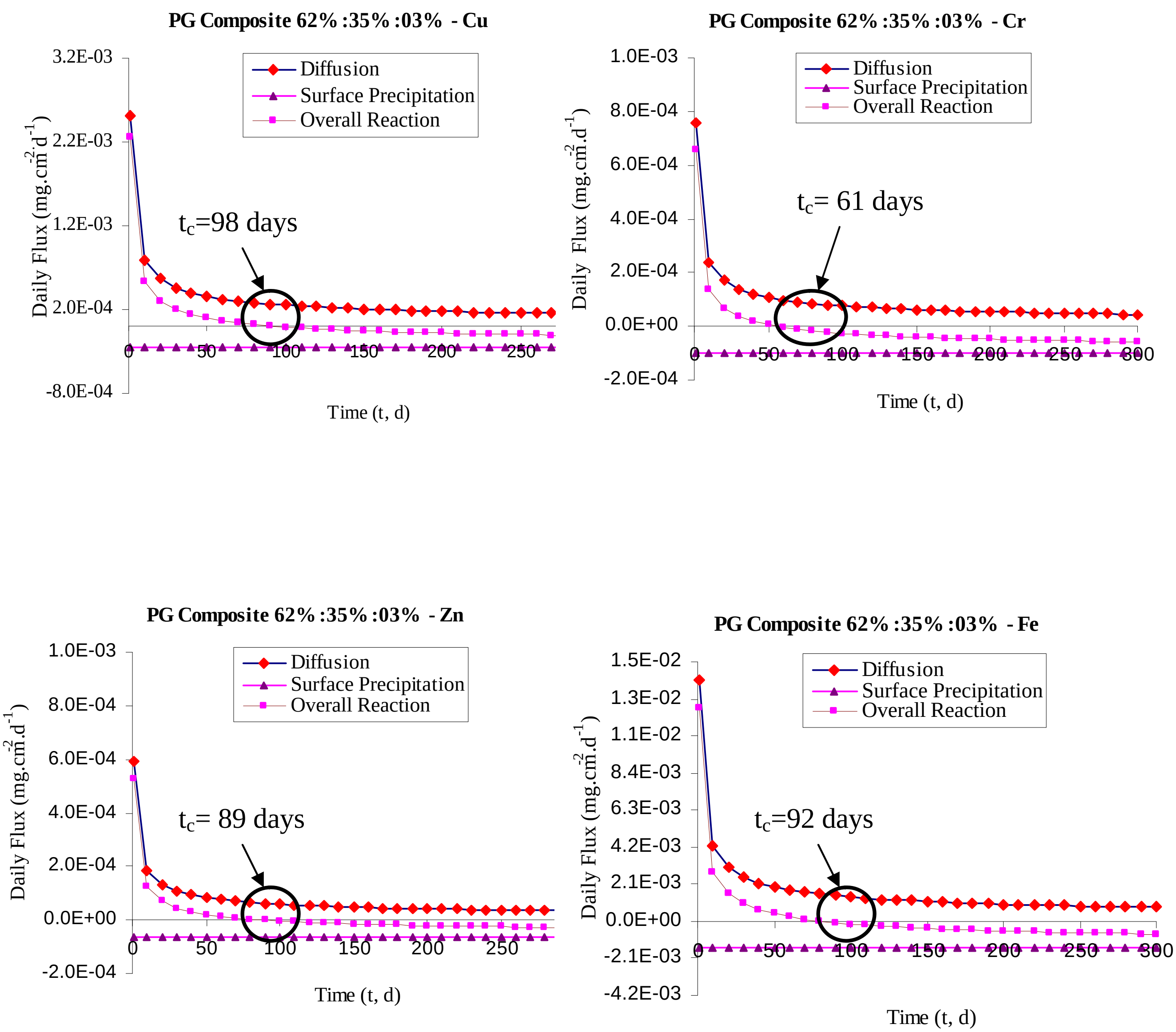


Figure K-1. Plots for Calculating T_c for all Heavy Metals for the 62%:35%:03% Composite Combinations.

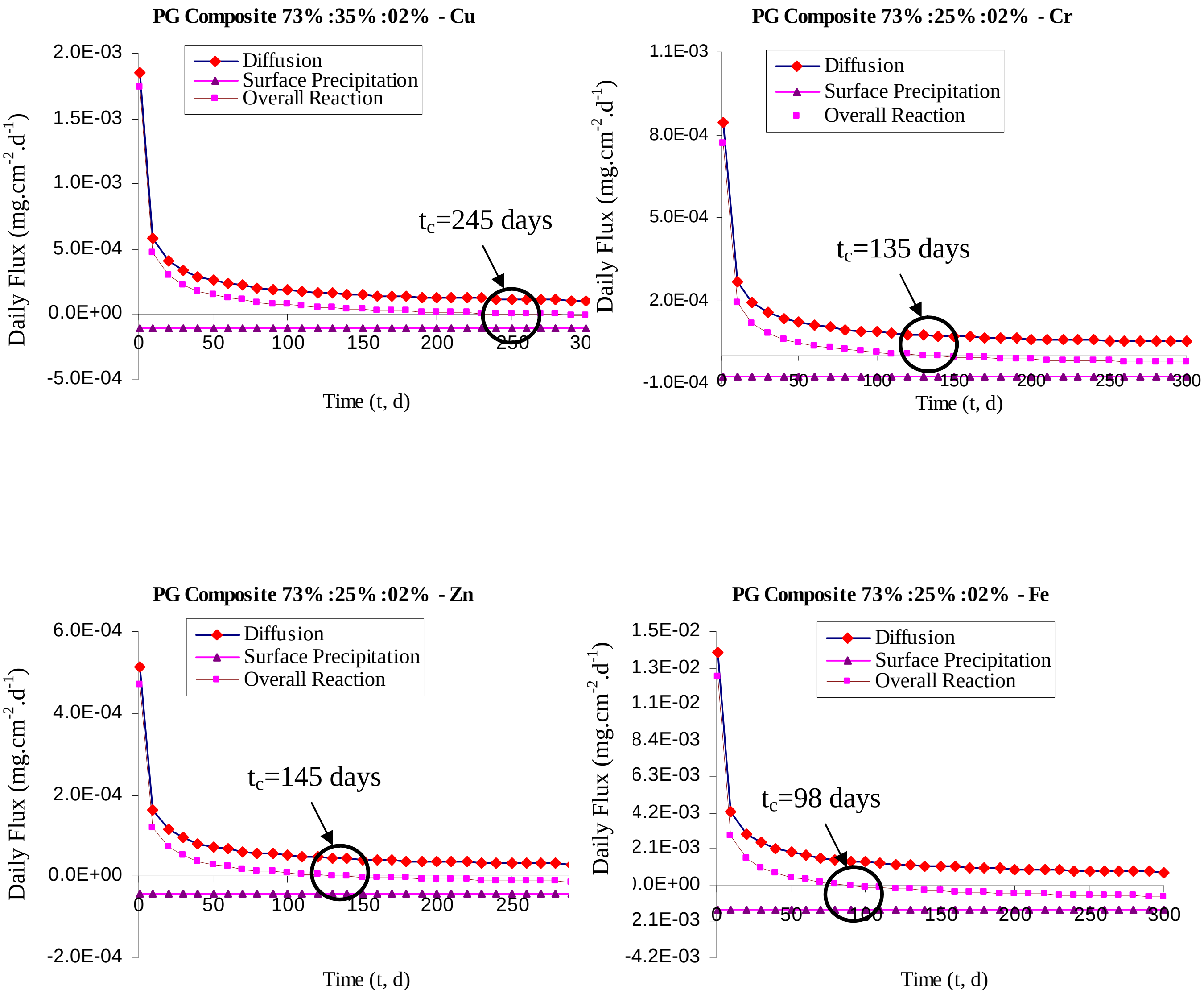


Figure K-2. Plots for Calculating t_c of the Heavy Metals for the 73%:25%:02% Composite Combinations.

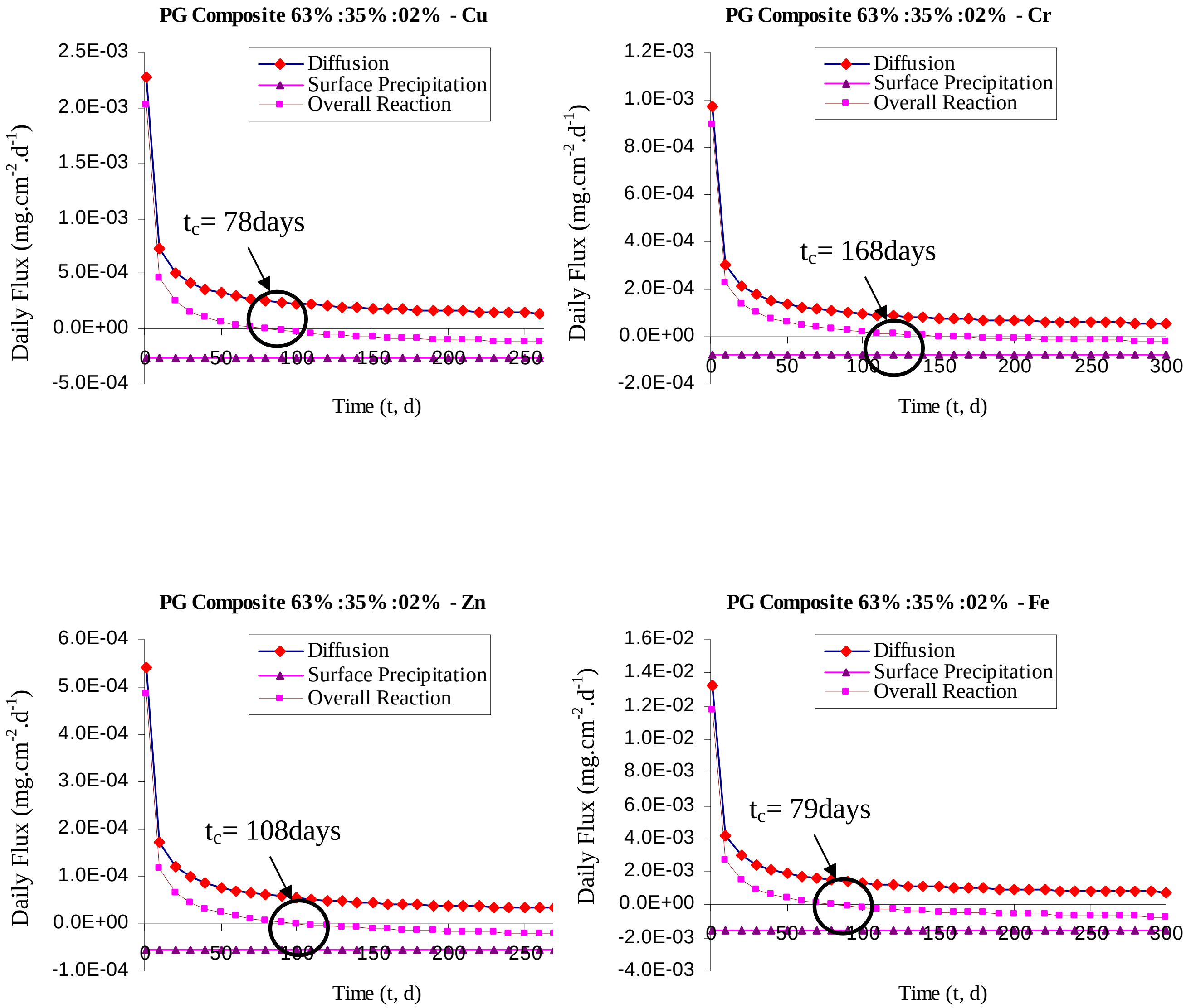


Figure K-3. Plots for Calculating t_c of the Heavy Metals for the 63%:35%:02% Composite Combinations.

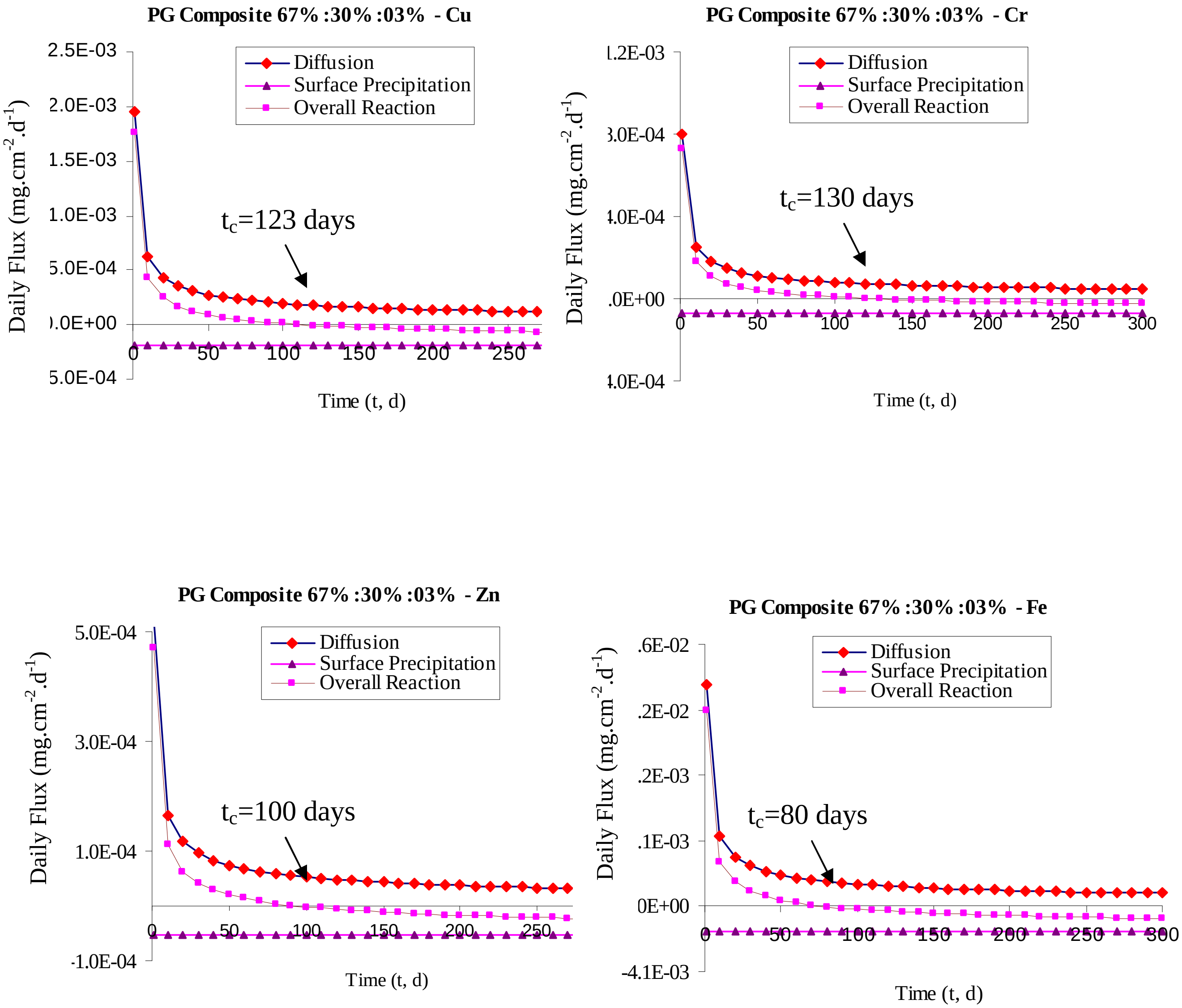


Figure K-4. Plots for Calculating t_c of the Heavy Metals for the 67%:30%:03% Composite Combinations.

Appendix L

CHEMICAL EQULIBRIUM CALCULATION FOR MAGNESIUM COMPOUNDS

CHEMICAL EQUALIBRIUM CALCULATION
FOR MAGNESIUM COMPOUNDS

Table L-1. Calculation of the Ion Productivity of Magnesium Sulfate for the Phase II Testing.

Best Four PG Compositions						28-Day Dynamic Leaching Study
ID	PG:Class C Fly Ash:Portland Type II Cement	Mean SO_4^{2-} Amount (mg/L)	Mean SO_4^{2-} Amount (mol/L)	Mean Mg^{2+} Amount (mg/L)	Mean Mg^{2+} Amount (mol/L)	Ion Productivity for $\{MgSO_4\}$
1A	73%:25%:02%	1900.4529	0.0198	475.6211	0.0196	1.67E-05
1B		1887.5328	0.0196	453.5891	0.0187	1.58E-05
1C		1827.7353	0.0190	440.7990	0.0181	1.49E-05
2A	67%:30%:03%	1843.6230	0.0192	469.6201	0.0193	1.60E-05
2B		1846.3414	0.0192	443.6669	0.0183	1.52E-05
2C		1787.8920	0.0186	448.8368	0.0185	1.48E-05
3A	62%:35%:03%	1821.8306	0.0190	476.1163	0.0196	1.60E-05
3B		1796.0579	0.0187	457.8834	0.0188	1.52E-05
3C		1773.3118	0.0185	459.9456	0.0189	1.51E-05
4A	63%:35%:02%	1949.7531	0.0203	486.1145	0.0200	1.75E-05
4B		1926.6773	0.0201	410.8952	0.0169	1.46E-05
4C		1870.9180	0.0195	447.1627	0.0184	1.55E-05
5A	63%:35%:02%	2147.1135	0.0223	470.9762	0.0194	1.87E-05
5B		2155.7894	0.0224	446.0430	0.0184	1.78E-05
5C		2168.7016	0.0226	451.7995	0.0186	1.81E-05
6A	63%:35%:02%	2046.4134	0.0213	473.8061	0.0195	1.79E-05
6B		2007.7580	0.0209	460.0816	0.0189	1.71E-05
6C		2034.8201	0.0212	464.5098	0.0191	1.75E-05
7A	63%:35%:02%	2142.3158	0.0223	470.9047	0.0194	1.87E-05
7B		2166.4149	0.0226	461.4579	0.0190	1.85E-05
7C		2143.4913	0.0223	468.6868	0.0193	1.86E-05
Sulfate Activity Coefficient = 0.12 (after Garrels and Thompson 1962; Stumm and Morgan 1996).						
Magnesium Activity Coefficient = 0.36 (after Garrels and Thompson 1962; Stumm and Morgan 1996).						
Solubility Product (K_{sp}) for $MgSO_4$ = 5.90E-03 (after Sawyer and others 1994).						

Table L-2. Calculation of the Ion Productivity of Magnesium Hydroxide for the Phase II Testing.

Best Four PG Compositions						28-Day Dynamic Leaching Study
ID	PG:Class C Fly Ash:Portland Type II Cement	Mean Mg^{2+} Amount (mol/L)	Mean pH	$Activity_{[OH-]}$	$(Activity_{[OH-]})^2$	Mean Ion Productivity for $\{Mg(OH)_2\}$
1A 1B 1C	73%:25%:02%	1.88E-02	8.05	1.12E-06	1.26E-12	1.84E-14
2A 2B 2C	67%:30%:03%	1.87E-02	8.11	1.29E-06	1.65E-12	2.09E-14
3A 3B 3C	62%:35%:03%	1.91E-02	8.10	1.27E-06	1.62E-12	2.09E-14
4A 4B 4C	63%:35%:02%	1.84E-02	8.11	1.27E-06	1.62E-12	2.02E-14
5A 5B 5C	63%:35%:02%	1.88E-02	8.34	2.17E-06	4.71E-12	7.20E-14
6A 6B 6C	63%:35%:02%	1.92E-02	8.28	1.90E-06	3.63E-12	5.61E-14
7A 7B 7C	63%:35%:02%	1.92E-02	8.32	2.07E-06	4.29E-12	6.58E-14
Magnesium Activity Coefficient = 0.36 (after Garrels and Thompson 1962; Stumm and Morgan 1996).						
Solubility Product (K_{sp}) for $Mg(OH)_2$ = 9.0E-12 (after Sawyer and others 1994).						

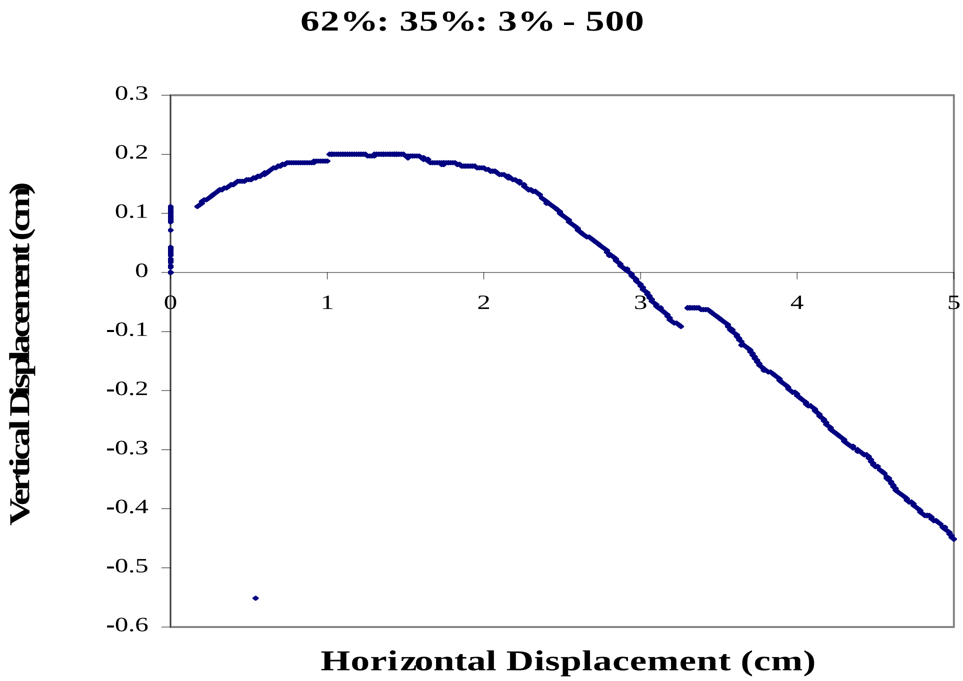
Table L-3. Calculation of the Ion Productivity of Magnesium Carbonate for the Phase II Testing.

Best Four PG Compositions					28-Day Dynamic Leaching Study
ID	PG:Class C Fly Ash:Portland Type II Cement	Mean Mg^{2+} Amount (mol/L)	Mean Carbonate Alkalinity (mg/L $CaCO_3$)	Mean $[CO_3^{2-}]$ (mol/L)	Mean Ion Productivity for $\{MgCO_3\}$
1A, 1B, 1C	73%:25%:02%	2.01E-02	100.67	1.01E-03	1.47E-06
2A, 2B, 2C	67%:30%:03%	1.96E-02	96.67	9.67E-04	1.45E-06
3A, 3B, 3C	62%:35%:03%	1.98E-02	103.33	1.03E-03	1.55E-06
4A, 4B, 4C	63%:35%:02%	2.04E-02	98.50	9.85E-04	1.46E-06
Magnesium Activity Coefficient = 0.36 (after Garrels and Thompson 1962; Stumm and Morgan 1996).					
Solubility Product (K_{sp}) for $MgCO_3$ = 4.0E-5 (after Sawyer and others 1994).					

Appendix M

SHEAR DATA

SHEAR DATA



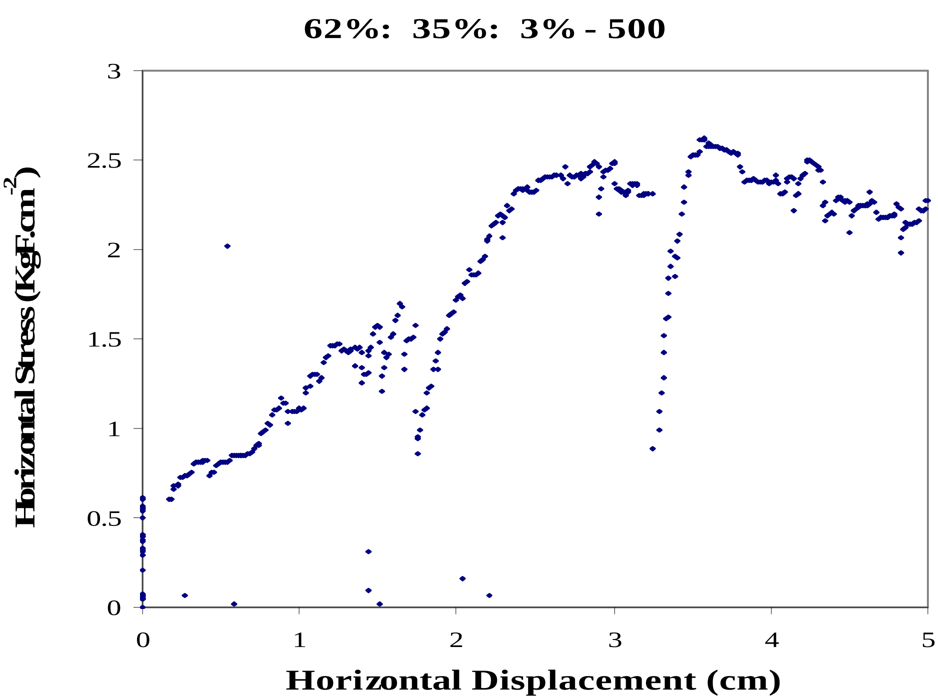
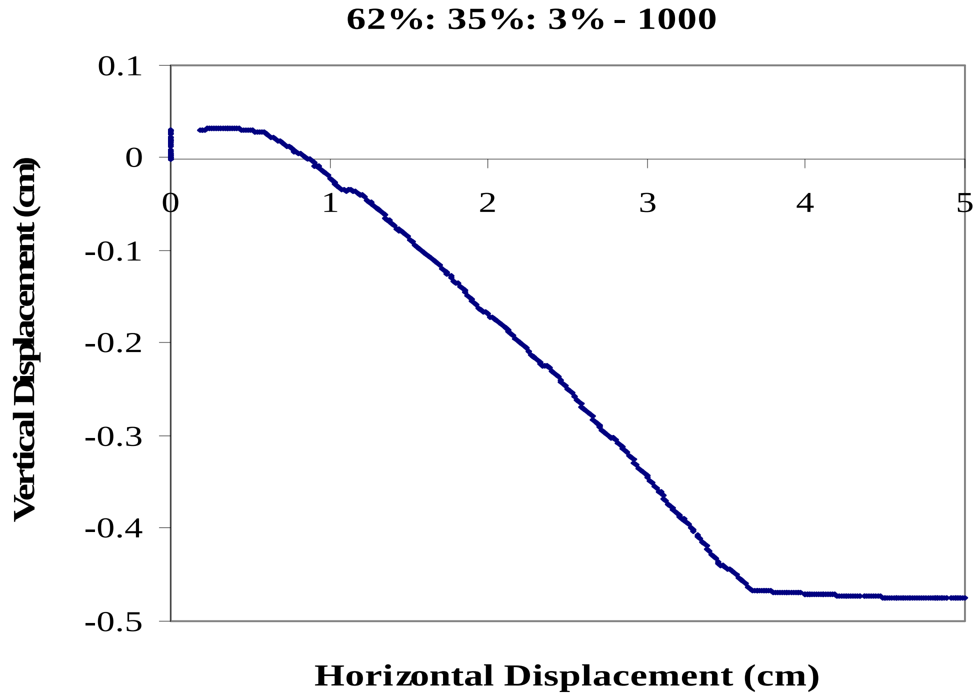


Figure M-1. Data Captured During Shearing of the 62%:35%:03% Sample at 500 pcf.



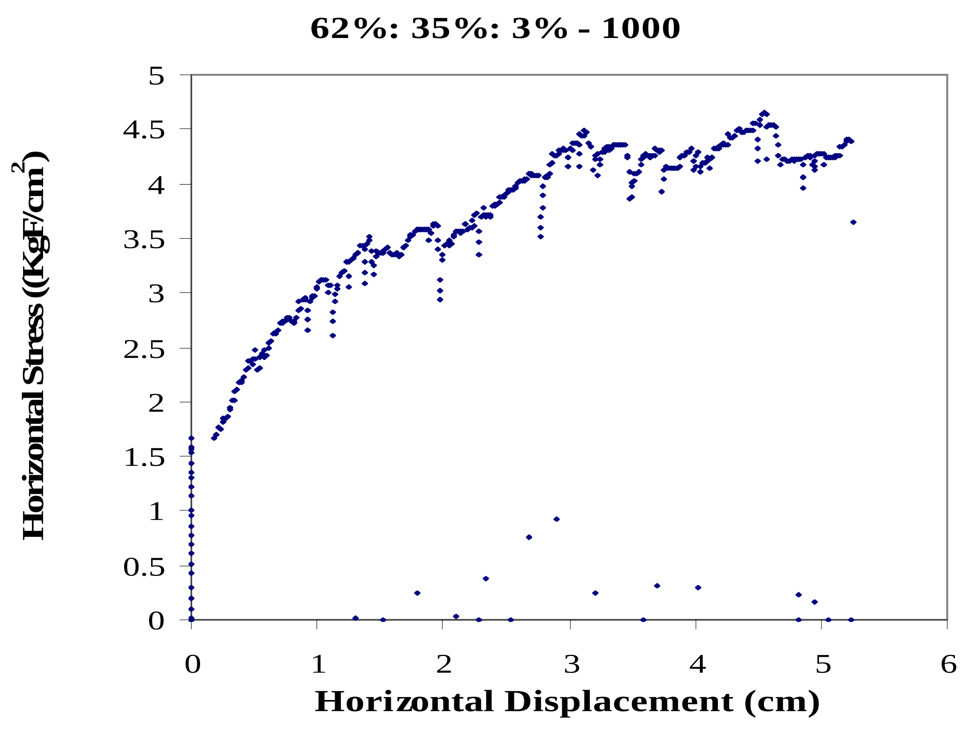
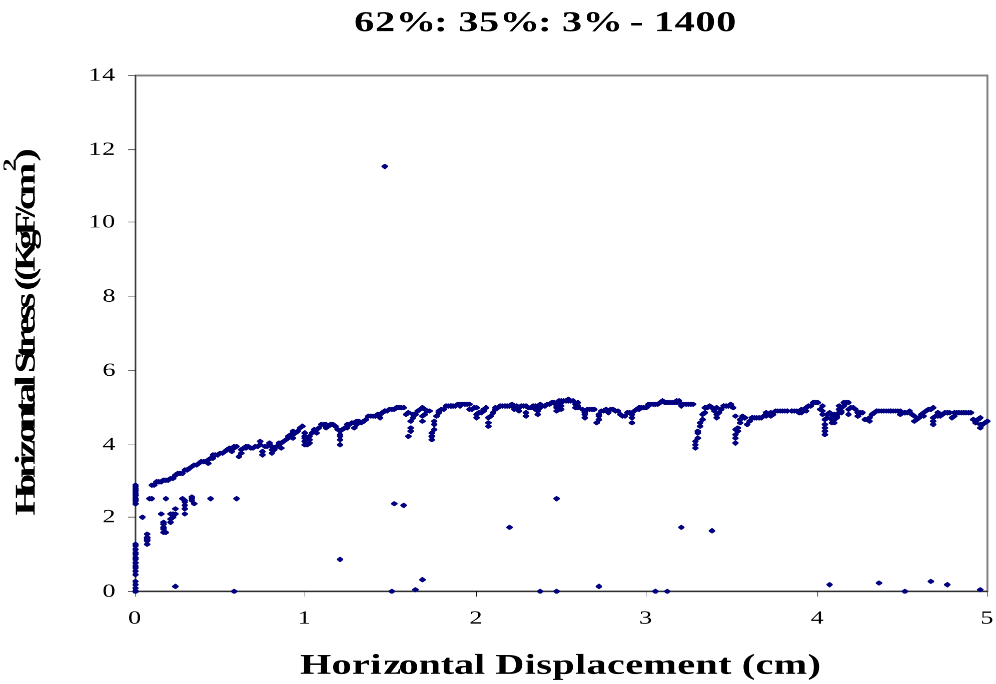


Figure M-2. Data Captured During Shearing of the 62%:35%:03% Sample at 1000 pcf.



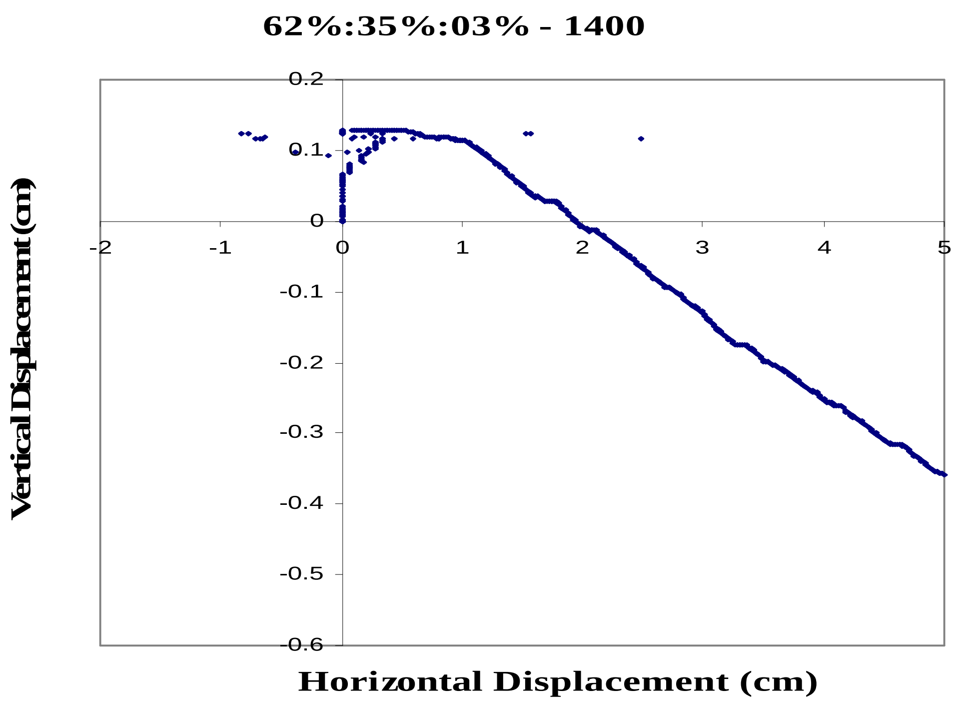
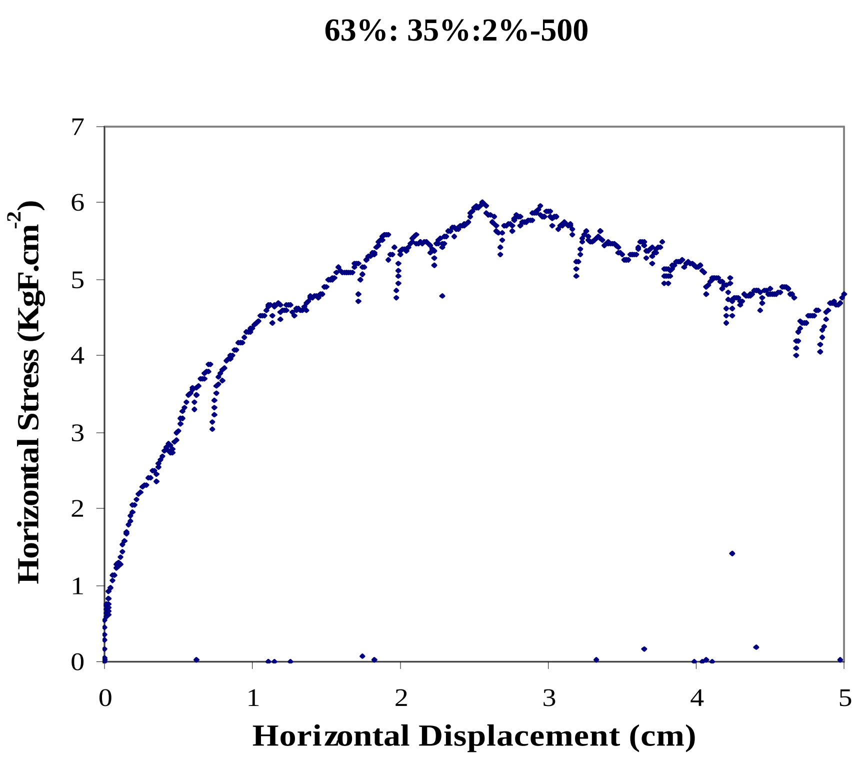


Figure M-3. Data Captured During Shearing of the 62%:35%:03% Sample at 1400 pcf.



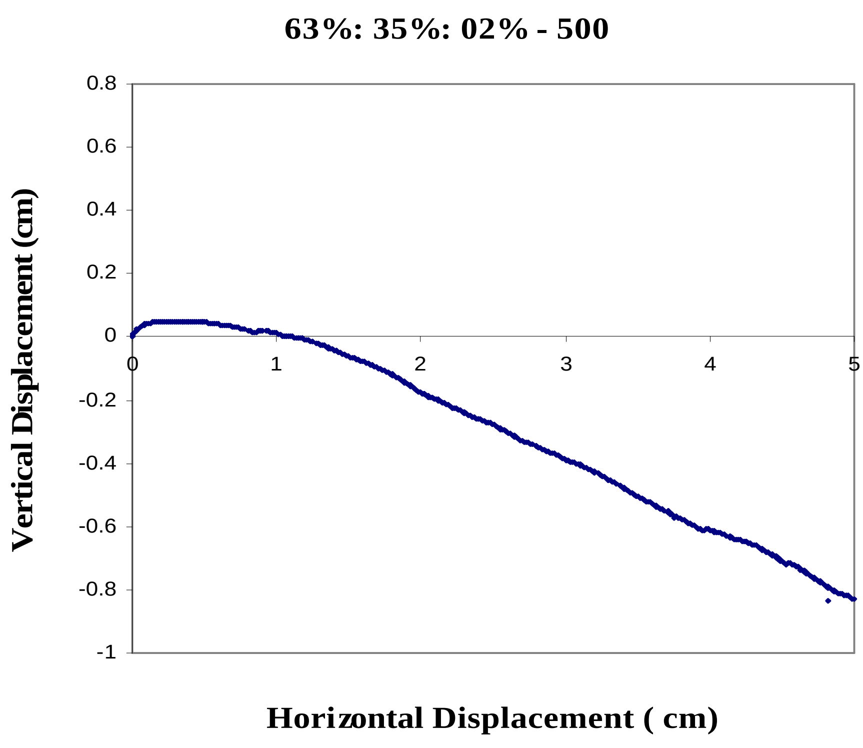
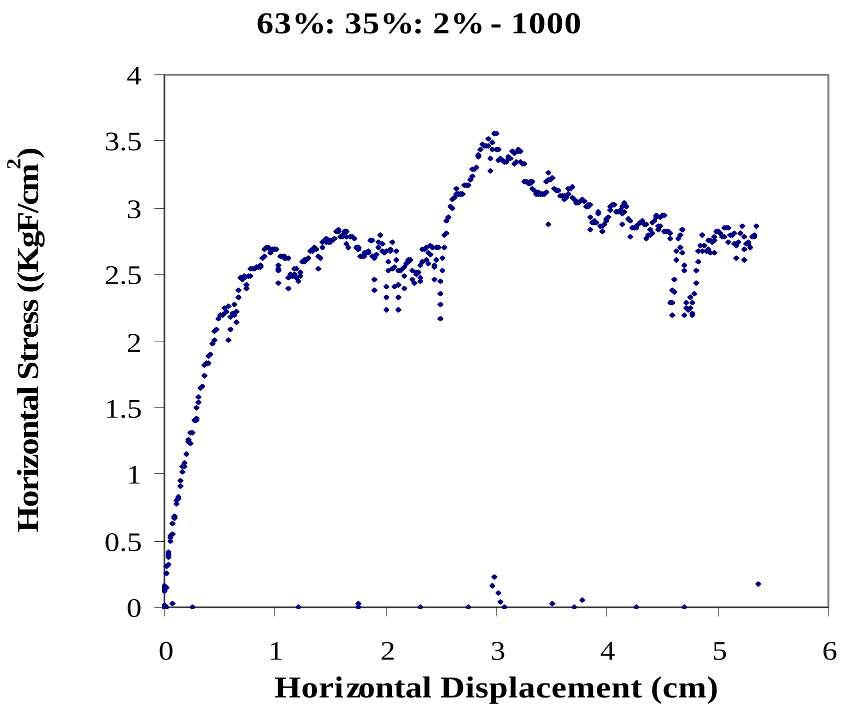


Figure M-4. Data Captured During Shearing of the 63%:35%:02% Sample at 500 pcf.



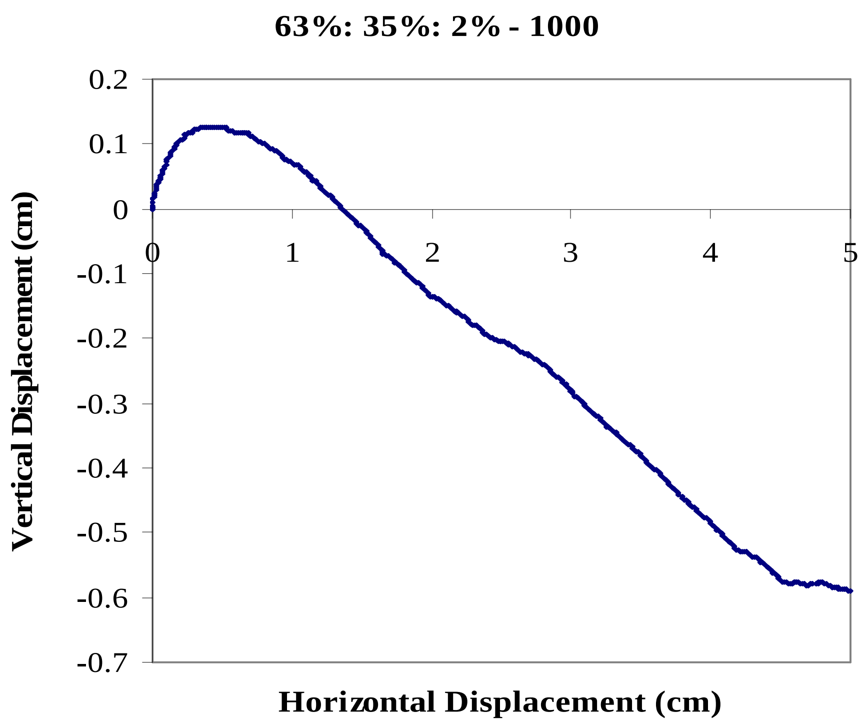
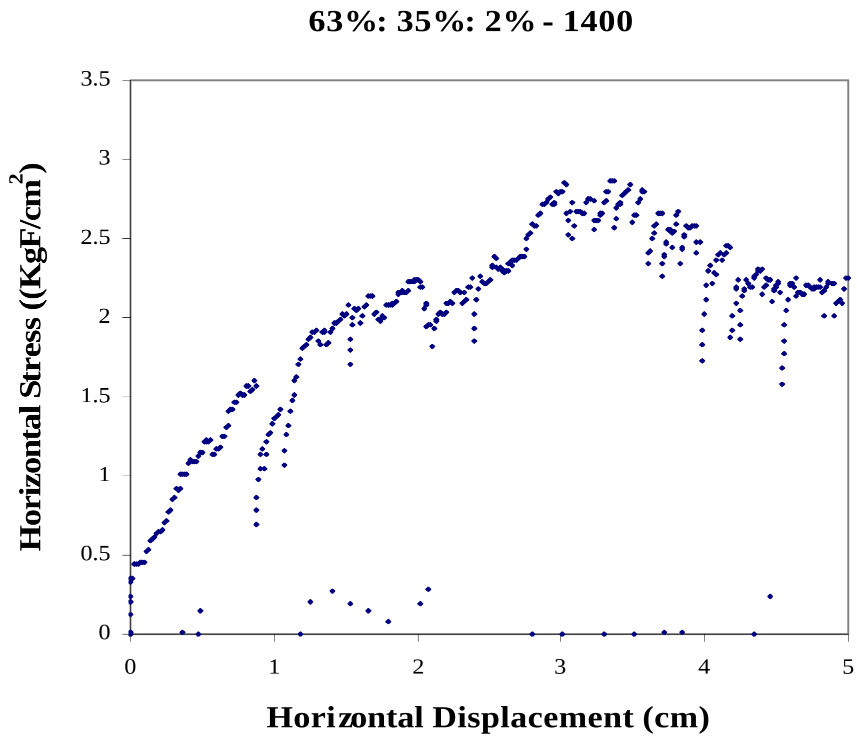


Figure M-5. Data Captured During Shearing of the 63%:35%:02% Sample at 1000 pcf.



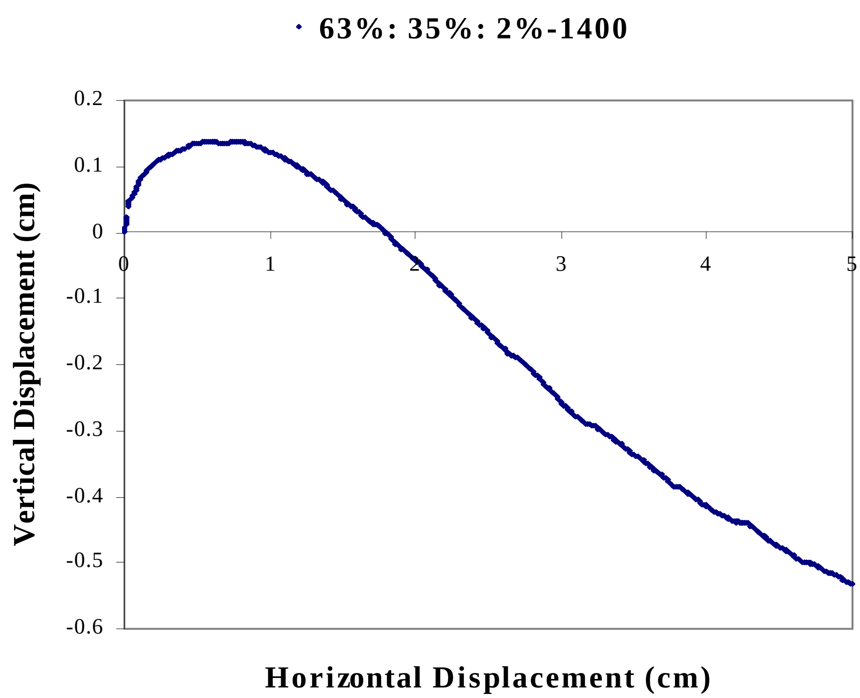


Figure M-6. Data Captured During Shearing of the 63%:35%:02% Sample at 1400 pcf.

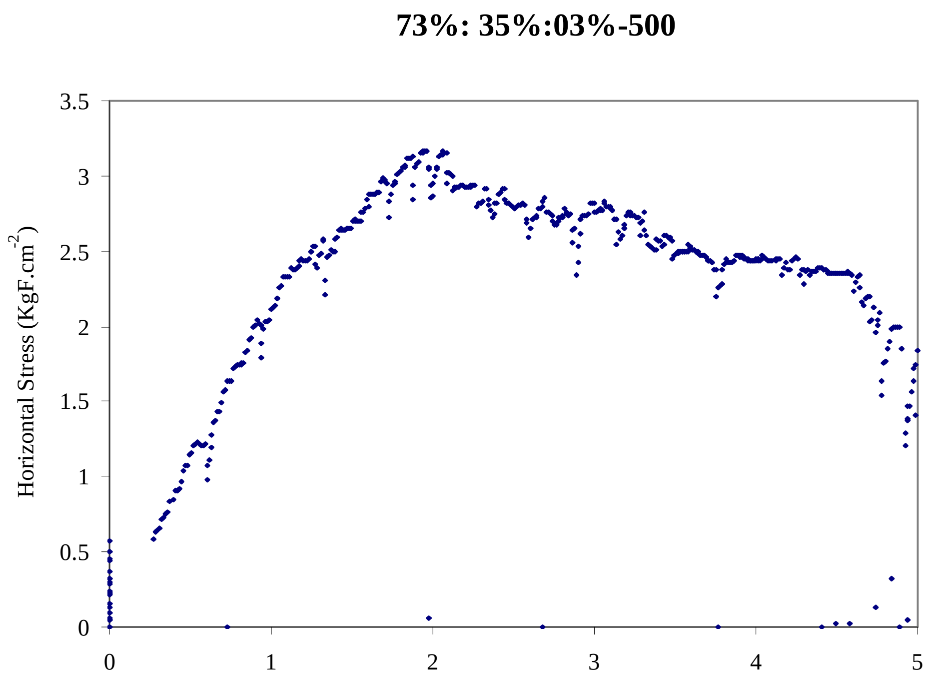
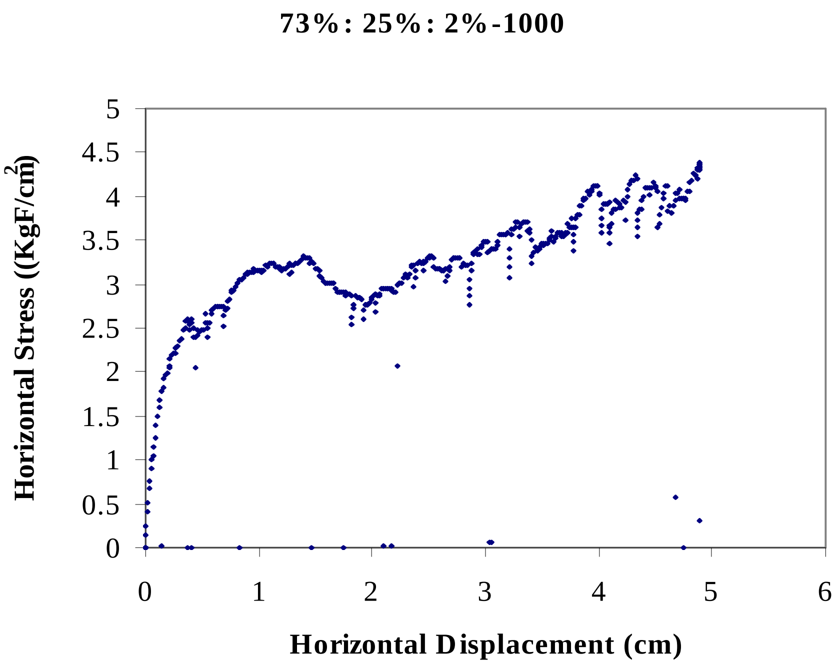


Figure M-7. Data Captured During Shearing of the 73%:35%:02% Sample at 500 pcf.



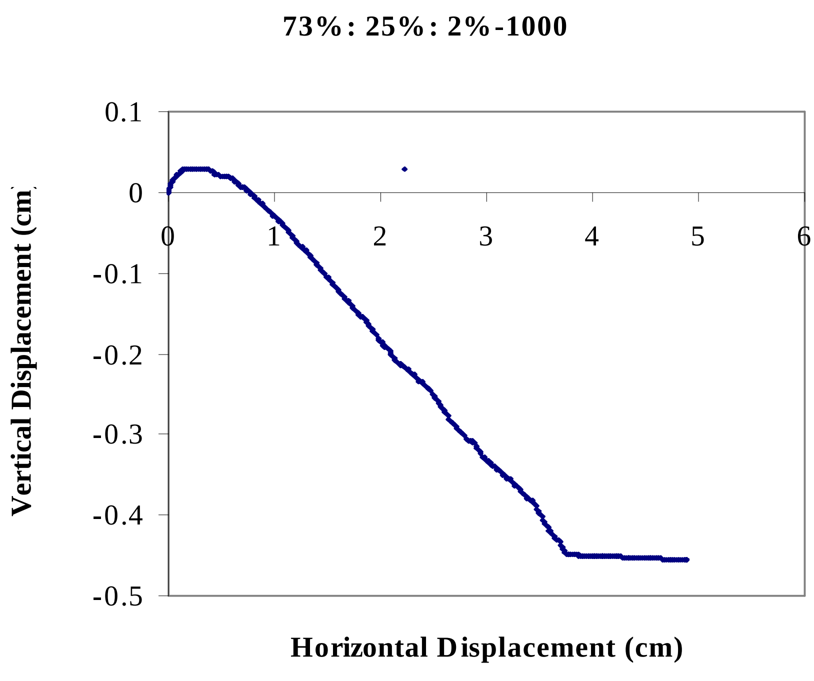


Figure M-8. Data Captured During Shearing of the 73%:35%:02% Sample at 1000 pcf.

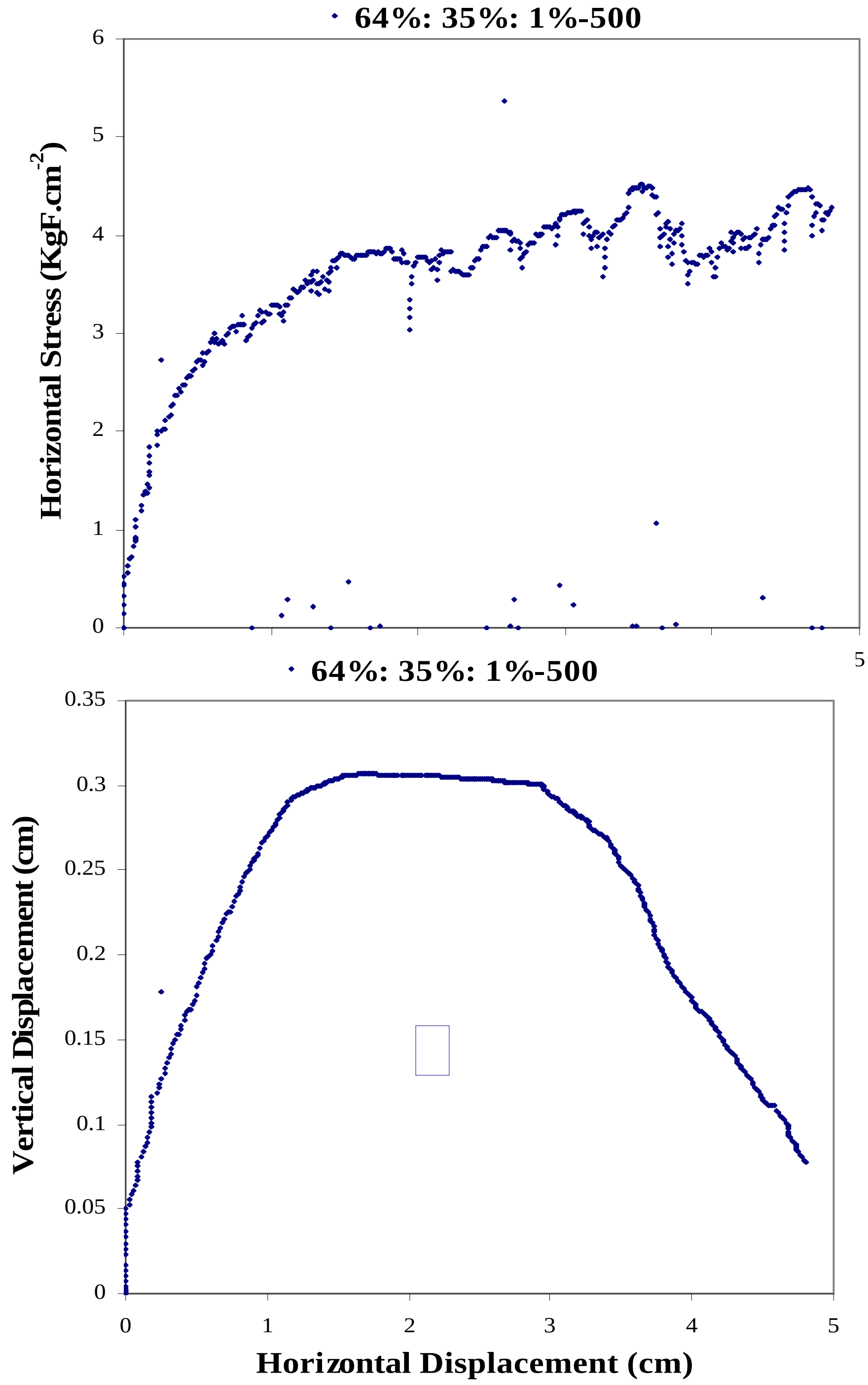
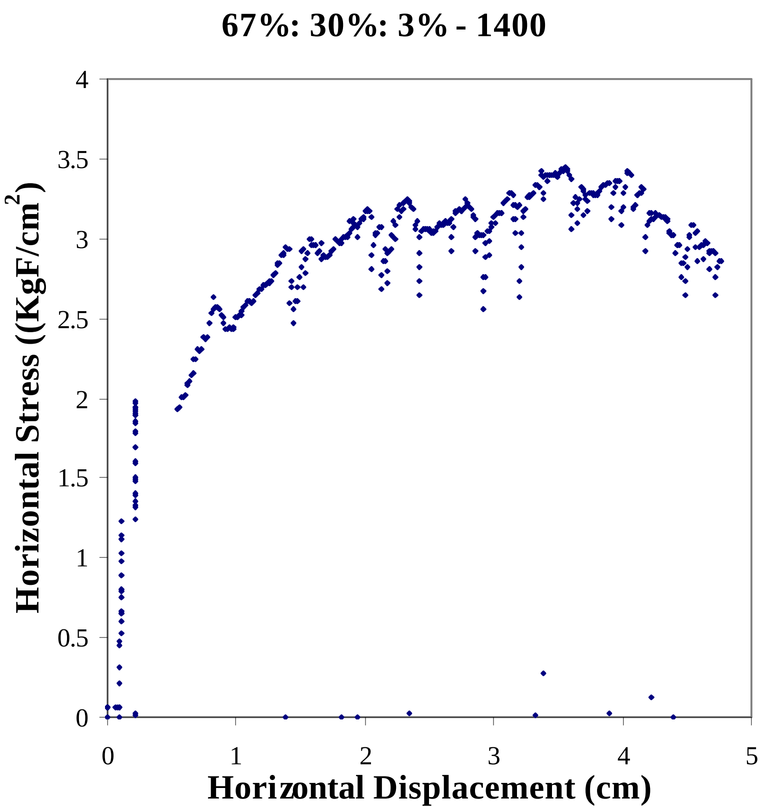


Figure M-9. Data Captured During Shearing of the 64%:35%:01% Sample at 500 pcf.



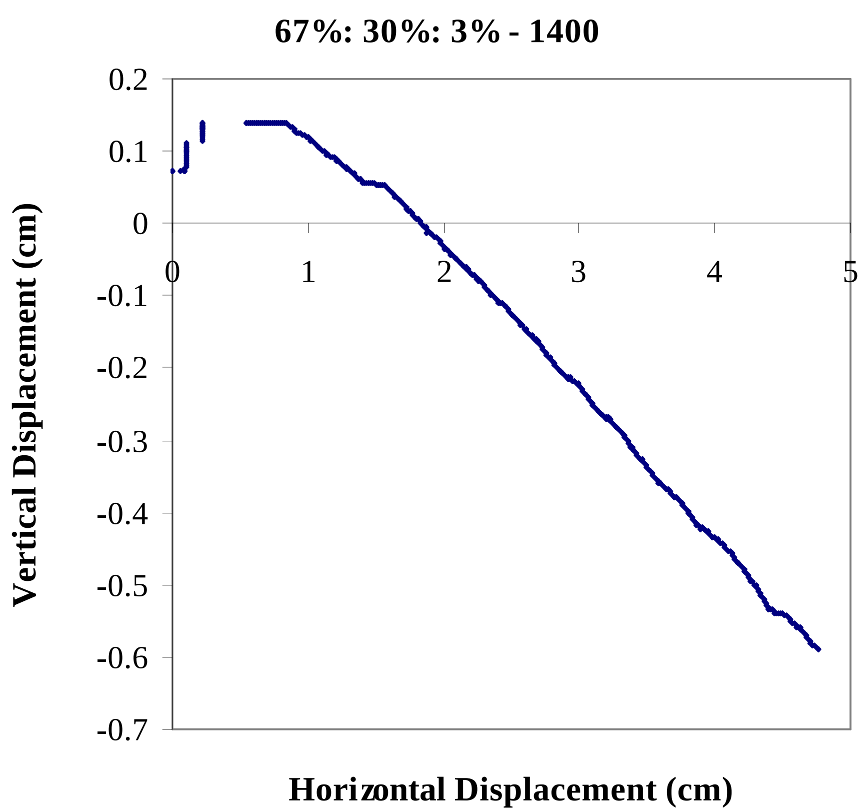


Figure M-10. Data Captured During Shearing of the 64%:35%:01% Sample at 1400 pcf.

Table M-1. Sieve Analysis for the 73%:25%:02% Sample After Shearing the Sample at 500 pcf.

Results of sieve analysis conducted on the **73%:20%:03%** sample sheared at **227kg** normal load.					
Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	22	91.6666667	91.666667	8.333333
3/4"	19.5	0.0176	0.07333333	91.74	8.26
1/2"	12.7	0.5754	2.3975	94.1375	5.8625
3/8"	9.51	0.1584	0.66	94.7975	5.2025
#4	4.75	0.2544	1.06	95.8575	4.1425
#10	2	0.1898	0.79083333	96.648333	3.351667
#18	1	0.0892	0.37166667	97.02	2.98
#20	0.85	0.0143	0.05958333	97.079583	2.920417
#40	0.43	0.049	0.20416667	97.28375	2.71625
#60	0.25	0.0248	0.10333333	97.387083	2.612917
#140	0.11	0.039	0.1625	97.549583	2.450417
#200	0.08	0.0063	0.02625	97.575833	2.424167
pan		0.0026	0.01083333	97.586667	
		23.4208			
Mass loss during sieve analysis is <0.0241333%.					

Table M-2. Sieve Analysis for the 73%:25%:02% Sample After Shearing the Sample at 1000 pcf.

Results of sieve analysis conducted on the **73%:20%:03%** sample sheared at **454kg** normal load.

Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	22	92.4369748	92.436975	7.563025
3/4"	19.5	0.0565	0.23739496	92.67437	7.32563
1/2"	12.7	0.5674	2.38403361	95.058403	4.941597
3/8"	9.51	0.1379	0.57941176	95.637815	4.362185
#4	4.75	0.2248	0.94453782	96.582353	3.417647
#10	2	0.1884	0.79159664	97.37395	2.62605
#18	1	0.092	0.38655462	97.760504	2.239496
#20	0.85	0.0145	0.06092437	97.821429	2.178571
#40	0.43	0.0508	0.21344538	98.034874	1.965126
#60	0.25	0.0242	0.10168067	98.136555	1.863445
#140	0.11	0.037	0.15546218	98.292017	1.707983
#200	0.08	0.0043	0.01806723	98.310084	1.689916
pan		0.0024	0.01008403	98.320168	
		23.4002			

Mass loss during sieve analysis is <0.0167983%.

Table M-3. Sieve Analysis for the 73%:25%:02% Sample After Shearing the Sample at 1400 pcf.

Results of sieve analysis conducted on the **73%:20%:03%** sample sheared at **635kg** normal load.					
Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	22	91.6666667	91.666667	8.333333
3/4"	19.5	0.0354	0.1475	91.814167	8.185833
1/2"	12.7	0.4322	1.80083333	93.615	6.385
3/8"	9.51	0.1827	0.76125	94.37625	5.62375
#4	4.75	0.2902	1.20916667	95.585417	4.414583
#10	2	0.2257	0.94041667	96.525833	3.474167
#18	1	0.1063	0.44291667	96.96875	3.03125
#20	0.85	0.0172	0.07166667	97.040417	2.959583
#40	0.43	0.0574	0.23916667	97.279583	2.720417
#60	0.25	0.0311	0.12958333	97.409167	2.590833
#140	0.11	0.0376	0.15666667	97.565833	2.434167
#200	0.08	0.0021	0.00875	97.574583	2.425417
pan		0.0013	0.00541667	97.58	
		23.4192			
Mass loss during sieve analysis is <0.0242%.					

Table M-4. Sieve Analysis for the 67%:30%:03% Sample After Shearing the Sample at 500 pcf.

Results of sieve analysis conducted on the **67%:30%:03%** sample sheared at **227kg** normal load.					
Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	20	92.5925926	92.592593	7.407407
3/4"	19.5	0.1888	0.87407407	93.466667	6.533333
1/2"	12.7	0.152	0.7037037	94.17037	5.82963
3/8"	9.51	0.1045	0.4837963	94.654167	5.345833
#4	4.75	0.2156	0.99814815	95.652315	4.347685
#10	2	0.267	1.23611111	96.888426	3.111574
#18	1	0.1462	0.67685185	97.565278	2.434722
#20	0.85	0.0211	0.09768519	97.662963	2.337037
#40	0.43	0.0753	0.34861111	98.011574	1.988426
#60	0.25	0.0462	0.21388889	98.225463	1.774537
#140	0.11	0.0295	0.13657407	98.362037	1.637963
#200	0.08	0.001	0.00462963	98.366667	1.633333
pan		0.0009	0.00416667	98.370833	
		21.2481			
Mass loss during sieve analysis is <0.0162917%.					

Table M-5. Sieve Analysis for the 67%:30%:03% Sample After Shearing the Sample at 1000 pcf.

Results of sieve analysis conducted on the **67%:30%:03%** sample sheared at **454kg** normal load.					
Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	23.8	92.2838309	92.283831	7.716169
3/4"	19.5	0.1594	0.61806902	92.9019	7.0981
1/2"	12.7	0.1626	0.63047693	93.532377	6.467623
3/8"	9.51	0.1039	0.40286933	93.935246	6.064754
#4	4.75	0.1865	0.72314851	94.658395	5.341605
#10	2	0.2499	0.96898022	95.627375	4.372625
#18	1	0.1352	0.5242342	96.151609	3.848391
#20	0.85	0.0223	0.08646762	96.238077	3.761923
#40	0.43	0.0734	0.28460644	96.522683	3.477317
#60	0.25	0.0436	0.16905777	96.691741	3.308259
#140	0.11	0.0297	0.11516092	96.806902	3.193098
#200	0.08	0.0015	0.00581621	96.812718	3.187282
pan		0.0014	0.00542846	96.818147	
		24.9694			
Mass loss during sieve analysis is <0.0318185%.					

Table M-6. Sieve Analysis for the 67%:30%:03% Sample After Shearing the Sample at 1400 pcf.

Results of sieve analysis conducted on the **67%:30%:03%** sample sheared at **635kg** normal load.					
Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	24	90.5660377	90.566038	9.433962
3/4"	19.5	0.37	1.39622642	91.962264	8.037736
1/2"	12.7	0.81	3.05660377	95.018868	4.981132
3/8"	9.51	0.3	1.13207547	96.150943	3.849057
#4	4.75	0.31	1.16981132	97.320755	2.679245
#10	2	0.36	1.35849057	98.679245	1.320755
#18	1	0.22	0.83018868	99.509434	0.490566
#20	0.85	0.004	0.01509434	99.524528	0.475472
#40	0.43	0.005	0.01886792	99.543396	0.456604
#60	0.25	0.004	0.01509434	99.558491	0.441509
#140	0.11	0.003	0.01132075	99.569811	0.430189
#200	0.08	0.0025	0.00943396	99.579245	0.420755
pan		0.001	0.00377358	99.583019	
		26.3895			
Mass loss during sieve analysis is <0.0041698%.					

Table M-7. Sieve Analysis for the 63%:35%:02% Sample After Shearing the Sample at 500 pcf.

Results of sieve analysis conducted on the **63%:35%:02%** sample sheared at **227kg** normal load.					
Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	20	95.2380952	95.238095	4.761905
3/4"	19.5	0.109	0.51904762	95.757143	4.242857
1/2"	12.7	0.1304	0.62095238	96.378095	3.621905
3/8"	9.51	0.1065	0.50714286	96.885238	3.114762
#4	4.75	0.2434	1.15904762	98.044286	1.955714
#10	2	0.2837	1.35095238	99.395238	0.604762
#18	1	0.009	0.04285714	99.438095	0.561905
#20	0.85	0.0004	0.00190476	99.44	0.56
#40	0.43	0.0012	0.00571429	99.445714	0.554286
#60	0.25	0.0006	0.00285714	99.448571	0.551429
#140	0.11	0.0008	0.00380952	99.452381	0.547619
#200	0.08	0.0003	0.00142857	99.45381	0.54619
pan		0.0005	0.00238095	99.45619	
		20.8858			
Mass loss during sieve analysis is <0.0054381%.					

Table M-8. Sieve Analysis for the 63%:35%:02% Sample After Shearing the Sample at 1000 pcf.

Results of sieve analysis conducted on the **63%:35%:02%** sample sheared at **454kg** normal load.					
Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	24	94.8616601	94.86166	5.13834
3/4"	19.5	0.1091	0.4312253	95.292885	4.707115
1/2"	12.7	0.1289	0.50948617	95.802372	4.197628
3/8"	9.51	0.1049	0.41462451	96.216996	3.783004
#4	4.75	0.2402	0.94940711	97.166403	2.833597
#10	2	0.2861	1.13083004	98.297233	1.702767
#18	1	0.1491	0.58932806	98.886561	1.113439
#20	0.85	0.0225	0.08893281	98.975494	1.024506
#40	0.43	0.0814	0.32173913	99.297233	0.702767
#60	0.25	0.0588	0.23241107	99.529644	0.470356
#140	0.11	0.0241	0.09525692	99.624901	0.375099
#200	0.08	0.001	0.00395257	99.628854	0.371146
pan		0.001	0.00395257	99.632806	
		25.2071			
Mass loss during sieve analysis is <0.0036719%.					

Table M-9. Sieve Analysis for the 63%:35%:02% Sample After Shearing the Sample at 1400 pcf.

Results of sieve analysis conducted on the **63%:35%:02%** sample sheared at **635kg** normal load.

Sieve Opening	Sieve Size Opening (mm)	Mass Retained on Each Sieve W_n (lb)	Percentage Mass Retained R_n	Cumulative Percent Retained E R_n	Percent Finer 100-E R_n
1"	25.4	24	92.3076923	92.307692	7.692308
3/4"	19.5	0.1187	0.45653846	92.764231	7.235769
1/2"	12.7	0.1737	0.66807692	93.432308	6.567692
3/8"	9.51	0.0805	0.30961538	93.741923	6.258077
#4	4.75	0.2211	0.85038462	94.592308	5.407692
#10	2	0.2066	0.79461538	95.386923	4.613077
#18	1	0.0937	0.36038462	95.747308	4.252692
#20	0.85	0.0141	0.05423077	95.801538	4.198462
#40	0.43	0.0476	0.18307692	95.984615	4.015385
#60	0.25	0.0242	0.09307692	96.077692	3.922308
#140	0.11	0.0282	0.10846154	96.186154	3.813846
#200	0.08	0.001	0.00384615	96.19	3.81
pan		0.0012	0.00461538	96.194615	
		25.0106			

Mass loss during sieve analysis is <0.0380538%.