Testing Soil

Mixed with Waste or Recycled Materials

Mark A. Wasemiller and
Keith B. Hoddinott, editors

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Peer Review Policy

Each paper published in this volume was evaluated by two peer reviewers and at least one editor. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

To make technical information available as quickly as possible, the peer-reviewed papers in this publication were printed "camera-ready" as submitted by the authors.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM.

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Foreword

This publication, *Testing Soil Mixed with Waste or Recycled Materials,* contains papers presented at the symposium of the same name held in New Orleans, Louisiana on 16–17 January 1997. The sponsor of the event was ASTM Committee D-18 on Soil and Rock.

The symposium chairman was Mark A. Wasemiller, IT Hanford Company. The symposium co-chairman was Keith Hoddinott, U.S. Army Center for Health Promotion and Preventive Medicine. They served as editors of this publication.

Contents

Overview

Culturally and politically, the world has been moving in the direction of recycling and finding new uses for materials that have long been considered "waste." As has always been and always will be the case, necessity is the mother of invention. The environmental arena has taken up the challenge of finding and developing new ways to use materials economically that have long been thought of as having little or no value. This need is driven by environmental regulation, public pressure on industry to find better and environmentally safe ways to get rid of the by products (and sometimes the end products) of production, the need to drastically reduce the amount of waste material being shipped to decreasing landfill space, and, for industry, to find inexpensive means to accomplish these objectives. The areas of waste that have seen extensive study and progress include: treatment plant waste, used tires and rubber shreds, plastics, foundry waste, coal combustion waste, and wood and paper production.

It is vital that each new area of use be looked at against the potential impacts to people and the environment. One area in which these "waste" products are now being used is in combination with soils. The hope is that by introducing these products, a soil's performance as a construction material, its water-holding capacity, its ability to act as an impervious barrier, or other desirable characteristics might improve (or show little to negligible change).

When these "waste" materials are added to soil, a change in the physical and/or chemical characteristics of the soil generally takes place. This Special Technical Publication has been published as a result of the 1997 symposium on Testing Soil Mixed with Waste or Recycled Materials, held in New Orleans, Louisiana, to bring together the representatives of the regulatory, research, and industrial sectors of the environmental arena to share advances and lessons learned in this relatively new and rapidly growing field. The symposium was the outgrowth of work within ASTM Subcommittee D18.06 on Physical-Chemical Interactions of Soil and Rock.

Since this area of research and application is relatively new, ASTM's committee D18 on Soil and Rock sought to bring together information in a wide and varied range of areas. As in all new areas of research and application, the sharing of personal insights is always helpful in advancing efforts at a faster pace than it would if those working in the field did not meet. The range of possible applications also broadens as ideas, hypotheses, and theories are presented, shared, discussed, attacked, defended, and resolved. These are all vital and necessary aspects of healthy development in any field of endeavor.

The 23 papers published in this volume strive to span a wide range of subject matter in this field. The papers have been grouped into six categories. Some papers could have been included in more than one group, but to give balance to the symposium, they were grouped as presented here. The groupings are:

- Physical Properties of Soil Mixed with Miscellaneous Materials (six papers)
- Physical Testing of Soil Mixed with Tire/Rubber Shreds (three papers)
- Testing Soil and Paper Sludge Mixtures (two papers)
- Testing Soil and Fly Ash Mixtures (three papers)
- Testing Soil Mixed with Other Ashes (five papers)
- Performance of Soil and Tire/Rubber Shred Mixtures (four papers)

Physical Properties of Soil Mixed with Miscellaneous Materials

The papers in this group cover many different types of waste materials and applications. The waste types addressed include water treatment plant residuals, foundry sand, asphalt pavement, construction demolition debris, and partially saturated and oil-contaminated clays. Many different tests of physical properties are examined such as Atterberg limits, Proctor compaction, moisture content, unconfined compression, direct shear, consolidation, triaxial compression, permeability, etc. Chemical testing includes laboratory tests for semi-volatiles, pesticides, PCBs, total recoverable petroleum hydrocarbons, and metals.

Raghu et al. look at the effect on the physical characteristics of top soil mixed with water treatment plant residuals. Test results show that the mixture, while having a low permeability, lacks durability and shear strength and is therefore not suitable to be used as structural fill. It does, however, show promise as a landfill liner since it can be compacted if the water content is equal to the plastic limit, for it is at this condition that the lowest permeability is achieved. It is recommended that continued research be done to explore this and other potential beneficial uses of this mixture.

Khera and So look at the shear strength of calcium bentonite as affected by the addition of cement and slag. It was observed that the strength of specimens increases as the proportion of slag to cement is increased, with ultimate strength being achieved at about 2% strain, with little change in strength beyond this point.

Bhat and Lovell look at using waste foundry sand as one of the fine aggregates in flowable fill. Flowable fill is a highly useful geomaterial that has recently been developed for geotechnical applications. The paper describes various tests necessary to its successful design and develops a conceptual framework to design and understand all kinds of flowable fill mixtures. Several physical characteristics are examined along with the development of new criterion to evaluate hardening. The culmination of the paper is the presentation of a simple mix design methodology.

Maher et al. look at soil-type properties of recycled asphalt pavement (RAP) in construction as used as base and subbase material in paving systems. The geotechnical characterization of the RAP includes determining the engineering classification, looking at gradation, and determining moisture-density relationships. The resilient properties of RAP are determined using a state-of-the-art soil machine under various load cycles to look at disintegration and separation and to developing a rutting index.

McMahon presents information on the development of a manufactured soil product resulting from construction and demolition debris. The process used to manufacture the soil is presented. Also discussed is the chemical analysis of the material (RCRA metals, semi-volatiles, pesticides, PCBs, and total recoverable petroleum hydrocarbons) since it is currently being used as a daily landfill cover and as temporary road fill material at construction sites in Northeast Florida.

Silvestri et al. look at the affects of motor oil contamination on compacted clays. Test results show a decrease in optimum water content, but with a much lower decrease in the corresponding optimum dry density. Results also show that for a very low percentage (2 to 4%) oil content, the optimum dry density is slightly greater than clays compacted without any oil contamination.

Physical Testing of Soil Mixed with Tire/Rubber Shreds

Stockpiled used tires number in the billions in the United States, with 240 million tires being added each year. With the promulgation of new regulations in many states that prohibit the land filling of waste tires, it is necessary to find economical uses for them. Proposed uses include their incorporation into structural fill in combination with geogrids and other such uses. These applications require knowledge of the dynamic and bulk mechanical properties of mixtures that utilize waste tires.

Romero and Pamukcu examine the use of low-strain harmonic excitation to produce propagating waves in a system of crumb rubber with a sandy soil mix. The system produces a wave response termed the "signature pattern" due to its uniqueness and repeatability. This signature pattern is used to characterize the material by predicting dynamic properties such as shear modulus.

Benson et al. evaluate how the mechanical properties and behavior of waste tire chips and soil-tire chip mixtures differ when fine- and coarse-grained soils are used in the mix. Tests to evaluate compressibility, deformation, shear strength, and one-dimensional creep were done. Test results show that tire chips and soil-tire chip mixtures behave like soils, but are more compressible and require more deformation to mobilize their ultimate shear strength. Incorporation of tire chips into backfill also results in a decrease in unit weight, and for mixtures containing sand or sandy silt, an increase in shear strength. Overall, soil-tire chip mixtures make desirable retaining wall backfill material because structural requirements for the wall are reduced.

Bernal et al. discuss the results of a direct shear and pullout testing program conducted to evaluate the interaction properties of a rubber-sand, and tire shred-sand mixtures with geogrids with varying aperture size.

Testing Soil and Paper Sludge Mixtures

The forest products industry has, for several years, striven to identify methods to manage the considerable amounts of nonhazardous sludge generated during the manufacture of pulp and paper. These efforts have been heightened as a result of more stringent environmental regulations and dwindling landfill capacity. Potential applications include hydraulic barriers, barrier protection layers, synthetic soils, and vegetative layers. As with other waste materials mixed with soil, characterization of the geotechnical and chemical properties is essential.

Moo-Young and Zimmie discuss the results of testing done on a cover that utilized high-water-content paper sludge in a landfill cover in Corinth, New York. The design and construction procedures for the landfill are detailed. Performance results in the areas of frost penetration, resistivity, effective stress, hydraulic conductivity, and temperature are presented.

Veillette and Tanguay present the results of a study done in the Donnacona area in the Canadian providence of Quebec to evaluate the impact of paper mill sludge on soil, plant tissue, and crop yield. Several cash crops and crop rotations are evaluated and significant increases in yield are reported with no significant effect on the chemical content of plant tissues.

Testing Soil and Fly Ash Mixtures

Fly ash has been used successfully in concrete batch mixes for over a decade to assist in improving strength and durability. Fly ashes that do not meet the standard requirements for incorporation into concrete, however, can be used in construction with soil and can prove to be an efficient and cost effective use of this coal combustion by product. Potential stabilization of soil using fly ash is looked at with regard to road construction and landfill capping.

Turner looks at the engineering properties of low-volume road subgrade soils modified by treatment with fly ash. A wide range of soil types is looked at with the results of improvements in compressive strength, resilient modulus, and wet-dry and freeze-thaw durability. The tests indicate that use of fly ash to stabilize subgrade soils can substantially decrease the required thickness aggregate.

Taha and Pradeep look at using fly ash to stabilize sand mixtures for the capping of sanitary landfills. Sand mixtures stabilized with 15 and 20% Class C fly ash were investigated. Tests conducted on these mixtures indicate that the mixture has increased strength, reduced permeability, and an increased resistance to freeze-thaw and wet-dry cycles, especially for the higher fly ash content. This points to a potential use of fly ash stabilized sands for the capping of sanitary landfills where fine-grained soils are not readily available or cost effectively imported.

Jalali et al. discussed the use of differential scanning calorimetry to test lime-fly ash mixtures during the formation of cementitious materials. One of the main reasons that more extensive use of fly ash in construction is hindered is the long period needed for lime-fly ash mixtures to gain strength. The induction period for the reaction between lime and fly ash is evaluated using this test method. A discussion of the equations developed, the time and cost savings of the method, and a simplified method of application are discussed.

Testing Soil Mixed with Other Ashes

Besides fly ash, there are other ash and ash-like materials that possess the potential for being used in construction applications. Research on quarry tailings, filter cake ash, kiln dust, bottom ash, and municipal solid waste ash is discussed.

Lee and Nicholson look at a mixture of municipal solid waste ash and quarry tailings for use in final landfill covers and also for road subbase material. The incineration of municipal solid waste to reduce volume is a common practice in today's world. Due to the limited resources in places like Hawaii (and small countries as well), a way to constructively use waste materials such as these helps to conserve valuable landfill space. Tests performed on these mixtures include compaction, Atterberg limits, grain size, permeability, direct shear, and one-dimensional swell. In conjunction with this work, Ding and Nicholson also look at improving the engineering properties of tropical soils by adding waste ash and chemicals.

McManis and Nataraj investigate the possible use of diatomaceous earth filter cake used in the manufacture of additives for petroleum products, as a light-weight fine aggregate in earth fill material, as road base and subbase, as a flowable construction fill; other potential uses are also presented. A complete chemical and physical characterization of the ash and its scrubber mud was performed.

Miller et al. look at the use of kiln dust to reduce the wetting-induced collapse potential of compacted soil and shale. This paper presents results of a research project focusing on cement kiln dust produced during the manufacture of Portland cement. Results show that the collapse potential at conditions greater than the optimum moisture content is reduced drastically and nearly eliminated when compared to untreated conditions.

Demars et al. evaluate the physical and chemical properties of bottom ash from refuse incineration. Testing was performed on natural bottom ash and bottom ash amended with other fine-grained natural aggregates such as clay and coal fly ash. These mixtures are evaluated for suitability as landfill liner material. These mixtures, based on limited TCLP testing, have been categorized as non-hazardous; however, batch and column leaching tests produce a leachate that is alkaline with elevated soluble metals and salts, making further studies and amending necessary to be able to use it outside of a landfill setting.

Performance of Soil and Tire/Rubber Shred Mixtures

Complementary to the geotechnical evaluation of used tire and rubber shreds is the study of the performance of these materials in field applications. The papers in this section look at the problem of spontaneous combustion of tire chip road fill material at two sites in the state of Washington, the performance of shredded tires used in the subbase layer of asphalt pavements, the impact to groundwater of tire chips used in road construction, and the use of tire chips to mitigate BTEX compounds in groundwater.

Nightingale and Green present a study on two sites in the state of Washington where tire chips had been used as part of the fill material when road construction was performed. While no concrete conclusions are drawn with regards to the reason behind the spontaneous combustion, the similarities between the sites are noted and a plausible reason for the spontaneous combustion is presented.

Papp et al. compare road subbase composed of virgin soil mixed with shredded tire chips to naturally occurring virgin soil. A number of experimental issues are discussed such as: method of compaction, optimum ratio of soil to tire chips, optimum size and gradation of the chips, and strength testing using the California Bearing Ratio.

Humphrey et al. look at the effect of tire chips used as thermal insulation along the shoulder of roads to limit frost penetration. Using groundwater monitoring wells to monitor both the groundwater beneath the test site and upgradient of the test site, the levels of nine metals and two halogens were measured. In all instances but one (manganese) none of the targeted analytes were above either primary or secondary drinking water standards, with Mn naturally present at elevated levels in groundwater in many areas.

Kershaw and Pamukcu look at the ability of tire chips to aid in the mitigation of BTEX compounds since research has shown that many rubber polymers have the ability to sorb many types of solvents such as those found in gasoline. Tests show that ground tire rubber possesses between 4 and 8% of the adsorption capacity of granular-activated carbon, and in column tests, utilization efficiencies ranged from 32 to 61% when in contact with the contaminant stream for 36 minutes.

In addition to the authors of the individual papers, the success of the symposium and this publication reflects the contribution of many individuals. The symposium committee and session chairmen worked diligently in soliciting abstracts, in selecting the papers for presentation, and in chairing the sessions. The committee consisted of: Keith Hoddinott, U.S. Army Environmental Hygiene Agency; Mark A. Wasemiller, Natural Resources Conservation Service; Dr. Ronald C. Chaney, Humboldt State University; James T. Mickam, O'Brien and Gere engineers; Dr. C. William Lovell, Purdue University; and Dr. Mark Marcus, RECRA Environmental.

Critical to maintaining the technical quality of this STP was the diligent work of the technical reviewers. Each paper was reviewed by a minimum of two technically competent individuals to help ensure that the work reported was original, accurate, reproducible, and meaningful.

Considerable appreciation must be given to the support staff at ASTM for their tireless dedication in seeing that both the symposium and this STP were of the highest quality. We all trust that the papers presented will aid in the efforts of industry toward continued efforts to develop and improve methods of handling "waste" products to the benefit of humankind and the environment which our creator has graciously given us stewardship over. May we

ever strive to show Him that we care about the big blue marble which He has given to us to care for.

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