RESEARCH NEEDS FOR MINING AND INDUSTRIAL SOLID WASTE DISPOSAL

Report of a Workshop held at Colorado State University, Fort Collins, Colorado, July 22 and 23, 1976, under the sponsorship of the National Science Foundation, through the initiative of the Embankment Dams and Slopes Committee of ASCE.

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PREFACE

On July 22nd and 23rd, 1976, a Workshop on Research Needs for Mining and Industrial Solid Waste Disposal was held on the Colorado State University campus at Fort Collins, Colorado. The ASCE Committee on Embankment Dams and Slopes proposed the Workshop, which was sponsored by the National Science Foundation.

This report was prepared by the participants in the Workshop, which included representatives of geotechnical and environmental engineering organizations, industries, and regulatory agencies. The participants identified 19 separate areas of needed research, which are described in this report.

It is intended that this report should provide guidance to the engineering community, both individuals and organizations, who may be interested in sponsoring or performing research. The report also points out the need for effective research studies to alleviate the critical and growing problems in the area of mining and industrial solid waste disposal. The engineering participants in the Workshop came mostly from the Geotechnical Engineering profession, and thus perceive the problems of solid waste disposal from this point of view. The group recognized, however, that effective solutions to solid waste disposal problems can only be achieved through multidisciplinary efforts, and consideration of a wide variety of economic, technical, environmental, and social factors.

INTRODUCTION

Changing mining and processing techniques, utilization of lower grade ores, and increasing demand for fuels and minerals are resulting in greatly increased quantities of waste materials from major mines, mills and plants throughout the world. These factors all contribute to the need for increased consideration for engineering of the refuse embankments and structures, especially those impounding fluids, from initiation of disposal through abandonment, reclamation, and ultimate re-use of the land. Failures of tailings and other waste embankments, and increasing potential hazards resulting from increased size and proximity to developed areas, require the immediate attention of the geotechnical engineering profession.

Literally thousands of existing refuse disposal facilities in the copper, coal, phosphate, taconite, lead-zinc, and other types of industrial waste are, or soon will be, under federal, state or other regulatory control. Most of these existing disposal facilities have "just grown"; their design, if any, was based on unique requirements specific to the site and the desire to dispose of the specific refuse at minimum cost. Recent disastrous events and environmental impact considerations have shown that these procedures may not be providing adequate public and environmental protection. In the future performance of these structures, risks may develop in such an insidious manner that their true magnitude is not realized in time to prevent serious consequences. The design and monitoring of new structures requires a much more detailed understanding of the nature of the problem.

There is an urgent need for research into the processing aspects, analysis and design, and monitoring and performance of waste disposal facilities. In today's society the concern for public safety, environmental protection and economic integrity of the resource development industry, demands that the problems be approached on an interdisciplinary basis between the geotechnical, mining and environmental disciplines, along with other related specialties, and with regard for the constraints of the regulatory agencies. In the following sections of this report, proposals are made which emphasize the geotechnical engineering aspects of the problems. The development and implementation of these proposals, however, will require interdisciplinary approaches.

NATURE AND MAGNITUDE OF PROBLEM

There are more than 6,000 mine, mill, and plant operations within the U.S.A. A large percentage of these operations have waste stockpiles, impoundments for water supply, and ponds for fine-grained refuse settlement.

Tailings dams associated with most metal mills and mining operations constitute a great and growing safety hazard. Some of these structures are over a hundred meters high and several that will be more than 180 meters in height are under construction. They constitute in effect some of the highest and largest hydraulic fill "dam" structures in the world. A good example of the immensity of these structures is a dam being constructed in Canada which eventually will have an impoundment capacity of 1.8 billion metric tons. The retaining embankment will be 160 meters in height and will have a volume of 70 million cubic meters.

New mines are being opened at a rate of about 50 per year, and numerous operations are being enlarged in size. Considering U.S. mine, mill, and plant solid refuse of all types, there were about 1.8 billion tons of solid waste generated in 1974, and this number is expected to increase to 2.7 billion tons in 1980. This is a large percentage of the total solid refuse generated in the U.S.A. Over the years, more than 20 billion tons of mining wastes have accumulated, of which it is estimated that 60 percent may have economic value because of mineral content or other possible uses. Thirty-seven percent appears to have no value and constitutes health hazards and aesthetic nuisances.

Disposal problems associated with two minerals--one metallic and the other nonmetallic--will serve to illustrate the nature and magnitude of waste disposal problems.

EXAMPLE - COAL

In the coal mining industry, 25 percent of the coal extracted from underground mines is rejected as waste and disposed of on the surface. Eastern coal fields contain 3000 - 5000 active and abandoned waste piles and impoundments totalling 3 billion tons of refuse. About 120 million tons of mine and mill coal refuse were generated in 1974. It is anticipated that this will increase to about 200 million tons by 1980.

Coal is eventually burned in power plants and this results in a disposal problem for the fly ash, bottom ash, and SO_2 scrubbing waste sludge that is produced. A modern coal fired 1000 megawatt power plant burns about 400 tons/hr. Of this about 10 percent or 40 tons/hr ends up as fly ash which must be disposed of in a safe and environmentally acceptable manner--usually in waste stockpiles. In 1974 a total of some 60 million tons of fly ash and bottom ash were produced. Since most coal contains some sulfur (up to 3% by weight) combustion of coal also results in SO_2 scrubber sludge which constitutes a disposal problem. In 1974, 12 utility plants had a potential to generate some 2.5 million tons of this waste.

EXAMPLE - COPPER

Modern copper mining methods result in very large amounts of waste or residual materials. Open pit copper mines are handling ores which often contain less than 0.4 percent copper with 99.6 per cent of the ore ending up as refuse or "tailings" product. As an example, in 1965 the ratio of solid waste to marketable copper by weight was 334, and it is estimated that by 1980 this ratio will be about 440. Some mines also have overburden stripping ratios on the order of 9 times the ore volume, with ratios of two to three being common.

Copper wastes are produced at an annual rate of close to 500 million tons, making this waste one of the largest.

SUMMARY

The amounts and volumes of waste material that must be disposed of poses a considerable challenge. Of equal concern are associated problems of health, safety, and environmental degradation caused by their mechanical, biological, chemical, and radiological characteristics.

Examples of these latter problems include degradation of water quality from oxidation of sulfides in coal mine refuse leading to increased acidity of receiving waters. This in turn reduces aesthetic, recreation, and habitat value of these waters. Large areas of land are often preempted from other uses by their use for disposal. Phosphatic clay slimes presently occupy over 40,000 acres of settling areas of valuable land surrounded by over 300 miles of earthen dams in the southeastern U.S.A. Also, huge quantities of water are diverted, used, stored, evaporated, or lost by seepage in the process of waste disposal, with potentially significant effects on the water budget of a region.

Safety and stability problems associated with waste stockpiles and tailings impoundments are of critical importance. These problems have been highlighted by the disastrous failure of a coal waste heap in Aberfan, Wales, in 1966 that killed 144 school children. More recently the failure of a coal waste dam on Buffalo Creek, West Virginia, in 1972 resulted in the death of 125 persons and destruction of over 500 homes.

Refuse disposal operations and spoil heaps have also resulted in air pollution problems. Dust and wind erosion is a problem common to disposal of many fine grained tailings. Noxious gases are produced by smoldering coal refuse heaps and under certain atmospheric conditions, acid mists emanate from these same waste piles.

NEED FOR INVENTORY

Although it is clear that the mining and industrial waste disposal problem is large and growing, there is at the present time no single source of information to show the full magnitude of the problem. The first recommendation of this report is that a study be conducted to determine the volumes of solid wastes in currently existing waste deposits; the characteristics of these deposits as regards to type of structure, height, slope, method of construction and chemical and physical character of the wastes; and the problems or failures which have been experienced with the deposits. This inventory should be updated annually to maintain a source of good information on waste disposal problems. In addition, estimates of future waste production should be made using information from industrial sources, and this estimate should be updated annually.

GUIDELINES FOR RESEARCH

Solution of the solid wastes problem requires a systems approach by interdisciplinary teams. In developing effective solutions, researchers should consider the compatibility of their solution into present technology and economics of the industry to which it will be applied.

Transfer of already developed technology from one discipline or industry to another will result in a minimum of duplication. Dissemination of closely held information will also avoid unnecessary duplication in research. Interdisciplinary conferences, seminars, continuing education, short courses, and workshops should be conducted to encourage technology transfer and rapid dissemination of research results, and to educate members of industry, regulatory agencies, and research and educational institutions of the needs and concerns of each. Where applicable, research should include demonstration programs in cooperation with industry to promote practical solutions.

Most of the problems on which research is needed can be grouped into a small number of categories. One possible grouping of problem areas or concerns would be: disposal facilities, material properties, process water, environmental effects, utilization, subsidence, technology transfer, and guidelines and legislation.

Research efforts are needed to solve the problems associated with abandoned, active, and future waste disposal facilities and also the processes that are generating the wastes. In an engineering sense, research must encompass the elements of planning, analysis, design, construction, operation, and maintenance (abandonment). However, the research and the intended implementation should maintain a proper perspective of the technological, economic, sociological, psychological, and political aspects of the problem being addressed.

Disposal facilities can generally be classified as wet (impoundments, lagoons, ponds) or dry (fills, embankments), and can be situated either on the ground surface or underground. The particular nature of the facility is a function of many factors, among which are the character of the waste, the experience of the industry, the economics of the situation, local site conditions, applicable regulations, available technology, as well as many others. The modification of existing processes and the development of new processes and industries (i.e., coal liquefaction and gasification) require a continuing evaluation of appropriate methods of disposal.

An important consideration in the design of disposal facilities is the character (physical/chemical/engineering/biological/radiological properties) and the condition or state of the waste material in the effluent stream. Consideration must also be given to the effects of processes and time on the properties of both effluent and disposed wastes. In the case of new processes or new technologies, the characteristics of the waste stream and potential disposal/utilization possibilities should be identified and studied in advance of the process or technology implementation. A decision-making process that involves trade-offs between the product and the waste disposal requirements should be encouraged.

A. Water related research needs include determining and insuring industries' requirements for water, reduction of water use, minimizing water loss through reduction of water "trapped" or "bound" in solid wastes, improved recycling of water, dewatering of solids to permit easier materials handling and placement in disposal areas.

B. Environmental effects of solid waste disposal are often significant and vary greatly depending upon the type of waste, variation in plant process method of transport and placement, and climate. Research needs involve prevention and control of combustion, prevention of dusting, limiting amount of leachate and controlling its effect on surface and ground waters, controlling gas formations and movement, evaluating and controlling gas formations and movement, evaluating and controlling radiation and the effects of excessive heat from processed or naturally oxidizing materials.

C. Research on utilization, due to the large volumes of waste available, should concentrate on possible uses involving large quantities of materials such as construction fill or aggregate. Consideration of utilization of waste in disposal settlements, bearing capacity and revegetation. Recycling to recover additional materials or other resources is also an attractive research area. The areas of needed research are described in detail in the following section.

LIST OF RESEARCH NEEDS

No. 1 - Inventory of Disposal Sites and Problems

At the present time, there is no single source of information which can be used to assess the magnitude of waste disposal problems. Research should be undertaken to gather and compile information on:

(1) the volumes of wastes in currently existing waste deposits,

(2) the characteristics of these deposits with regard to type of structure, height, slope, method of construction, and chemical and physical character of wastes, and

(3) problems and failures with the deposit.

The inventory should be updated annually to maintain a source of good information on waste disposal problems. Estimates of future waste production should be made using information from industrial sources, and the estimates should be updated annually.

No. 2 - Consolidation and Stabilization of Waste Slurries

Disposal of fine-grained waste materials represents a major cost and a serious environmental problem for many mining and chemical process industries. Many of these materials consist of colloidal clays and other gel-like materials which retain large quantities of water. As concern for the environmental effects of these materials increases, and the availability of large land areas for waste disposal decreases, the traditional methods of disposal are becoming unacceptable.

Industries which produce large quantities of these materials include phosphate, alumina processing, coal, tar sands, and many chemical processes. Research is needed to develop improved methods of consolidation and stabilization in order to minimize storage requirements, reduce the use of water, reduce hazards of water pollution, and facilitate land reclamation.

Numerous approaches have been tried in specific industries to enhance consolidation. Those that have demonstrated effectiveness and need additional research include the following: drainage (using vertical, horizontal and vacuum drains); chemical additives (coagulants, organic modifiers, pH adjustment); admixing with coarse particles (sand, fly ash, gypsum, municipal waste); increasing confining stress (by surcharge or decreasing pore water pressures); application of shear forces (stirring, rakes, vibration); evaporation (use of ambient conditions and modification by heat); transpiration (development of effective plant systems).

Other approaches which could lead to long-term solutions based on significant developments in basic technology include the following: compaction, biological treatment, magnetic separation, adsorption, semipermeable membranes, filters, reinforcement techniques, vegetative growth, and explosives. Combinations of two or more of the above approaches also need to be considered.

No. 3 - Seepage Control

Seepage of water through solid-waste disposal facilities is of special concern from the standpoint of its effects on both the quantity and quality of ambient water. Oxidation of iron-sulfide minerals in coal refuse piles produces substantial quantities of sulfuric acid in many localities. The acid is "flushed" into receiving waters by seepage through the refuse pile. Seepage from tailings impoundments transports any dissolved organic and inorganic contaminants that may be present into the underlying ground water or into the streams. Overburden disturbed by strip and pit mining operations is a potential source of salinity and trace metals in ground water and interflow, yet the significance of trace metal content in the overburden with respect to water quality remains largely unknown. Spoil from strip and pit mining operations placed back in the pit sometimes replace sections of aquifers, thereby influencing water levels and quality in the original aquifers. The relatively recent, increased concern for the integrity of the quality and quantity of surface and ground waters places a new emphasis and importance on analysis and design of methods for seepage control. A corresponding emphasis on a more complete accounting of seepage water in time and space is required. This may involve analysis of seepage in partially saturated materials and special designs to direct seepage to designated areas where it can be re-used or treated.

No. 4 - Surface Stabilization

Waste impoundments are subject to surface erosion by wind and water, with resulting land, air, and water pollution, and adverse visual impact. In the long term, continued erosion can cause deterioration of slope angles and failure of abandoned structures.

Research is needed to find effective and economical techniques and materials for surface stabilization during operation, reclamation, and abandonment. The effect of the proposed technique on the structural stability should be considered to insure that physical properties of the waste are not detrimentally altered by the control method. Cost comparisons should be made so that operators can choose the most economical applicable alternative.

Suggested areas of study include chemical additives, irrigation by spray systems, waste rock cover, and vegetative cover for each climate or geographical location.

No. 5 - Tailing Dam Design

Problem: To establish design guidelines for design of tailing dams.

Recommended Research:

1. Inventory available data on existing tailing dams.
   - (a) Types of dams and dimensions
   - (b) Construction procedures
   - (c) Waste materials impounded
   - (d) Decanting methods
   - (e) Flood flow facilities
   - (f) Design parameters and basis
   - (g) Engineering properties of foundation and construction materials
   - (h) Cost
   - (i) Past performance

2. Review existing dam design literature and guidelines--state, federal, and other.

3. Develop a compendium of up-to-date guidelines for stable, environmentally acceptable tailing dams with due consideration of:
   - (a) Site conditions, including geology and groundwater
   - (b) Foundation conditions
   - (c) Engineering performance, characteristics of the waste product to be impounded and likely variations
   - (d) Method and rate of deposition of waste product
   - (e) Available construction materials and their engineering performance characteristics
   - (f) Chemical characteristics of tailing and slurry water

(g) Probable construction schedule

(h) Seismic and strain-induced loadings

(i) Methods of handling slurry water

(j) Handling flood flows during construction, operational life and after abandonment

(k) Seepage control to:

i. assure stability of dam

ii. handle potential contamination of ground and surface water, where appropriate

(l) Cost effectiveness

No. 6 - Site Selection

Research is needed to develop site selection methodology which will enhance the ability of decision makers to effectively evaluate alternative sites with respect to alternative design and operating proposals. This evaluation should be based upon site-specific considerations as well as adjacent and potentially effected areas.

The methodology developed must be based on a systematic and analytical evaluation of all factors effecting the suitability of a site for waste disposal. These factors would include, along with the traditional site considerations, adjacent natural resources, adjacent land uses, social values, water and air quality, area-wide economics, and population centers. Quantification of these factors should be attempted so that alternatives can be evaluated on a consistent basis. Also important to the site selection procedure would be an analysis of the potential cost of a failure for a particular site and design proposal, and an estimate of the probability of failure. This analysis would clearly demonstrate the risks and consequences of a site-design decision and provide an additional basis for the evaluation of alternative disposal proposals. In all cases the methodology employed must be systematic, and the methods analytical and complete, so that decisions can be supported and defended.

No. 7 - Design Floods for Retention Structures

There is a need to develop techniques for establishing design floods which are particularly adapted to the characteristics of waste retention structures. As a first step in this undertaking, it appears to be logical to compile the available data on hydrologic and flood control techniques used by various agencies in planning and design of water resource and transportation projects, and the criteria used by regulatory agencies relative to various potential hazard categories. Using these data, it would be possible to develop criteria suited particularly to the flood potential hazards in the mining industry. The research should include conditions during construction and after abandonment.

No. 8 - Field Instrumentation

Little data or geotechnical experience exists on the behavior of embankments constructed of coal waste, metal, or non-metal waste materials. Engineers have during past decades developed geotechnical data and experience on the behavior of earth dams, some of which is transferrable to the minerals industry. However, several factors preclude complete transfer of the experience with earth dam behavior: waste materials have different properties, the properties vary widely from place to place and time to time, the embankments are constructed differently, and construction may extend over several years. Consequently confidence levels for predicting factors of safety and overall embankment performance are poor.

Technology can be improved by establishing a series of field instrumentation monitoring installations in both existing and new structures with the following objectives:

1. Via instrumentation, evaluate on a routine schedule the short- and long-term performance (stress, strain, etc.) of typical waste embankments.
2. Evaluate via routine surveillance the reliability and effectiveness of existing and new instruments.
3. Develop practical techniques and guidelines to monitor water pressure and displacement in tailings dams and waste embankments.
4. Observe and relate placement techniques to embankment performance, both short- and long-term.

The above objectives can best be accomplished by a cooperative demonstration between geotechnical engineers and industry.

<u>No. 9 - Engineering Properties</u>

The properties of materials used in tailings dams, dikes and waste piles vary widely depending on the product being mined and processes being used. Research is needed to define the engineering properties of these materials to properly design new structures and predict the performance of existing or modified structures. Much of the experience from past designs of the traditional earth and rock structures is not applicable to the mine waste fill technology because the materials are different. Research is needed on shear strength parameters including time effects, permeability characteristics and dynamic behavior.

Special areas are developing such as in oil-shale development where large volumes of a material essentially new to the engineering profession will be generated, and satisfactory disposition of and containment of these materials will require knowledge of their engineering properties.

No. 10 - Chemical and Biological Properties

It is evident that many of the industrial and mining waste materials are not stable and nonreactive, and that the chemical and biologic characteristics of these materials must be considered in developing suitable methods of disposal. Safe stable disposal of these materials may be accomplished only by use of other technologies, i.e., chemical, electrochemical, physical chemical, or biological methods.

In order to assess the nature of these materials to arrive at a method of safe disposal, it will be necessary to do research on the portions of these materials passing the 200 mesh to determine their chemical, physical, and biological properties. The required properties include the following:

size distribution	surface charge
surface area	Coulomb forces
Zeta Potential	gel strength
density	exchange capacity
chemical analysis	chemical structure
mineralogy	water, bound, free or crystal
heats of solution or crystallization	solubilities
BOD if organic	SEM scans before and after treatment such as pH modification or effect of electrolytes, etc.

<u>No. 11 - Abandonment of Waste Deposits</u>

The need for stability and environmental compatibility of a waste deposit will continue long after the industry generating the waste has disappeared. In fact the needs may become even more critical because of changed land uses nearby and rising standards of environmental expectations. To facilitate abandonment, features should be designed and constructed into the deposit which will, as nearly as possible, allow the deposit to exist indefinitely into the future without problems. In some cases, the waste deposit will become the site of a new endeavor which can then assume maintenance responsibilities; but this will happen only if the deposit causes few problems to the new use, maintenance is simple, and stability against floods or earthquakes is assured.

In other cases where the deposit is given back to nature, the deposit should be able to exist into the indefinite future under the action of natural processes. This is an onerous criterion, because in the long term the deposit may be subjected to major floods, natural decomposition, and geomorphic processes.

Research in the following areas will improve design for abandonment:

1. What is a reasonable frequency of the floods which should be handled without damage by the deposit after abandonment?
2. What is a reasonable expected life of any structure incorporated into the deposit? For example, spillways commonly have an expected life of 50 to 100 years from time of construction.
3. What embankment slope protection is sufficiently durable to exist on say 3 to 1 slopes for 100 years without maintainance against the effects of rainfall, animal burrows, and public use?

4. What is the durability of impervious barriers which may be incorporated into a deposit as a seal against seepage?
5. What rate of seepage of various toxicants can be tolerated in the long run?

<u>No. 12 - Optimization of Material Handling</u>

Since most tailings are transported hydraulically, information is needed on the characteristics of the slurries and the influence these characteristics have on the various means of separation and deposition of the solid and liquid phases in the tailing area.

Where waste material is to be deposited by mechanical methods, the properties of the waste and its subsequent performance is affected by the mode of deposition. Field investigations are desirable.

<u>No. 13 - Optimization of Material Placement</u>

Tailings dams typically exhibit variability in gradation and moisture content from place to place along their length due to the placement methods used. These variations result in significant differences in performance characteristics and thus the strength or integrity of the structure.

Research activity is needed in the following specific areas.

1. How much increase in stability can be obtained by compaction mechanical or vibratory?
2. How can consistency in properties and placement from end to end of the embankment be achieved?
3. Determine the optimum moisture content for various dike materials and suggest ways of obtaining it such as lengthened drying time, discing, harrowing or other techniques.

4. Determine optimum incremental placement rates for various materials as regards drying time, and height of lift.
5. Determine if there are quality differences in dikes due to the kind of equipment and construction method used in their construction.

No. 14 - Influence of Climatic Conditions

Climatic conditions can place substantial restraints on the efficiency of disposal methods and on the stability of the embankment. Conversely, the unusual characteristics of certain waste products may have a substantial effect on the micro-climate adjacent to the disposal area. Also, the tremendous size of some waste disposal areas may lead to alterations of the micro-climate.

Freezing conditions can interrupt the basic disposal plan by causing pipeline problems, by changing the normal flow or distribution patterns of slurries due to icing on the disposal area, and can lead to instability when frozen tailings and included ice layers melt. Freezing or icing in filter drains and other seepage collection facilities can result in the buildup of excessive pore pressures in slopes, leading to their failure. Heavy snowfall may obscure potential trouble spots that would otherwise be detected by conventional routine inspection. Waste piles formed by dumping may include snow and/or ice which could contribute to slope failures upon thawing. Freezing temperatures make effective compaction of tailings and other waste materials difficult if not impossible. Research is needed to develop effective methods of placing slurries during freezing conditions, or alternately, to develop disposal strategies which will minimize the adverse effects of winter placement. Methods need to be devised for protecting filter drain outlets and other seepage control facilities.

Some recovery processes result in waste products being discharged at extremely high temperatures. For example, in recovery of oil from shale, it is expected that as much as 10,000 tons per day of waste at a temperature of 480^{0} C may be generated. This is certain to result in great changes in the microclimate in the disposal area, such as heat-induced winds and excessive evaporation of water. Research is needed to develop methods of mitigating adverse effects.

No. 15 - Spontaneous Combustion

(a) Extinguishment of Burning Refuse Piles

Objective: To develop a positive, inexpensive, and relatively unsophisticated method of extinguishing burning refuse banks.

Discription of proposed work: Since the method of digging out the heated material to cool it is a hazard to personnel, other methods such as the use of chemicals need to be developed.

Benefits: Digging out the hot materials has caused fatalities. The operation also adds to air pollution and requires space to spread out the material. The development of new or improved covering and grouting techniques would eliminate the hazardous and polluting digging operation.

(b) Compaction Required to Prevent Spontaneous Combustion

Objective: To produce additional design and construction techniques which can be used by industry to ensure "combustion free" development of coal waste disposal sites.

Description of proposed work: Previous studies have shown that compacting the refuse will decrease the ventilation within the refuse pile and decrease spontaneous combustion. Additional research is needed to determine how the compactive effort changes with thickness of layer of refuse and the carbonaceous content. The effect on stability of clay layers placed between layers of refuse should be investigated.

Benefits: The waste piles could be constructed economically and not subject to spontaneous combustion.

No. 16 - Elimination of Coal Slurry Ponds

Wet washing of coal results in two major waste products. The first is a coarse refuse which is normally trucked or conveyed in solid form to a waste dump, variously referred to as a gob pile, refuse pile, or slate dump. The second product is a slurry consisting of finely divided coal and clay suspended in water. This product, usually appearing in the form of a thickener underflow, is normally pumped to impoundments for permanent storage. These impoundments create major problems, both from the standpoint of safety and environmental quality. Embankments are expensive to construct and maintain. Failure has created at least one major disaster with substantial loss of life and property. Wind-blown dust from dried ponds create air pollution problems and the overflow frequently contains sufficient suspended solids to adversely affect nearby streams.

A decided incentive exists to eliminate slurry ponds. One of the more obvious routes is to incorporate the fine solids, after some dewatering, into the coarse refuse. Geotechnical research is needed to determine the extent of dewatering necessary to permit mixing with coarse refuse while still maintaining the requisite coarse disposal pile characteristics, e.g., slope stability, mechanical strength for vehicle movement and erosion resistance.

No. 17 - Alternative Uses for Wastes

The problem of waste disposal can be alleviated if alternate uses for the waste can be found. Considerable progress has been made in some instances, such as the use of fly ash as a construction material. Studies identifying large volume use such as road base materials or construction aggregate can transform a waste into a resource, thereby contributing to both environmental and economic benefits.

No. 18 - Alternative Waste Disposal Techniques

Waste piles and impoundments result in social and environmental problems, and developing procedures for their complete elimination is a desirable goal. Research is needed to evaluate the feasibility of disposal by backfilling in surface or underground mines, and other procedures which can eliminate the need for waste piles and impoundments. The research should consider both costs of the alternative methods of disposal and the benefits to health, safety, and environmental quality.

No. 19 - Improvement in Process Technology

Research is required to determine whether process technology can be changed to reduce waste disposal problems. Typical examples include:

(a) Treatment of waste during processing, or prior to disposal, to improve the environmental acceptability of the waste, i.e., neutralization of basic or acidic water.

(b) Development of processes for economical extraction of secondary products and consequent reduction of the volume of waste.

(c) Reassess mining and extraction processes to determine if waste disposal problems can be reduced, i.e., develop a dry extraction process for phosphate using mine dewatering and conveyor transport to reduce sedimentation problems and large land requirements for waste disposal.

SUMMARY

Representatives of the geotechnical and environmental engineering professions, industry, and governmental agencies participated in a two-day Workshop to identify research needs in the area of mining and industrial solid waste disposal. This report, which was prepared by the participants during the Workshop, identifies 19 areas of needed research.

The most critical need is for establishment of a reliable source of data concerning the magnitude of the waste disposal problem. Other areas of needed research are properties of wastes, seepage, surface stabilization, tailing dam design, site selection, design floods for retention structures, field instrumentation, abandonment, materials handling, material placement, climatic conditions, spontaneous combustion, and new methods of disposal.

The participants of the Workshop considered it essential that solutions to waste disposal problems be sought through a multi-disciplinary approach. To be effective, research must consider economic and social factors, as well as a broad-based technical view of the problems.

APPENDIX A

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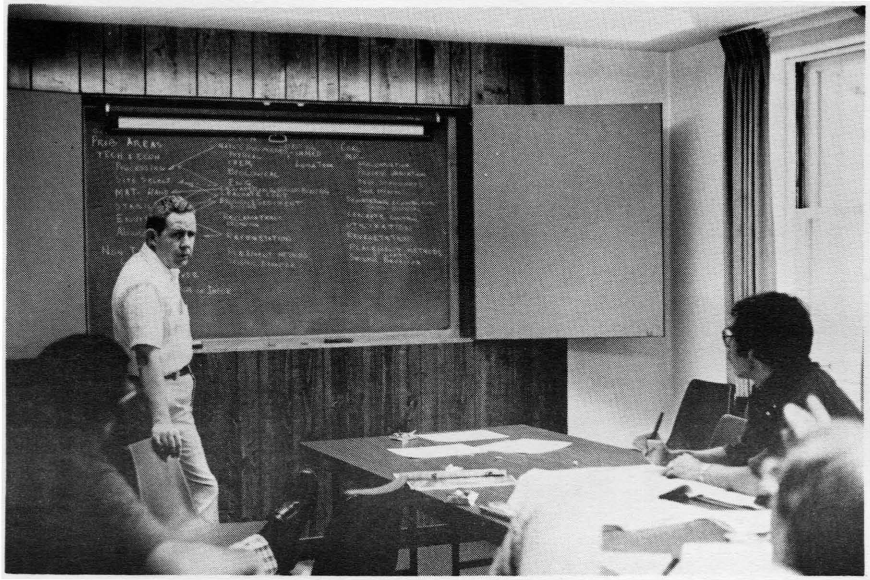
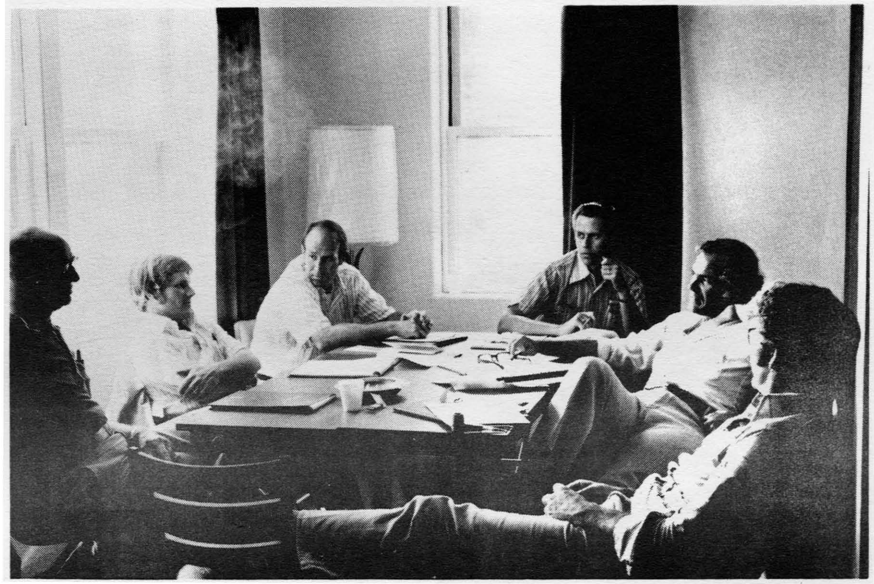
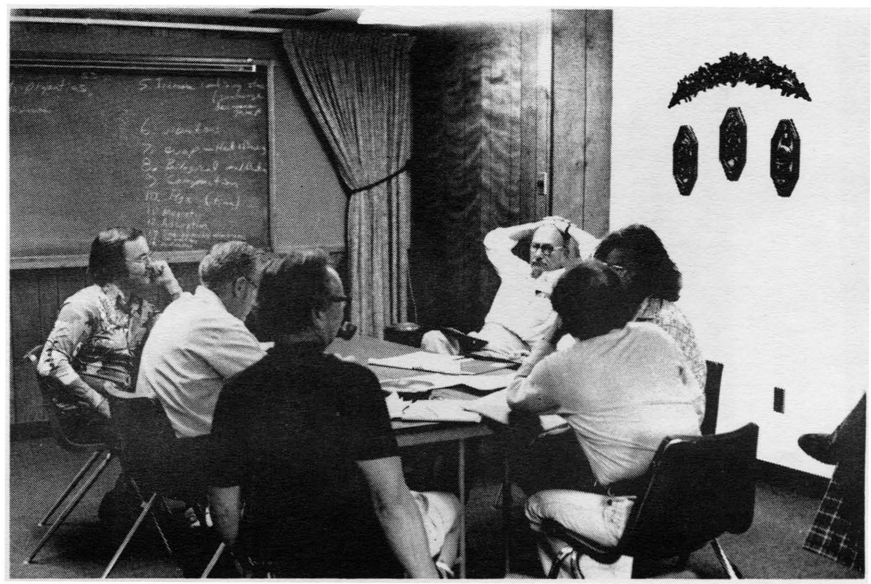
APPENDIX B

PHOTOGRAPHS OF WORKSHOP

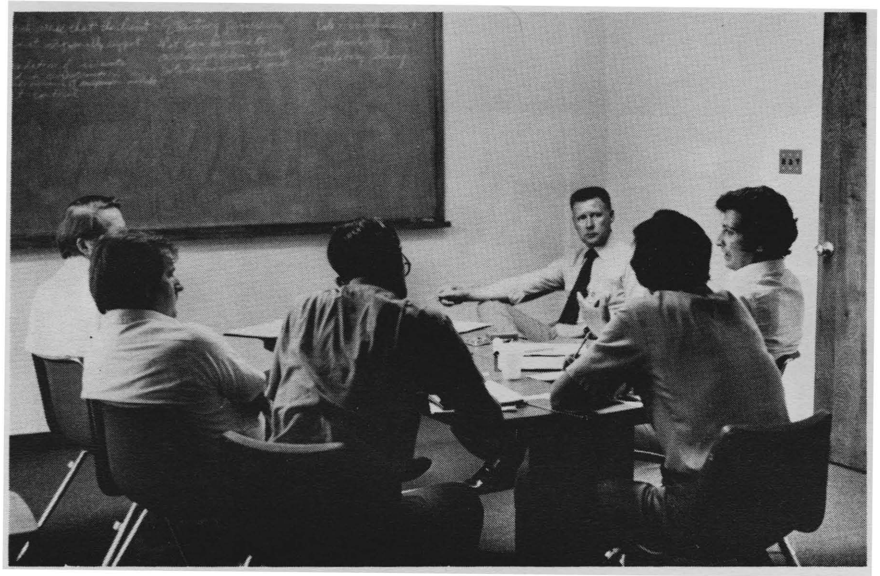
Front Row: W. A. Charlie, R. Fujimoto, J. D. Welsh, E. S. Smith, C. O. Brawner, J. W. Peck, G. F. Sowers, D. Barr, T. Shepherd; Middle Row: C. S. Grove, C. D. Kealy, E. L. Dodson, J. H. Hunter, R. L. Volpe, M. B. Kahle, J. L. Bolles, K. V. Taylor, L. Bromwell, R. E. Gray, J. M. Duncan, J. D. Nelson; Back Row: D. L. McWhorter, F. H. Kulhawy, D. C. Griffin, J. J. Ellam, R. K. Seals, G. Barthauer, C. L. Aplin, R. M. Hays, D. H. Gray, S. G. Wright, R. M. Hardy, W. M. Haas, S. T. Thorfinnson, D. J. Raden, N. R. Morgenstern.







INDIVIDUAL GROUPS AT WORK

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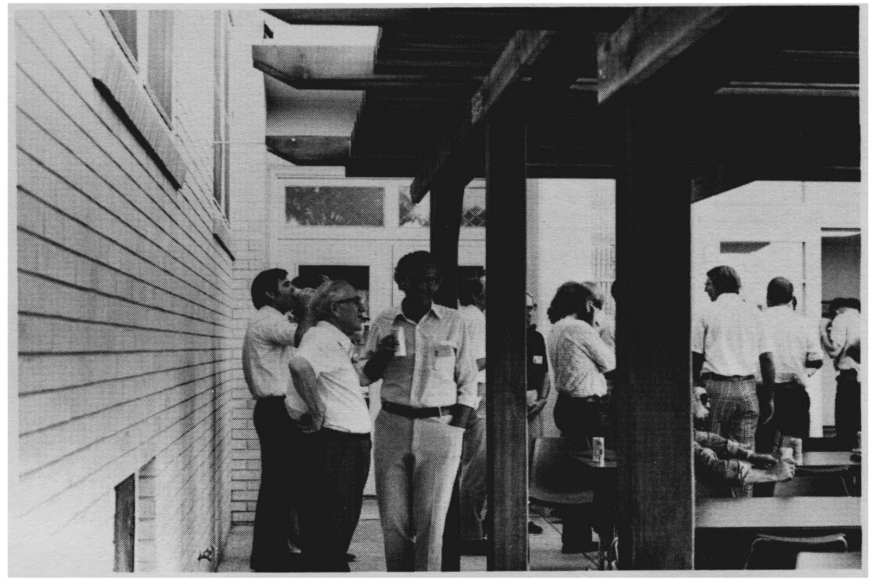

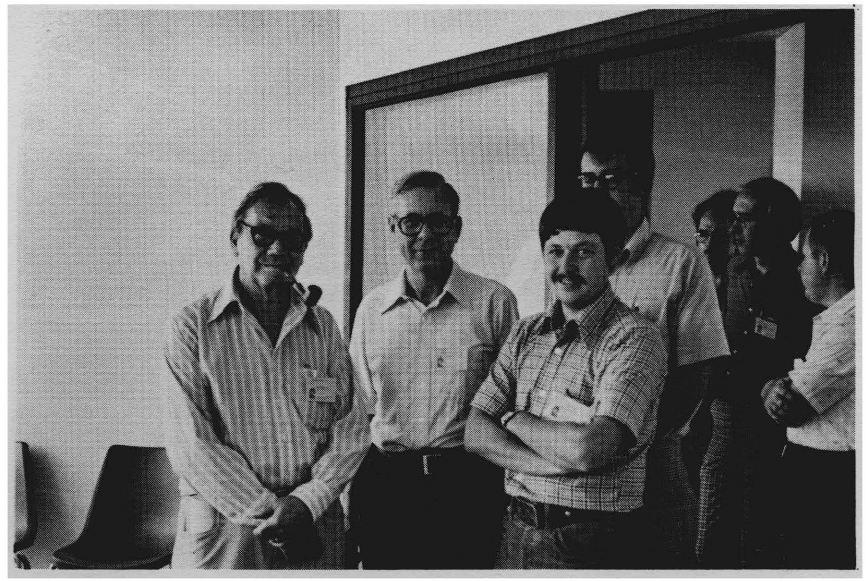

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