Overview

Reduction of the subsurface movement of fluids, especially hazardous wastes, has been the subject of much research and considerable controversy over the last few years. The characteristics of the contained fluid play a very important role in determining the properties of the soil and rock system—the solid earth environment. In turn, designers and installers of irrigation ditches, canals, and reservoirs, waste ponds and lagoons, mine tailings ponds, solar energy ponds, excavation dewatering systems, and other types of impoundments are interested in reducing to a minimum fluid movement through the soil and rock and retention installations. Thus, ASTM Committee D18 on Soil and Rock has been concerned for some time about the quality and quantity of the ground water or of any other fluids contained in or moving through the soil and rock voids. A mechanism for reducing leakage from such installations is some type of barrier to hydraulic movement through the soil and rock.

Data and information related to the very complicated interaction of the environmental system of soil and rock containment, fluid barrier, and enclosed fluids must be valid, compatible, and comparable to be useful in the development of guidelines for the designer and installer of any impounding installation. Because the need was recognized for the formation of a broad interdisciplinary consensus group to develop standards related to all types of fluid barriers in soil and rock, Subcommittee D18.20 on Impermeable Barriers was formed in 1981. Since its formation, the group has recognized that probably few, if any, completely impermeable barriers exist, so a name change to "Hydraulic Barriers in Soil and Rock" subsequently has been proposed.

Subcommittee D18.20 now provides a common meeting place where technical experts representing a wide variety of disciplines, and including researchers, users, and manufacturers' representatives, can share experiences for the development of high quality, uniformly acceptable, consensus standards. In addition to its primary objective of the development of needed standards for test methods, the subcommittee's objectives include the establishment of standard methods or guidelines for the quality control of liner or slurry wall installations and of the soil and rock containments; the coordination of data and information on hydraulic barriers; the development of basic testing methods for the soil and rock and associated materials as used for hydraulic barriers; and the promotion of needed research and dissemination of data, information, and research results among people involved in the design and installation of hydraulic barriers.

In partial fulfillment of some of its objectives, ASTM Committee D18, through its Subcommittee D18.20 and in cooperation with the U.S. Committee on Large Dams (USCOLD) of the International Commission on Large Dams, organized a one-day symposium on impermeable barriers, held 25 June 1984 in Denver, Colorado. This ASTM special technical publication presents papers from the symposium, but the title has been changed to conform to the proposed new title of the subcommittee.

The symposium consisted of two half-day sessions—the first on slurry walls and the second on clay and soil-admix liners. For the purposes of this publication, these two types of hydraulic barriers are defined as follows:

Slurry walls—nonstructural walls constructed underground as vertical barriers to the lateral flow of water or other fluids. Slurry walls usually are trenches excavated to a horizontal strata of low permeability material and filled with a slurry of either soil-bentonite (SB) or cement-bentonite (CB).

Soil or soil-admix liners—nonstructural liners placed on horizontal or moderately sloping surfaces as barriers primarily to the vertical flow of water or other fluids. These liners either consist of compacted clay soil or soil admixes using bentonite, cement, and asphalt; chemical; or other additives mixed with the natural soil in order to improve hydraulic properties.

As mentioned at the beginning of this overview, the use of hydraulic barriers to impede the flow of fluids in soil and rock has been the subject of considerable controversy, especially for the past decade. The controversy has in part arisen from environmental concerns over barrier integrity and in part from the interest and desire of the geotechnical engineering design profession and construction industry to provide barriers that will fulfill established requirements and regulations. The central issue is whether a hydraulic barrier, whatever material is used for the barrier, will function satisfactorily over the intended lifetime of the facility. Although the function of the barrier may depend upon several factors, preservation of low permeability has become the primary performance criteria. Deterioration of a slurry wall or lining material resulting in the permeability exceeding a prescribed value has become the definition for "failure," that is, the barrier leaks more than the prescribed amount. Accordingly, the determinations of permeability and changes in permeability in the laboratory and in the field have become among the foremost problems requiring investigation in the field of hydraulic barrier design and installation.

Three previous ASTM symposia relating to the general subject of permeability have been sponsored by Committee D18 on Soil and Rock: *Symposium on Permeability of Soils, ASTM STP 163*, in 1955; *Permeability and Capillarity of Soils, ASTM STP 417*, in 1966; and *Permeability and Ground Water Contaminant Transport, ASTM STP 746*, in 1979. The state of the art undoubtedly has advanced over the 30 years spanned by these symposia. Unfortunately, most studies until recent years have been concerned almost exclusively with the permeability to water, primarily relatively pure ground water, whereas much of the interest today is related to the movement of all kinds of fluids, many of them very hazardous, through the soil and rock or as contaminants to the ground water.

A final consensus on the detailed methods for permeability determinations, either in the laboratory or in the field, may not be in hand, but the problems associated with the methods and with the interactions due to the chemistry of various fluids and the chemistry of the soils and rocks are at least finally recognized. Thus, there is now the start of an empirical basis that can be used by experienced investigators in designing reliable and valid testing programs for the wide range of specific soil or rock and fluid situations that may be encountered. Considerations to be made in the design of laboratory or field testing programs range from the selection of the type of apparatus to the determination of the effects of the permeant on the barrier materials and the soil or rock containment. The possible sources of deviations in test results become greatly compounded for testing using fluids other than water. Interactions between the barrier material and the fluid may cause actual time-dependent changes in permeability as well as affect test conditions or even test equipment, such that apparent changes that have no relationship to real field performance may be observed. Thus, not only must the mechanics of testing be mastered, but the physical and geochemical processes must be understood to such a degree that they can be related to actual field conditions and field performance, so that invalid results can be recognized and discarded.

Another problem exists even if the investigator is aware of all these problems, and that problem relates to quality control of the barrier installation. All of the preliminary testing data can be negated by improper installations that provide different conditions than those assumed in the testing program. There seems to be much that remains to be done to develop adequate field installation quality control standards for hydraulic barriers.

The symposium presented in this special technical publication consisted of both invited and offered papers. In order to accommodate more papers during the one-day symposium, a number of papers were presented as posters with the author available for discussions of the posters during the coffee breaks and part of the lunch hour. Full-length versions of most of the brief poster presentations are published in this special technical publication in addition to most of the papers presented orally. Near the end of each half-day session all authors appearing in that session assembled as a panel to answer questions provided on forms submitted from the audience. After the symposium, all questions were sent to all authors so they had the chance to provide answers even to questions that had not been directed to them. The questions and answers are published in this special technical publication following the pertinent paper or at the end of the publication for those questions of a general nature.

The morning session of the symposium was devoted entirely to presentations on slurry walls and their use as hydraulic barriers. It was pointed out that slurry wall technology apparently was first developed in Italy during the late 1940s as a method for construction of a structural-type wall. During the 1950s in the United States, the technology developed further as nonstructural barriers to impede the flow of water. In more recent years, the growing concern and efforts to mitigate pollution of our ground water is requiring accelerated change and developments in the design, construction, and testing of slurry walls.

The seven papers contained in the first part of this publication present some of the latest innovations and advancements in slurry wall technology from design aspects through construction and testing methodology. The papers discuss soil-bentonite walls, cement-bentonite walls, composite walls of clay and high-density polyethylene sheeting, and grouted walls constructed by use of the vibrating beam technique. One paper also compares the conventional slurry wall construction to the vibrating team technique.

The increasing use of slurry walls as barriers to the movement of pollutants or of contaminated ground water led to questions as to the life of such barriers. The lack of information on the compatibility of the slurry wall materials with many types of permeants has resulted in recent research and standard test method development. Several papers in this special technical publication discuss the effects of organic as well as inorganic permeants on bentonite, describing the testing techniques used and drawing conclusions regarding the effects of the particular chemical permeants.

It is apparent that the technology regarding the use of slurry walls to contain hazardous wastes of all types is in its infancy. The papers presented in this publication represent some of the latest advances in both the construction and the testing for slurry walls. However, further advancement is needed in developing tests of slurry wall materials to determine their long-term performance. As a means of providing improved quality control for slurry walls, ASTM Subcommittee D18.20 has already developed three standard test methods related to the basic properties of a slurry, in particular, density, sand content, and filtration properties of bentonitic slurries.

The afternoon session of the symposium was primarily concerned with clay and soil-admix liners used as hydraulic barriers. Of the fourteen papers presented in the latter part of this publication, four were originally presented in briefer form as posters. The papers presented herein describe a variety of laboratory studies and case histories including the following: direct evaluation of permeability tests utilizing both fixed-wall and flexible-wall permeameters; a proposed field permeability test procedure using a large diameter covered ring; an overview on the construction, testing, and research for soil-cement liners; and the potential use of fly ash in reducing the permeability of otherwise permeable soil liners. Other papers examined factors that affect desiccation cracking of compacted soil and clay liners, the effects of brine on an earth lining, and various other case histories on permeant effects on clay linings. Most papers, however, related to the laboratory studies on the effect of a variety of fluids on bentonitic or soil-admix liner materials. This was not by accident but rather due to a concerted effort by the program committee to bring such studies to light. These papers discussed the effects of such permeants as hydrochloric acid and sodium hydroxide, acid liquor from phosphogypsum disposal, organic leachates, paper mill wastes, brines, and acidic uranium mill tailing liquids on liner materials of compacted natural soils and soil-bentonite mixtures.

Some general scientific conclusions, as well as some philosophical postulations, can be developed from the study of the clay and soil-admix papers published in this publication. The overall objective for permeability determinations is to allow valid predictions of any leakage that may take place through a liner and in the case of waste products of the contaminant transport rates and concentrations with a degree of accuracy acceptable for the operating conditions of a facility. It is, therefore, not sufficient to hypothetically account for perceived differences between tests and full-scale field conditions, but instead there is a need for the actual performance of completed linings to be verified whenever possible. Case studies of constructed linings and possible methods to evaluate field performance are presented in this special technical publication. Such case studies, supported by reliable measurements, must be encouraged to provide support for continued studies of such hydraulic barriers. Also, as brought out during discussions, differences in performance between laboratory-prepared samples and lining materials constructed in the field should be studied further, in particular of linings to be permeated by different fluids other than water. Differences in permeabilities as tested in the laboratory and as tested in the field or as represented by performance in the field may not be due to the test apparatus but rather to the different material placement methods used in the field and in the laboratory.

The testing of lining materials undoubtedly presents a challenge to testing laboratories and the geotechnical profession. The quality of the results is established by the performance of the completed lining. If the permeability remains below the prescribed criteria—without remedial work—then the installation and its supporting testing and engineering design have been successful. In support of this effort, a number of subcommittees and task groups of ASTM Committee D18 on Soil and Rock are actively developing standards for the permeability testing of fine-grained soils.

Despite the recognized difficulties, the investigations presented in this publication demonstrate that clay and soil-admix materials can perform well and maintain low permeabilities when subjected to a variety of permeants. In some cases, additional benefits have been observed due to soil mineralogy, natural attenuation, or buffering by the soil materials. However, there is also evidence of incompatibility between the soils intended for use as a lining and the particular liquid to be impounded. In such cases, alternate lining methods should be investigated irregardless of the measured short-term permeability. There seem to be no valid reasons why linings of clay and soil-admix liners should not be considered from the outset on an equal basis with other lining types in the investigation for a particular application. The techniques and results described in this publication should contribute to successful investigations of lining materials when the interpretations and applications are based on the specifics of each situation.

Many unanswered questions still remain, but this seems inevitable at this relatively early stage of development and investigation for the design and installation of hydraulic barriers, especially when used for fluids other than water. However, the editors believe that the symposium met many of the original objectives of Subcommittee D18.20, namely, to develop information usable in developing useful standards, the promotion of needed research, and the dissemination of information and research results among those people who are involved in the design and installation of hydraulic barriers.

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