Case Histories of Geotechnical and Hydrological Management and Remediation of Solid, Hazardous and Low-Level Radioactive Wastes, Including Liner Cover Systems. Paper No. GR-X

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CASE HISTORIES OF GEOTECHNICAL AND HYDROLOGICAL MANAGEMENT AND REMEDIATION OF SOLID, HAZARDOUS AND LOW-LEVEL RADIOACTIVE WASTES, INCLUDING LINER COVER SYSTEMS

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INTRODUCTION

Ten papers were submitted to this session, covering a broad range of topics. The papers can be divided into the following five general categories:

1.	Containing and Capping Wastes	3 papers
2.	Construction on Landfilled Waste	2 papers
3.	Compression Characteristics of Waste Fills	2 papers
4.	Environmental Degradation of Soil Properties	1 paper
5.	Contaminated Dredge Fills	1 paper

The tenth paper discusses ground improvement technologies for construction on soft, but non-contaminated soil.

The papers in this session represent case histories in Australia, Canada, China, India, Italy, Portugal and the United States. The Canadian case history included co-authors from Switzerland and the United States.

WASTE CONTAINMENT

In their paper *"Capping of an Extremely Soft Neutralised Uranium Tailings - A Case History in Environmental Geomechanics"*, Sheng, Peter, Wei, and Milnes report on a successful trial cap of extremely soft uranium tailings at the Ranger Uranium Mine, Northern Territory, Australia. Uranium is leached from the ore using sulfuric acid. The waste liquid is then neutralized with lime and is deposited in a tailings dam. The resulting tailings have a gel-like structure with a high water content, low permeability and low shear strength. The average water content of the tailings is about 55 percent. Based on in-situ measurements, the coefficient of permeability varies between 3×10^{-6} and 1×10^{-8} m/s. Undrained shear strengths varied from about 3 to 12 kPa.

Planned remediation includes capping the tailings. Two techniques were considered for constructing a cap on the soft tailings: high tensile strength geotextile (HTSG) reinforcement and wick drains to improve shear strength of the tailings. A trial cap using HTSG reinforcement was selected and implemented.

Design considerations for the trial cap included stability, cap thickness, and properties of the reinforcement material. Stability analyses indicated that the factor of safety would be less than 1.0 for a 2m thick, unreinforced cap. Reinforcement was designed to provide a safety factor of 1.3. A finite element analysis was also performed to evaluate lateral deformation in the tailings due to the cap load.

Cap construction began August 1996 with the placement of the HTSG and 0.6m of sand. A 1.0m lift of rock fill was then placed in October 1996, followed by a 0.9m lift of rock fill in May 1997. Pore pressure, settlement, and lateral displacement were monitored during and after cap construction. Monitoring results indicated that the reinforced tailings had adequate strength to support the cap and that measured deformations agreed with predictions. However, it was found that the tailings tended to "liquefy" from operation of earth moving equipment. Measured pore pressures were found to be 1.5m above values estimated due to static loads. This was considered to be a serious problem, especially at the initial stage of cap construction.

Ciubotariu, Schneeberger, Wilson, and Hague describe the remediation of a priority hazardous site in Quebec Province, Canada, in their paper *"The Environmental Remediation of Clark Island, A Former Allied Signal Inc. Site"*. Clark Island is a 63 ha island in Lake St.-Frances, part of the St. Lawrence River, Quebec, Canada.

Industrial operations began on Clark Island in 1941 with construction of a sulfuric acid plant. Initially, pyrite was used as the raw material, resulting in pyrite cinder waste that was pumped into settling ponds. Alum production began in 1946, and resulting alum muds were also pumped into settling ponds. Beginning in 1956, hydrogen fluoride was produced using fluorspar as raw material. The resulting gypsum wastes were pumped along with alum muds into settling ponds. Most production facilities were decommissioned in 1983.

Pyrite cinders waste is a uniformly graded silt sized material, essentially composed of iron oxide and traces of several heavy metals. More than 120,000 m^3 of pyrite cinders waste were identified on site. The pyrite cinders were classified as hazardous. The gypsum/alum waste is primarily calcium sulphates with leachable lead. The gypsum/alum wastes were classified as non-hazardous.

Site characterization identified nearly 60,000m^3 of soil with heavy metal contamination. Elevated levels of cadmium, iron, zinc, lead, and fluoride were found in groundwater. Groundwater modeling indicated that heavy metals were leaving the island and entering Lake St. Frances.

The selected remediation included connection of nearby residences to municipal water supply, excavation and containment of contaminated soil in a single lined cell, excavation and containment of acidic pyrite waste in a double lined cell, capping of the gypsum/alum waste, and continuous monitoring.

Remediation was performed from 1991 to 1993. Subsequent monitoring indicated reduced levels of heavy metals in both river water and groundwater. The general conclusion of the project is that confining acidic wastes in lined cells is a safe and economical method to protect the environment.

Guedes, Garrido, Lopes, and Freitas submitted a paper titled *"Alcanena Industrial Waste Landfill - Description of a Portuguese Case History"*. Alcanena is near the center of Portugal, where about 85 percent of the Portuguese tanning industries are located. For decades, the resulting industrial waste was disposed directly in the ground, and waste water was discharged into the river without treatment. In the 1970s, Portuguese authorities began efforts to remediate the Alcanena area. First, a waste water treatment plant (WWTP) was constructed along with a lagoon for deposition of "mud" from the WWTP process. Then, a landfill was constructed for deposition of tanning scraps. Last, another landfill was constructed for disposal of the pretreated WWTP muds. The paper focused on design and construction of this WWTP mud landfill cell and pretreatment procedures.

The liner and leachate collection systems at the base and side slopes of the landfill cell were designed in accordance with the recent European legislation for toxic waste landfills. At the base of the cell, the liner system comprises: 0.5m of clay having a coefficient of permeability less than 1×10^{-9} m/s, followed by a non-woven geotextile, 2 mm smooth HDPE geomembrane, non-woven geotextile, 0.2 m of clayey soil protection layer, and a multi layer drainage system. On side slopes, the liner consists of a 2 mm textured HDPE geomembrane overlain by a geocomposite drainage system.

The WWTP muds were stabilized using pulverized ash and other hydraulic agents to increase the solids content to about 35 percent. This treatment tended to immobilize contaminants in the muds, and the resulting high pH levels eliminated pathogens. Odors were dramatically reduced after treatment, and the treated mud had adequate strength to support construction equipment.

Treated muds are spread in 0.3 m lifts using low ground pressure dozers. Mud strength, pH, and solids content are monitored during landfilling for quality control. Air and ground water monitoring in the vicinity of the landfill indicated that air and groundwater quality is within allowable limits.

CONSTRUCTION ON WASTE FILLS

Modeer and Lamie discuss the environmental assessment and design criteria used to construct an embankment on top of a landfill in their *"Regulatory, Environmental and Geotechnical Solutions To Construction of a Roadway Embankment Over a Landfill"* report. The new IL-143 alignment was constructed with the new Clark Bridge that crosses the Mississippi River in Alton, IL. This alignment included construction of an embankment with fill heights ranging between 4.5 m to 7.6 m over a landfill. Using the "Brownfield" concepts, the IEPA (Illinois Environmental Protection Agency) approved the construction without having to remediate the site, contingent upon a deed restriction, restricting groundwater use and prohibiting intrusive activities. The current Brownfields program was not formalized during the negotiations between the Illinois Department of Transportation and the IEPA; however, the initiatives used to streamline the revitalization of an unproductive urban site were utilized.

During construction, the landfill was preloaded with a test fill of 5.2 m of soil and reloaded with 7.6 m of soil when embankment construction commenced with the planned fill and an additional 3 m surcharge. Settlement plates and inclinometers were used to monitor the earthwork performance during and after construction.

Settlement readings showed 10 to 15% of landfill thickness consolidated beneath the embankment. Settlement two years after embankment construction showed the landfill was settling 1.8 cm per year. Settlement after three years showed less than 1 cm per year.

"A Particular Foundation Problem On A Waste Fill" by Colleselli and Marcoratti discuss design criteria for the construction of a new aerobic water treatment system for a chemical plant in northern Italy. The treatment facility lies in an area once used as a waste landfill. In order to avoid the spread

of contamination to the subsoil and surrounding environment, shallow foundations were utilized; deep foundations were not considered.

Using a FEM program and geotechnical characteristics from SPT and CPT borings, a design to preload the embankment was developed in relation to the dimension and loads transmitted by the proposed facilities and the soil bearing capacity. Measured settlement during preloading and during hydraulic testing of the tanks and basins was evaluated. Distortion analyses demonstrated that all tanks had undergone settlements and distortions along their edges less than permissible limits.

COMPRESSION CHARACTERISTICS OF WASTE FILLS

Two papers discuss the compression characteristics of waste fills and describe the observed compression behavior using two different models. One paper presents the behavior of landfilled industrial waste and the other models the observed behavior of 4 sites with putrescible household refuse, commonly termed municipal solid waste.

In their paper, *"Test Fill to Determine the Compression Behavior of a Closed Industrial Waste Landfill,"* Bergstrom and Dugan present the observed settlement behavior of a test fill which was constructed on a closed, industrial waste landfill. The landfill contained a varying mixture of non-hazardous wastes such as foundry sand, ash, construction/demolition debris, and wastewater treatment sludge. The closed landfill surface was relatively flat and contained approximately 9.1 m of waste; the bottom 4.6 m of the waste was saturated. Underlying deposits included 2.4 m of glacial till over limestone. A test fill of clay was placed on the surface of this landfill and the settlement response was monitored. The test fill contained 3,800 m^3. It was approximately 49 m by 43 m in plan and was up to 3.7 m thick.

Settlement of up to 0.15 m occurred concurrent with construction of the test fill. Thereafter, settlement was essentially linear with logarithm of time. During 16 months of monitoring after completion of the test fill, additional settlement of up to 0.15 m was observed. These results have been evaluated using the traditional primary/secondary clay compression model, long in use by the geotechnical community, to estimate compression characteristics. The results yield estimated primary compression ratios, defined using traditional nomenclature as $C_c/(1+e_0)$ of 0.031 to 0.054. Estimates of secondary compression ratios, defined as $C/_{\alpha}(1+e_0)$, range from 0.0039 to 0.010.

In *"Procedure to Predict Settlement of Solid Waste Landfills Using Power Creep Law,"* Kumar presents a description of the power creep law in which settlement is an exponential function of time. He defines two empirical compressibility parameters. The first parameter is termed reference compressibility andis denoted as m. It is defined as the ratio of compression strain to the applied stress at a reference or unit time, such as one day or one year. The exponent of time is the second parameter. It is termed rate of compression and is denoted as n.

Published settlement data from 4 municipal solid waste landfills are evaluated using the power creep law. These sites included locations where fresh refuse was consolidating under its own weight, under small additional loading from no more than 1 m of waste, and under active filling with surcharge loading exceeding 6 m of additional waste. The sites also included locations where old refuse was consolidating under its own weight, under a surcharge load, and under its own weight after excavation, relocation, and compaction. Estimates of the compressibility parameters m and n are provided for each of the monitored locations. Estimated values of n ranged from 0.26 to 1.17. The fresh refuse sites yield the largest variation in estimates but, in general, the estimates of m and n for the fresh refuse are larger and smaller, respectively, than the estimates derived from the sites with old refuse. Graphs of observed settlement versus time for two different sites are presented with the corresponding predicted settlement-time curves resulting from application of the power creep law. The graphs compare favorably.

ENVIRONMENTAL DEGRADATION OF SOIL PROPERTIES

In their paper *"Effect of Effluents of Industrial Waste on Soil Properties,"* Shah and Shroff present the results of a testing program to determine the effects of dye industry waste effluents on the behavior of clay native to the region around Vadodara City, Gujarat, India. The clay is classified as a CH soil, with a liquid limit of 59 and a plastic limit of 26. Varying mixtures of waste and clay were tested for plasticity characteristics, swelling behavior, compaction behavior, compression characteristics, and shear strength. Changes in soil chemistry were also examined.

With increasing waste concentration, the soil liquid limit, plastic limit, free swell index, and swelling pressure all are reported to increase while the shrinkage limit decreases. In comparision to uncontaminated soil, the contaminated clay also exhibits a higher specific gravity, maximum dry density, optimum moisture content, compression index, and angle of shearing resistance. Cohesion and preconsolidation pressure are reported to be lower in the contaminated soil. Chemical analysis of the contaminated soil indicates that the contaminated soil exhibits increased base exchange capacity, pH, and concentrations of sodium, potassium, calcium, magnesium, iron, and copper.

CONTAMINATED DREDGE FILLS

In the *"Design of Contaminated Dredged Fills Utilizing Geosynthetics"* report, Chaney, Demars and Richardson discuss regulatory requirements and design criteria for confined disposal facilities (CDF). Approximately four million cubic yards of sediments are dredged annually from the Great Lakes to maintain navigation in channels and harbors for commercial, military and recreational users, and as part of environmental projects. Approximately one-half of the dredged sediments are sufficiently contaminated to preclude their release to the environment. Basic design considerations for contaminated sediment disposal in the USA are to control all potential contamination migration pathways. The Clean Water Act requirements for the disposal of dredged material are based on contaminant levels and partitioning potential of sediments under consideration. The application of geosynthetic components for limiting contaminant pathways in the CDF containment basin were discussed.

GROUND IMPROVEMENT

Zhirong and Changyong describe two ground treatment methods used for constructing a 6-story building over irrigation canals in their paper *"Case Histories of Two Kinds of Composite Foundation."* Soils at the building sites are alluvial silts and sands, and ground improvement was necessary to improve bearing capacity and to reduce liquefaction potential. Two ground improvement technologies were used: sand columns and powder deep mixing (PDM).

Sand columns were installed by driving pipe piles and then backfilling with sand as the pipe piles were withdrawn. The sand was compacted by vibrating the pipe as it was withdrawn. Sand columns were 6 m long with diameters of 400 mm, spaced at 1.1 m. Installation of the sand columns compacted the alluvial silt and sand soils between columns. The sand columns also functioned as drains.

Deep soil mixing columns were also constructed at 1.1 m spacing. The PDM columns had diameters of 500 mm and extended to depths of 4.3 m. Approximately 60kg of cement powder was added per meter of column. The deep soil mixing technique did not densify the natural soils between column locations.

The authors concluded that sand columns successfully reinforced loose, soft soil, improving bearing capacity and improving resistance to liquefaction. PDM also improved ground strength and bearing capacity. However, use of PDM columns was judged to be inferior for improving liquefaction resistance. Use of PDM is not recommended for soils with high organic contents since the organic matter will impede hydration of the cement powder. Construction of the multi-story structures was successful.