FLORIDA BIOREACTOR DEMONSTRATION PROJECT UPDATE

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ABSTRACT

The New River Regional Landfill in north Florida is hosting a Florida Bioreactor demonstration project. The primary goal of the landfill bioreactor demonstration project is to design, construct, operate, and monitor a full-scale landfill bioreactor in Florida in a manner that permits a complete and fair evaluation of this technology as a method of solid waste management in Florida, with appropriate consideration of science, engineering, environmental and economic issues.

The demonstration includes recirculation of leachate, injection of air into portions of the landfill, and the ability to monitor gaseous emissions from the bioreactor. The landfill bioreactor has been instrumented for the purpose of collecting *in-situ* measurements of such parameters as leachate head on the liner, waste moisture content, waste load, gas composition, and temperature of the waste. This presentation will provide a description of project construction and operation and of *in-situ* monitoring instrument employed.

INTRODUCTION

The Florida Bioreactor Demonstration is located at the New River Regional Landfill (NRRL) in Union County, Florida. The NRRL serves sources in five surrounding counties, receiving primarily mixed residential, commercial, and industrial waste. Waste receipt averages approximately 800 tons/day. The landfill consists of four contiguous, lined cells totaling approximately 46 acres. Cell 1 is equipped with a composite bottom liner consisting of a 60-mil High Density Polyethylene synthetic geomembrane and 36 inches of compacted clay soils overlain by 24 inches of 10^{-3}-cm/sec sand. Cell 2 is provided with a double liner system consisting of a primary leachate collection system overlaying a geomembrane with a leak detection system and geomembrane beneath the primary liner. Cells 3 and 4 liner system configuration, starting from the bottom, is compacted clay, geomembrane, triplanar geonet, geomembrane, triplanar geonet, geotextile, and finally a granular drainage media.

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> *Design, construct, operate, and monitor a full-scale landfill bioreactor in Florida in a manner that permits a complete and fair evaluation of this technology as a method of solid waste management in Florida, with appropriate consideration of science, engineering, environmental and economic issues.*

Construction of the Florida Bioreactor demonstration project is nearly complete. The contractor on the project is National Pipe & Construction, a division of GSE. Construction began in November 2001 with completion of the contractor's work in May of 2002. University researchers (University of Florida, University of Central Florida, and Mercer University) will complete piping and data management portions of the project in the summer of 2002. Startup of the bioreactor is expected during late summer of 2002.

The primary construction elements of the bioreactor include:

- A system of wells installed in all of Cell 1 and part of Cell 2 (for a total of ten acres) that permit injection of air, leachate, and water,
- Modification of the leachate collection manholes to allow collection and monitoring of leachate from distinct areas within the landfill,
- Grading of the landfill to prepare for installation of an exposed geomembrane cap installed on the slopes and the top of the landfill area subjected to treatment, and
- A gas extraction system to allow gas emissions to be collected and characterized.

In addition to the above bioreactor construction elements, instrumentation has been provided that permits monitoring of in situ moisture content, temperature, gas composition, and leachate and gas flow rates; landfill surface profiling to evaluate settlement; and parallel studies to investigate head on the liner and pressure at the liner due to overlying wastes.

INSTALLATION OF MONITORING AND INJECTION WELLS

Sensors and leachate/air injection wells were installed using a CME 85 rig to drill 4-in open flight auger holes. Two-in schedule 40 PVC injection wells were installed in clusters of three, reaching approximately 20, 40 and 60 feet (Figure 1). The monitoring wells were drilled to similar depths and a probe placed at the bottom of each well. Injection wells were temporarily capped. Cables serving in situ instrumentation were brought to the surface and threaded through small diameter PVC pipe. Eighty-seven cluster holes were drilled for a total of 268 wells. Forty-five injection well clusters were drilled for a total of 135 wells. The monitoring wells consisted of 42 clusters for a total of 133 wells. Air and moisture sources will be supplied by HDPE main headers installed under the cap. Researchers will tie PVC laterals located above the cap serving individual injection wells to HDPE headers.

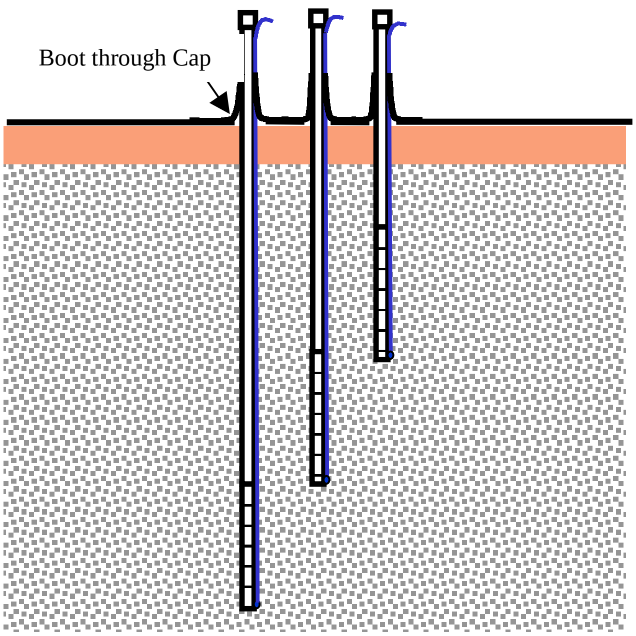

FIGURE 1. CLUSTER INJECTION WELLS

EXPOSED GEOMEMBRANE CAP

In preparation for installation of the Exposed Geomembrane Cap (EGC), on-site fill was used to grade the bioreactor area. Site preparation was challenging because of the presence of injection well caps and instrumentation cables. The cover was hand compacted around these obstacles. Toe drains were then installed around the entire site to collect side seeps and gas condensate that may collect under the cap. Drainpipes were placed in rock-filled trenches protected by a geotextile. A system of 3-ft horizontal trenches was installed at 120-ft intervals at the bioreactor surface to capture gas. These trenches are quite similar to toe drains in construction. Each trench is provided with a gas well consisting of HDPE pipe booted through the EGC. A network of HDPE pipe placed above the cap links gas wells. Gas wells are equipped for temperature measurement, gas sampling, and gas flow rate monitoring.

GSE provided 16 acres of 40-mil very flexible polyethylene textured geomembrane for the EGC. The geomembrane was placed in 22.5-ft strips that were double wedge fusion welded at overlaps. An extrusion weld was used to join geomembranes in anchor trenches, spaced at 120 ft provided to prevent uplift at projected maximum wind speeds of 80 mph. Once the EGC was installed, gas monitoring wells, leachate/air injection wells, and monitoring ports (for a total of 300 penetrations) were booted through the cap. Prefabricated boots were designed and manufactured to accommodate settling (Figure 2). The EGC extended beyond the filled area, therefore it was necessary to boot around leachate collection manholes as well. Manholes have been reconfigured to permit leachate monitoring from individual landfill collection bays. Gas-tight manhole covers have been provided.

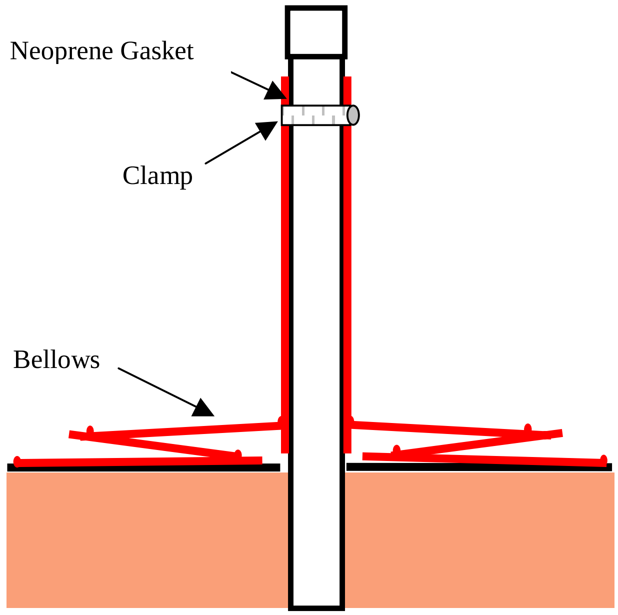

FIGURE 2. EXPANSION BOOT

GAS COLLECTION AND TREATMENT SYSTEM

Gas collection is accomplished using three 25-horsepower centrifugal pumps capable of compressing 800 scfm. Two 20-horsepower positive displacement type blowers will serve to supply injection air. Each blower will be capable of providing a range of flows up to 750 scfm of ambient air to a discharge pressure of 10 psig. A variable frequency drive will allow direct manual control of the pump flow rate. Extracted gas will be destroyed in a candlestick flare. Methane, oxygen, and flow rate of extracted air will be continually monitored at the gas collection station with data transmitted to the on-site research trailer. The entire system was skid mounted and installed on a concrete pad provided on the northwest corner of the bioreactor site.

INSTRUMENTATION

In Situ Moisture Content

Measurement of in situ moisture content remains a challenge because of the heterogeneous nature of landfills and the variability of leachate characteristics. Time domain reflectometry (TDR), time domain transmissivity (TDT), and electrical resistance technology have been utilized at the NRRL to measure moisture content. TDR and TDT units were purchased, however probes that permit temperature, gas composition, and moisture monitoring (MTG) were fabricated at Mercer University. Because of its low cost (approximately $25/unit as compared with $500/TDR unit), the MTG, which is based on electrical resistance technology, is the primary means of monitoring moisture content at the NRRL. However, twelve TDR units have been installed in parallel with MTG sensors for comparison purposes. In addition, TDT units are being evaluated in the laboratory.

TDR is analogous to the concept of radar where a signal is emitted and the analysis of the reflected signal gives characteristics of the medium or object under examination. With TDR the signal that is emitted is an electromagnetic wave and the physical characteristic that is analyzed by the propagated waves is the relative permittivity or the dielectric constant of the medium. TDR theory states that the time for a transmitted electromagnetic pulse to be reflected is dependent on the relative permittivity or dielectric constant of the medium, a characteristic that can be related to moisture content. TDT is similar to TDR with the exception that the signal is not measured as it is reflected but rather as it is transmitted.

Electrical resistance soil moisture sensors are comprised of a pair of electrodes inserted into a porous matrix. The two predominant types of devices (gypsum block and granular matrix sensors) use a soluble salt that serves to insulate the sensor from fluctuations in the salinity of the external environment. For both sensor types the salt that is used is highly soluble calcium sulfate (gypsum). When inserted into the medium to be measured the sensors come into hydraulic contact with the soil solution, which is absorbed, or released depending on the matric potential gradients set up between the sensor and the surrounding media. Ideally a steady state or equilibrium condition is attained between the sensor and the medium. The absorbed moisture dissolves a portion of the calcium sulfate salt. In this moistened state the sensor consists of a non-conducting matrix, highly resistant air pockets and a relatively conductive liquid. The resistance of the sensor is ultimately a function of the soil water content. Past use of these sensors has shown that once wetted, they tend to remain wet.

For the NRRL, a sensor was built to operate in conjunction with a data logger to measure the moisture content of the surrounding media. The sensor was designed to measure the electrical resistance of the moisture between two electrodes embedded in a granular insoluble media. The resistance has been found to be inversely proportional to moisture content.

The sensor body is an 8-in section of 2-in. diameter PVC well screen (2 in. ID, 2.375 in. OD) (see Figure 3). A slot size of 1/8 in. was used. Two 4-in thick by 2-in diameter solid PVC plugs were cut for the top and bottom of the sensor. In the bottom plug a 1/8-in diameter hole was drilled ¼ in deep and a corresponding diameter, fully penetrating hole drilled in the top plug. A small indentation was filed in one of the edges of the top plug to allow access for the mesh wire. A 7.5-in long, 2-in diameter slotted (0.2-in wall thickness) schedule-40 PVC length of pipe was cut. A 6-in by 6.4-in rectangle of market-grade stainless steel mesh (the mesh was sized according to the particle size) was prepared. A short piece of 18-gauge copper wire was soldered onto the long edge of the mesh near the middle. A 7.7-in piece of #6 stainless steel threaded rod was cut. All the PVC fittings were primed. The bottom plug was glued into one end of the PVC slotted pipe. The mesh was inserted into the slotted pipe with the 6-in edge running parallel to the pipe axis and with the copper wire at the top. One end of the #6 rod was dipped in PVC cement and then lightly tapped into the hole in the bottom plug. The rod was centered and the sensor then filled with sand to a height just exceeding that of the mesh. The upper plug was then glued in place. The wire and # 6 rod were attached to electrical connectors serving as the electrodes of the sensor.

Roctest TPC Total Pressure Cells

During the summer of 2000, Roctest total pressure cells (TPC) were installed in Cell 3 of the NRRL. The purpose of the TPCs is to measure the loads found on the liner system of an operating landfill during and after waste lift placement. While Cell 3 is outside of the current bioreactor area, it was felt that data obtained would be helpful in interpreting results of bioreactor operation.

The TPCs are traditionally designed to measure pressures in fills, embankments, piers, culverts and stresses found in concrete structures. The TPCs measure the vertical

FIGURE 3. MTG GRANULAR MOISTURE SENSOR.

force exerted on the liner system resulting from waste placed in the landfill. In addition to load measurement, the TPCs are equipped with thermistor units that yield temperature data at the liner.

The TPCs are constructed of steel with a sealed distribution pad. This pad is composed of two steel plates welded together and filled with degassed oil. The oil-filled distribution pad is connected via a long steel tube to a vibrating wire pressure transducer (see Figure 4). The design of the pad ensures that it is affected exclusively by forces normal to the pad (vertical forces).

To install the TPCs , the drainage system of the landfill cell was excavated to just above the geotextile component of the bottom liner system. A plywood board was placed on the drainage material to stabilize the instrument. A reading was recorded before backfilling the excavation. The depth of sand at which the hole was excavated was recorded and the instrument was buried.

Typical results from the TPC are presented in Figure 5. The data clearly demonstrate the incremental pressure step increases that result from lift placement. When coupled with landfill surface measurements obtained using a Global Positioning System unit to evaluate settlement, a highly accurate waste specific weight can be determined.

Leachate Head on the Liner Monitoring

The depth of leachate on the liner is a primary regulation in the US to protect groundwater and is a major concern for regulators approving bioreactor permits. Because the waste within the bioreactor test area had been placed prior to the initiation of this project, it is difficult to monitor this parameter. However, pressure transducers are being evaluated for this purpose in a 100-ft x 100-ft portion of Cell 2 (where waste had not yet been placed), as well as in Cell 3. For Cell 2, a total of 128 transducers was installed in May 1999, equally divided between the KPSI Series 700 and Druck Series 1230 pressure transducers. Cell 3 has 88 Druck pressure transducers, installed in June 2000.

Transducers are provided with a watertight and submersible connection between the cable and the body. Pressure measurement are taken using a standard differential voltage signal calibrated over a gage pressure range of 0 to 5 feet and an excitation voltage of 2.5 volts. The cables from each transducer run outside of the landfill area and connect to a datalogger and relay multiplexer. The datalogger interprets electrical signals emitted by the transducers and stores them. The multiplexer increases the number of transducers that can be scanned by the datalogger from 16 to 64. A cellular phone is attached to the datalogger to enable downloading data from long distances. A 12-volt DC battery that is continuously recharged by a solar panel powers the station.

To date a significant number of pressure transducers have failed for a variety of reasons (as high as 75 % at Cell 3). Initially transducers were coated with marine grease and encapsulated in plastic sleeves to minimize biological growth. In some cases, the use of grease may have interfered with transducer operation. Subsequent installations used copper discs to minimize growth. In addition a lightening strike has destroyed a number of Cell 3 transducers. It is also suspected that the pressure of compactors and overlying waste may be deforming some of the transducers and causing erroneous readings. In general however, transducer results suggest that preferential flow of leachate plays an important role in leachate transport to the collection system. Cell 2 results are highly variable and the “parabolic” head profile projected by mathematical equations has not been observed. Cell 3 results confirm the effectiveness of the “pipeless” design.

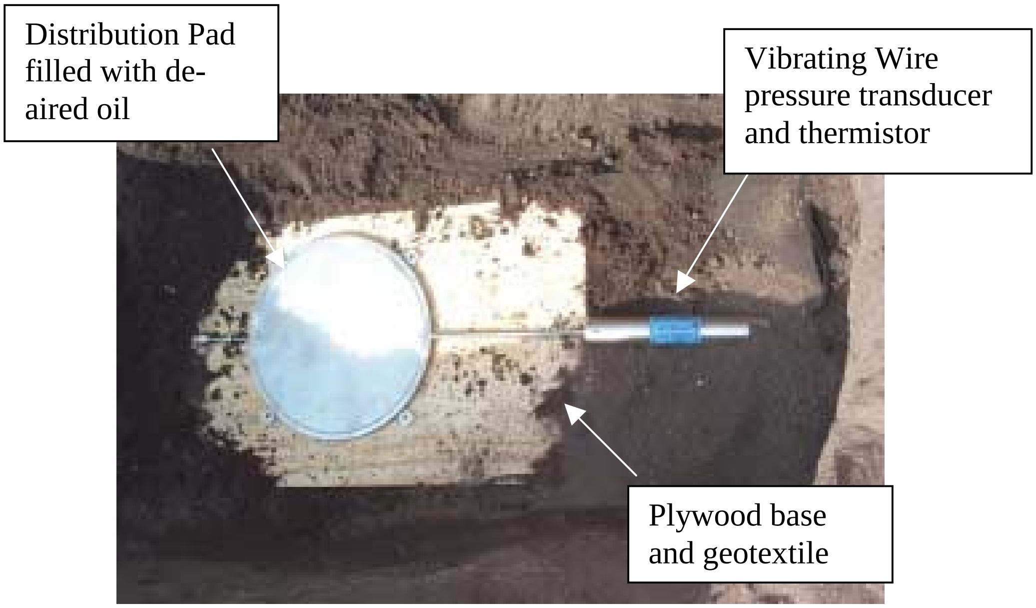

FIGURE 4. ROCTEST TOTAL PRESSURE CELL.

<u>Data Interpretation</u>

Geographic information systems (GIS) allow for the processing of spatially referenced data into useful information pertaining to the system of concern. Unlike computer assisted drafting (CAD) programs, such as AutoCAD, GIS programs link geographical data to information/properties specific to that location. For example, monitoring well data can be represented by both location and monitoring results. GIS programs also are capable of performing mathematical analyses on spatial data. Thus, by using a GIS-based model, both spatial and mathematical analyses of a system are possible, making the use of GIS programs to analyze engineering systems an attractive option.

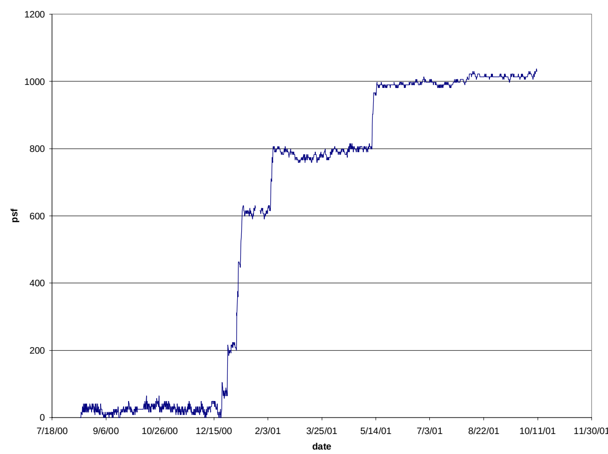

FIGURE 5. PRESSURE MEASUREMENTS OBTAINED USING THE TOTAL PRESSUE CELL.

To determine spatially averaged moisture content of a landfill, a conceptual 3-D GIS model was developed. The model performs a spatial interpolation of the in-situ moisture content data throughout the landfill and then averages the average moisture contents at each spatial interpolation step by performing a series of algebraic operations on interpolated layers of moisture content data for each level of moisture sensors. This procedure will also be applied to variables other than moisture content, such as temperature and gas composition.

The first step in implementing the GIS model developed is to input into ArcView GIS 3.2 (the GIS program used) all global positioning system (GPS) data for all monitoring well locations and their respective depths within the landfill, as well as GPS locations defining the extents of the landfill. The next step is to input data obtained for each monitoring well location and to perform the procedure described above.