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General Report - Session 6

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GENERAL REPORT - SESSION 6

6a. Case Histories on Soil Property Improvement

6b. Case Histories on Geo-environmental Problems

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ABSTRACT

This general report provides a summary of 40 accepted papers submitted to sessions 6a on ground improvement methods and session 6b on geoenvironmental engineering. The papers are contributed by the researchers and professionals from the United States and 15 other countries and they cover a wide range of topics based on laboratory experiments, field design, construction and monitoring, and mathematical modeling. A brief summary of each paper is provided under organized sections and the reader is referred to consult the full paper for details. Finally, the topics for discussion are listed.

INTRODUCTION

This General Report presents a summary of the 40 papers accepted for the session 6 focused on research and case studies on Ground Improvement Methods (session 6a) and Geoenvironmental Engineering (session 6b), both topics have always been receiving significant attention of the geo-professionals worldwide. Papers are contributed by authors from 16 countries, reflecting the range of issues and practices worldwide. The papers deal with a wide range of topics based laboratory testing, field implementation and monitoring and mathematical modeling studies.

Ground improvement method is the process of improving the geotechnical characteristics of soil used in construction. Several types of ground improvement techniques have been developed, including mechanical methods, chemical admixtures, grouting, etc. The session papers on ground improvement theme present properties and behavior of problematic soils and discuss various ground improvement methods, such as dynamic compaction, admixtures, deep soil mixing, grouting, drains and preloading, and geosynthetics, used in the design and construction of various geotechnical systems. In some cases, the monitoring of the improved ground and geo-structures was performed, based on which valuable lessons have been learned on the efficacy of the improvement methods used.

Geoenvironmental engineering is an emerging area which deals with the protection of geoenvironment from wastes and hazardous chemicals as well as addresses the effects of pollution in the geotechnical engineering. The session papers on the geoenvironmental theme identify issues dealing with landfills, contaminants/chemicals in soils and groundwater, and stormwater issues.

The aim of this General Report is to provide a brief summary of each paper, so that the reader can get a quick overview of each paper and then refer to the papers that deal with the topic of interest for more specific details. Topics for discussion are also presented. It should be noted that all of the papers cited in this general report are listed at the end of this report.

CASE HISTORIES IN GROUND IMPROVEMENT

Properties and Behavior of Problematic Soils and Rocks

AlHattamleh (2013) examined the effect of salts dissolution on the collapse potential of a soil. A set of samples of evaporated Dead Sea soil was prepared and tested to evaluate the effect of the presence of brine on the collapse potential of the soil. The soil specimens after being washed from the dissolved and precipitated salts were treated by adding Dead Sea brine. Time was allowed for the additive brine to be crystallized or fully dissolved before the test was initiated in Oedometer cell. A considerable amount of collapse takes place for the sample with increasing the initial applied pressure on the sample regardless the initial molding water content. However, the dry of optimum sample shows larger collapse than that on wet side of optimum. At low applied initial stresses, the more the brine percentage present on the sample is increased, the larger the collapse occurs. Moreover, the amount of collapse tends to increase with increasing the applied pressure to reach certain value for a given brine percentage, then the amount of collapse asymptote to its maximum value with increasing the pressure on the sample.

Biringen and Davie (2013) examined the effects of fractures on the relationship between shear wave velocity (V_S) and rock quality designation (RQD) for three different rock types located in Virginia, South Carolina and Florida. The Virginia rock is strong metamorphic (gneiss), the South Carolina rock is strong igneous (granodiorite), and the Florida rock is moderately weak to strong sedimentary (limestone). High quality H- and P-size rock cores were taken in multiple borings at each site and RQD for each core was recorded. Rock thickness ranged from about 90 ft to over 300 ft. V_S was measured in each boring at 1.64-ft intervals using P-S Suspension logging. Correlation between V_S and RQD was computed for each site using all of the recorded data. Reasonable correlations were achieved at the two hard rock sites, although the relationships were predictably different. The relationships at the two hard rock sites being closer compared to that at the weaker rock site. The relationships derived for V_S versus RQD could be used to obtain an approximate V_S profile using the RQD measurements, if V_S measurements are not made.

YousefzadehFard et al. (2013) evaluated liquefaction potential of soils along the alignment of a proposed subway train (Tabriz Urban Train Line 2, Iran). All required parameters including soil types, water levels, total stresses, pore water pressures and effective stresses were collected based on 53 preliminary boreholes with standard penetration resistance test (SPT). For evaluation of liquefaction potential based on SPT at different depths, the latest techniques offered by Idriss - Boulanger (2008) were used with the datum acceleration 0.35g for earthquake of magnitude 7.5, and liquefaction risk evaluation was done by Iwasaki method. Based on this, some areas where liquefaction risk exists were identified.
Fallah (2013) determined the dynamic properties (shear modulus and damping ratio and their variation with shear strain) of rockfill for the stability analysis of a dam based on large scale static and cyclic triaxial tests. The test specimens are made of a modeled gradation with D_{max} of 5 cm, reduced from the real D_{max} of 80 cm by scalping method. Static triaxial tests resulted in the rockfill shear strength parameters within the expected range. On the other hand, the cyclic triaxial parametric tests results were used to define shear modulus and damping curves of the rockfill, and they were found to be different from that of coarse materials.

Bandyopadhyay and Abdullah (2013) presented properties of four weak and strong sandstones, obtained from three projects in India. The grain density of all four sandstones is similar, though their bulk densities, apparent porosity and slake durability index show great variation. The weak and strong sandstones show qualitative difference in their uniaxial compressive strength and wave velocity (compression and shear, both); and the two properties are directly proportional. The study clearly demonstrates that there is no one-to-one correspondence between any two properties and parameters, but there is a diffused and/or qualitative relationship between different sandstones, or certain properties and parameters of a particular variant.

Mansouri et al. (2013) investigated the effect of water salinity on engineering properties of fine-grained soil. Saline water used in this study was obtained from half saline water of Ajichay River (with total dissolved solids (TDS) more than 1877 ppm) and saline branch of Korchay (with TDS more than 97000 ppm) located in Northwestern of Iran. Fine-grained soil studied is from Korchay dam core. Due to the high hardness of water in this river, the feasibility of using saline water as the water required in clay core of the dam process has been studied in this research. Tests results showed Atterberg limits, compression index, swell index, coefficient of volume compressibility and coefficient of compressibility have decreased and consolidation coefficient and shear strength parameters have increased as water salinity increased. The main reason for these changes has been attributed to an increase of attractive force between soil particles, establishment of bonding between them, formation of salt crystals in pores of soil and role of the cement. It is concluded that saline water can be used in processing of dam core, avoiding the additional cost for procuring water to the site.

Rosyidi (2013) developed a new technique called Wavelet Spectrogram Analysis of Surface Waves (WSASW) for measurement of the soil dynamic properties at a soft marine clay soils site. The WSASW is able to evaluate the reliable surface wave spectrum of the noisy signals and to develop an enhanced phase velocity dispersion curve from the surface wave measurement at the site. Good agreements were obtained between the measured shear wave velocities and the corresponding dynamic shear modulus by the WSASW technique compared to Continuous Surface Wave (CSW) method and well known Hardin and Drnevich model.

Ground Improvement using Mechanical Methods

Mechanical methods for ground improvement can include methods such as dynamic compaction and vibro-compaction and are mostly applied in granular soils.

Kozompolis et al. (2013) presented the results of dynamic compaction in loose, saturated granular deposits. The dynamic compaction was performed by two approaches: (1) the conventional method of Falling Weight Treatment (or Deep Dynamic Compaction - DDC), and (2) the more recent Rapid Impact Compaction (RIC) method. Both improvement approaches yielded satisfactory soil improvement in terms of bearing capacity, settlement, and liquefaction potential. DDC is better suited for relatively thick target zone (on the order of 6 to 8 meters), or in cases where the pre-improvement soil conditions are relatively poor; whereas, RIC is better suited to influence depths on the order of up to 5 to 6 meters.

Belani et al. (2013) described the use of vibro-compaction for improvement of loose sandy soil in a seismic area to mitigate liquefaction and to increase bearing capacity. Over 5,500 square meter area was treated in one month time using one rig, demonstrating the speed of this method. The standard penetration test (SPTs) and Electric Cone Penetration Test (ECPTs) results were used to confirm the soil improvement. A relative density of more than 60% was achieved in improved sand layers.

Ground Improvement using Physical and Chemical Methods

The physical and chemical ground improvement methods can include methods such as use of admixtures (e.g., lime, cement, etc.), grouting, deep soil mixing, and heating and freezing.

Roy (2013) investigated the benefits of using rice husk ash (RHA) and lime with clayey soil as the subgrade material in flexible pavements. Four ratios of RHA of 5%, 10%, 15% and 20% mixed with the clayey soil by weight were tested. To further improve the soil, lime was added to the soil in varying proportions from 1% to 3% by weight of soil. The compaction characteristics and unconfined compressive strength tests were conducted on these different mixed soils. Addition of rice husk ash and lime in increasing proportion with the alluvial soil decreased the maximum dry density and increased the optimum moisture content of the mixed soil. The unconfined compressive strength increased gradually for addition of increasing amount of lime and rice husk. The maximum unconfined compressive strength was attained for 10% rice husk ash and 3% lime.

Alireza et al. (2013) investigated stabilization of a weak low plasticity soil with lime and nano-silica. California bearing ration (CBR) tests were conducted in this study. The stabilization of the soil with lime alone was found to be ineffective. Addition of nano-silica increased the CBR strength of the soil and soil-lime mixture up to 21 and 7.5 times, respectively. The CBR strength of the soil-lime mixture increased more rapidly with adding nano-silica. Stabilization of the soil with 5% lime and 3% nano-silica was found to be optimum for utilization as subgrade, subbase and base materials in the road construction.

Ashango and Patra (2013) investigated dynamic properties of highly expansive clay for a road subgrade. The clay soil was treated with Rice Husk Ash and Portland cement slag. Strain control cyclic triaxial tests were carried out on the stabilized clay for different amplitudes of shear strain at frequency of 0.5Hz and 100kPa effective confining pressure. The damping ratios increased with increase in amplitude of shear strain and varied from 7-9% to 14-19% for $\gamma= 0.4\%$to 1%, respectively. The shear modulus decreased with increase in amplitude of strain. The modulus of degradation index decreased at a very fast rate for the first 50 cycles. This variation of dynamic propertied of stabilized clay with strain amplitudes can help design the road subgrade.

Gennadii and Ilya (2013) assessed improvement of soils using cement, lime, or slag binder. Comparing with cement and lime, blast furnace slag used for improvement of soft clays was more effective. Test results showed that soil strength and stiffness properties are highly dependent on the content of slag. Increase in the total water to total solids ratio caused decrease in the mixture strength. Increase in the curing time produced increase in the mixture strength.

Gingery and Arora (2013) described the use of compaction grouting for ground improvement to mitigate liquefaction and seismic slope instability hazards at an historic bridge retrofit project site. They provided a brief description of the overall retrofit design strategy, and detailed descriptions of the design and application of compaction grouting. Pre- and post-construction Standard Penetration Test data were compared to assess the soil improvement. The compaction grouting program was successful in achieving the ground improvement levels required by the design. The compaction grouting program successfully densified the treated soils to the minimum mean $(N_1)_{60}$ value of 25 required by the specifications. This level of improvement mitigated the liquefaction and lateral spreading hazards at the site, thus allowing the existing pile foundations at the bent to remain in place without expensive and difficult to construct retrofit measures. The use of limited access grouting equipment and angled grout injection columns overcame the restricted working space at the site. Careful surveying during construction assured accurate coverage of the treatment zone and that existing utilities were not damaged by the grout injection.

Chin et al. (2013) described the design and construction of compaction grouting work completed for a tank replacement project. The subsurface soils at the project site were determined to be highly susceptible to soil liquefaction and lateral spreading under a design earthquake event per the building code. Compaction grouting was designed and constructed to strengthen the foundation soils supporting the new steel tank that is 115 feet in diameter and 40 feet in height. The design of the compaction grouting was completed using the design guidelines outlined in ASCE/G-I Standard 53-10. Detailed quality assurance/quality control processes were implemented during grouting operations to account for the variability in soil conditions being grouted. Real time monitoring was also completed to evaluate the ground movement induced by the grouting process and its impact to adjacent structures and critical utilities. Pre- and post-grouting CPTs were completed to verify that the intended ground densification was achieved. A hydrostatic test was also completed with the tank filled with water. The tank foundation settlement under the hydrostatic test was found to range between ¼ to ¾ inches and met the acceptance criteria per API-650 and API-653 Standards. The estimated soil movement beneath and within the tank footprint is estimated to be small under the building code design earthquake event.

Baillie (2013) described the use of deep soil mixing with geosynthetic inclusions to improve the flood plain very poor soils to support flood protection embankment levees. Deep soil mixing is a technique used to create cement/soil bonded columns that are utilized as end load bearing elements. The columns were used to bridge the soft foundation soils and create a semi rigid foundation for support of the levee embankment. A high strength geosynthetic reinforcement was incorporated into the design and installed over the columns. Reinforcement can decrease the area replacement ratio required by design and provide embankment edge stability. The use of reinforcement for edge stability can reduce or eliminate the need to increase column density along the outer edge. Localized column separation may also be minimized with the reinforcement acting as a binding tensile platform. With the proper use of reinforcement, these applications can become even more efficient in time and cost vs. unreinforced case. Considerations in the selection of geosynthetic reinforcement are presented and discussed.

Ground Improvement using Hydraulic Methods

Hydraulic methods for ground improvement include methods such as drains and preloading (surcharge loading).

Stamatopoulos et al. (2013) described a field study of soil improvement by preloading at a site with soil profile consisting of a soft clay layer to depth of 3.5m, a medium-dense silty sand layer at depths 3.5-7m and a soft silt layer below. Preloading was applied by a temporary embankment 9m high. A partial embankment failure occurred during the preloading process. Preloading caused settlement of about 0.6m with vertical strain ranging from 10% at depths above 3.5m to 1% below. The increase in lateral stress ratio as a result of the preloading process varies between 0.9 and 0.1. The large value corresponds to depths 0-3.7m. As a result of preloading, the shear wave velocity increased by a factor of about 2 at shallow depth to a factor of about 1.1 at depths below 3.7m. The cyclic liquefaction strength of a silty sand layer at a depth of 3.7-7m increased from 0.39-0.50 to 0.46-0.55, or by about 10%. In addition the cyclic liquefaction strength of a non-plastic silt layer at depth 7-15m increased from 0.38 to 0.43, or by about 13%.

King (2013) described the use of prefabricated wick drains in combination with a temporary surcharge load to improve soft clay to reduce post-construction consolidation settlement of a building pad. To construct the building pad, 8.5 feet of engineered fill was placed over a field of prefabricated wick drains. Four additional feet of fill was used as a surcharge load during a period of 69 days. Throughout the approximate 4 month monitoring period during building pad construction, an average settlement of 3.43 inches was measured; with over 6 inches in some locations. This ground improvement method reduced the settlement period from several years to about four months.

Lee et al. (2013) described ground improvement with wick drains and surcharge fill placement to improve the soft lacustrine clay at a power plant site. Settlement monitoring instrumentation was installed before placing structural fill and surcharge fill. The monitoring period was extended even after surcharge fill removal to observe the rebounding behavior of the foundation soil. This paper presents the challenging site conditions, such as soft soil, the design optimization implemented to accelerate the settlement period, and the comparison between predicted and measured settlement at the project site. Relatively high fill was rapidly placed using wick drains, which dissipated excessive pore water pressure in a relatively short time period. Field instrumentation and monitoring of displacements and pore pressure build up in the foundation layers provided useful information, such as degree of consolidation, during construction and surcharging periods.

Ground Improvement using Inclusions and Confinement

Ground improvement using inclusions includes the use of geosynthetics, stone columns, etc.

Sabry and Mostafa (2013) described the use of stone columns to improve soft silty clay to support 50 concrete embedded pipes to carry sea water to settling basin and intake of a thermal plant. The offshore stone columns were constructed using blanket method utilizing two vibro floatation probes. Load test and post-construction settlement monitoring was performed and concluded that this soil improvement approach to be efficient and economical to reduce the settlement of embedded pipes.

Metcalfe et al. (2013) described a new variation of rammed aggregate pier methods, called the Rammed Compaction

Point^{TM} (RCP) method, to treat a layer of liquefiable sand that was overlain by a non-liquefiable layer of clay. RCP involves densification with a multi-tined driven mandrel. Pre- and post-CPT tip resistances were used to assess the effectiveness of the improvement. Design methods used to calculate liquefaction susceptibility and post-liquefaction settlement are presented.

Hemmati et al. (2013) described a case study involving stabilization and reinforcement of slope by geogrids. The slope had height of 4-29 m and length of 370 m, and a high-rise building is located upper and near edge of slope. The slope is located in a high seismic risk location. Geotechnical site investigation is showed existence of 13 different geotechnical zones of rock mass with R.Q.D less than 10% and slope wash and fill material.

Gor et al. (2013) investigated stabilization of expansive soil using geotextile and cushion material such as flyash to support highway pavement. The soil was improved with reinforcing geotextile overlain with cushion material. Effect of cushion material on swelling of expansive soil has been investigated along with the ability of geotextiles in locked and unlocked condition with cushion material was scrutinized. Better cushioning due to use of flyash can be attributed to pozzolanic activity forming stable compounds. It is observed that the use of flyash as cushion material provides better swelling control as compared to quarry dust. Unlocked geotextiles did not prove as effective as locked textiles with the use of either of the cushion materials. The unlocked textiles proved advantageous with quarry dust but did not prove as advantageous as only flyash. The most important two functions of geotextiles namely separating and reinforcement have been most effectively used in the locked condition. The study was further extended to stabilize the expansive soil with metakaolin. Swell pressure test and UCS results on samples treated using 1% metakaolin provided its effectiveness in controlling the swelling characteristics of expansive soil as well as strength improvement.

Ullagaddi and Nagaraj (2013) investigated the effect of inclusion of the geosynthetic reinforcement on California Bearing Ratio (CBR) value of a two layered soil system with black cotton soil at bottom and granular soil at top as a buffer layer, with different thickness configuration and geotextiles of different physical and mechanical properties in laboratory and field. The reduction in the thickness of pavement can be achieved up to 53.53% depending upon the thickness configuration and the type of the geotextile used. The field CBR tests yielded the results similar to those obtained in the laboratory test.

Beena (2013) described the advantages and case studies on the use of coir geotextiles in roadway construction projects. The coir geotextiles can be used for erosion control, blanket drains, vertical drains, and reinforcement and separation layer between subgrade and base course in roadway pavements. The coir geotextiles are natural materials and economical, hence are eco-friendly and sustainable. Experimental studies conducted demonstrate that these geotextiles possess desirable properties such as resistance to sea water and absorption of solar radiation. The successful deployment of these geotextiles in roadway projects is demonstrated.

Chirica and Talos (2013) described the use of different geotextile types for proper drainage and filtration of a fly ash embankment. Laboratory testing and stability analyses were conducted. Geotextile presence is shown to reduce the moisture of fly ash, thereby increase fly ash strength and embankment stability.

Agarwal et al. (2013) described soil reinforced with geosynthetics (reinforced earth) to improve seismic bearing capacity of a weak soil. An analytical approach is developed to obtain the seismic bearing capacity of a strip footing resting on reinforced earth. The approach is based on a strip footing subjected to static load and considering both vertical and horizontal accelerations in terms of seismic coefficients. Non-dimensional charts are developed to calculate seismic bearing capacity and their use is demonstrated by a hypothetical example.

He-ping et al. (2013) described the improvement of an expansive soil using dynamic compaction with geogrid reinforcement method for highway subgrade. The construction procedure and monitoring methods are described. The soil improvement is found to be effective.

Alternative Approaches to Ground Improvement

Instead of using ground improvement, some other alternatives can be possible. These mainly include changing the structural system itself based on the site soil conditions. For example, the use of lightweight fill material can reduce the stresses on underlying weak soil and also the analysis and design of structural system including adapted foundations based on the existing soil conditions.

Lingwall and Anderson (2013) described construction of large embankments using various lightweight fills to limit distress to the adjacent utilities. Each lightweight fill was successful in reducing the amount of foundation settlements observed during and after construction. Slag was used extensively due to its price and availability, and showed dramatic decreases in settlements. Scoria was used, often in conjunction with regular weight fill or lightweight cellular concrete, in reducing settlements to buried utilities. EPS geofoam was used to protect in place a buried steel pipeline directly beneath a new approach fill for an overpass structure on extremely soft soils. Though the most expensive lightweight fill, the settlement performance of the embankment indicates that EPS geofoam designs can be successful. Settlement estimates from traditional engineering methods and FLAC3D analyses were compared to the observed settlement data. Sensitive buried utilities were successfully protected by use of lightweight fills, and engineering settlement estimates were shown to agree well with measured settlement data. Lightweight fills also reduce the needs for embankment reinforcement (high strength geotextiles, soil treated fills, etc.), PV drains and surcharging, saving costs to partially offset the greater costs of the lightweight fill itself.

Chirica et al. (2013) presented various foundations options under static and seismic loads for a wind farm located at a site with a soft cohesive strata alternation over 40m deep. Based on the physical and mechanical characteristics of the subsoil in static and dynamic conditions, three types of foundations are recommended for a generator: (1) Direct foundation on improved soil by methods compatible with saturated soft clay with salt water; the minimum height for slab is 5. m, bottom slab will be designed as a rigid compensating box with a "skirt" on outline circular for plastic yielding reduced growth areas and rotation. The wind tower foundation can be optimized by making "slurry" wall with thickness of 80 cm on circular diameter contour ~ 20 m to 20 m depth before land improvement. Also this kind of improvement reduce the pressures on soil and increase the active surface from 54% for direct foundation without skirt to 70% for direct foundation with skirt; (2) indirect foundation through a system of piles - large diameter piles connected by a slab designed as a rigid compensating box for reduced deformations; and (3) Mixed foundation: piles foundation on improved soil.

Dehghanpoor (2013) presented a new mathematical method for analysis of piles under a combination of static and dynamic loads considering soil inhomogeneity and soil stratification. The characteristic effects of surrounding soil on the pile response are determined using stiffness and damping parameters of the soil - pile system. These effects can be taken into account if a proper soil reaction is employed. The soil reaction on the pile is represented by springs and dashpots, which are modeled using elasto-dynamic theory or elastic half-space theory. The pile is divided into cylindrical segments connected rigidly at nodes connected by stiff spring, which are characterized using linear elastic theory. Also effective parameters have computed in complex stiffness of the soil - pile system such as pile slenderness ratio, mass ratio, Poisson's ratio, excitation frequency, wave velocity ratio and pile static load and no separation is allowed in the soil-pile interface. The method has been validated using an existing solution for the analysis of pinned, fixed, and free ends of piles. A parametric study has been carried out and shown that the soil stratification can affect significantly the stiffness and damping characteristics of piles. As demonstrated, the method is an efficient and simple method for analysis of piles under harmonic vibration. In particular, the effects of the soil inhomogeneity in the vertical direction even with complicated stratifications can be easily captured.

CASE HISTORIES IN GEOENVIRONMENTAL ENGINEERING (SESSION 6b)

Case Studies on Landfills

Jedele and Buschmeier (2013) described the design and construction of a large industrial building at a former industrial landfill site. Due to the soil and groundwater conditions along with potential environmental impacts, support of the building using shallow spread foundations or conventional deep foundations, such as driven or cast-in-place piles or drilled piers were not considered to be reasonable foundation support alternatives. Therefore, ground improvement was deemed the best alternative to support the building, floor slabs and machine foundations for the project, although timber piles with a structural slab were also considered. Controlled modulus columns and rammed aggregate piers were the two options considered feasible for the project since these two methods would generate little to no soil cuttings or groundwater at the ground surface requiring special handling and disposal to a regulated landfill. Controlled modulus columns were ultimately selected by the Owner and designed for vertical compression and uplift loading conditions for the building and for support of machine foundations and floor slabs. This resulted in significant cost savings to the owner and from an environmental perspective, saved precious landfill space. The vertical extent of the tips of the CMC elements was limited to the upper clays and did not penetrate into the underlying water-bearing rock formation. This was a priority of the project to protect the underlying water-bearing rock formation from being compromised environmentally.

Kavazanjian (2013) described the unique challenges for closure construction and post-closure redevelopment at the McColl Superfund site which contained 12 unlined pits containing refinery waste from World War II due the caustic nature, low bearing capacity, and high odor potential of the waste, the proximity of residences, and a mandate to restore portions of a golf course over several of the pits. Closure design included special testing to demonstrate the durability of materials that could potentially come in contact with the waste and to evaluate the potential for migration of waste through native subsurface materials, design of a lightweight geosynthetic cap on top of the waste, reconstruction using mechanically stabilized earth of a non-engineered waste-retaining embankments separating the waste, and construction of a slurry wall up a 3H: 1V (Horizontal to Vertical) slope. Remedy performance has been so satisfactory since closure that EPA has a reduction in the frequency of monitoring at the site.

Meegoda et al. (2013) described the Calgary Biocell that was constructed to acquire data and demonstrate the applicability of the Biocell concept under severe winter temperatures. MSW settlement, leachate recirculation and landfill gas generation of Biocell were monitored over five years. The Biocell is currently operating as an anaerobic bioreactor. It is expected to continue with the remainder of an anaerobic phase of Biocell and then to anaerobic and mining phases and the monitoring and data gathering will continue. In order the facilitate the last phase of Biocell, resource mining, a comprehensive mathematical model was developed by solving both mass balance and energy equations, and temperature dependent decay constants were used to compute the biodegradation of biomass. The numerical model developed can predict temperature and gas generation due to biodegradation by using more realistic decay constants and mass values. First order decay equation was assumed to model the biodegradation of waste. Conservation of mass as well as energy was maintained. MSW was divided into four groups with different decay constants. The heat generated was coupled with the decay constant through the Arrhenius equation. Implicit method of numerical solution was developed to solve the governing equations. The predicted thermal profile from the numerical simulation depicted a realistic temperature variation with time. Top layer temperatures were around 290K confirming numerical stability. At the bottom layers, a temperature increase of approximately 318K from 290K was observed within 1000 days.

Carpenter et al. (2013) investigated seismic surveys to characterize changes in dynamic properties (e.g., shear wave velocity and Poisson's ratio) of MSW to infer the extent of degradation and provide the input needed for seismic stability evaluation. To achieve this goal, a seismic survey was performed in a MSW landfill to image seismic velocity structure and the Poisson's ratio of MSW. Seismic data were collected through the cell using "fan shot" direct P- (compressional) and S- (shear) wave surveys. The fan shot surveys employed a sledgehammer source on one side of the landfill and geophones on the opposite side, thus exploiting the landfill's topography and geometry to image MSW to a depth of at least 10 m. P- and S- wave velocity tomographic models from these direct-wave (through-pile) raypaths indicated a dramatic velocity increase below 5 m depth, perhaps indicating consolidation and compaction of MSW. Shear-wave velocity ranged from 150 m/s to 170 m/s. The P/S ratio ranged from 1.8 to 3.7, with an average of about 2.7 and Poisson ratios ranged from 0.29 to 0.46, with an average value of 0.42 (standard deviation 0.024). Below 4-5 m depth, compressional-wave seismic refraction profiling also indicates a subtle change in velocity. Repeated electromagnetic (EM) conductivity measurements with maximum sensitivity at 10 m depth show conductivity increased in the MSW approximately 20-40 mS/m over a 14 month period. Conditions appear to be more uniform at depth as well, after this 14-month interval. Overall, this study showed that seismic and EM surveys have potential to monitor spatial and temporal variation of dynamic properties of MSW and infer the extent of degradation.

Case Studies on Soil and Groundwater Contamination

Kolev and Gevezova (2013) presented an interesting case study where deformation and subsidence of the road pavement and some facilities occurred at a plant for chemically contaminated water. Geophysical (such as geo-radar, electro-tomography) surveys were performed, shallow borings were drilled, and laboratory testing was conducted to evaluate the site conditions. A historical review of the construction and reconstruction and different aspects of topography and geological history of the area were studied. The site consists of swelling clay dust on layers of sand and silt. A dense network of pipes, cables and ducts also existed at the site. The cause of deformation and subsidence are attributed to multiple factors such as site geology, chemical aggression of water, electrostatic catalysis and corrosion of steel pipelines, suffusion, and others. Several caverns and unsealed areas were also found which are formed by collapses of flooring and threatening the sustainability of some of the equipment. The voids and unsealed areas are filled by injecting cementitious grout, and the ground under the foundations of endangered facilities was reinforced. With the remedial measures, the plant is in normal operation and there is no risk to the sustainability of buildings and facilities.

Falamaki et al. (2013) presented stabilization of a soil polluted with Pb and Cu using dicalcium phosphate (DCP). Leachate column tests were conducted to determine the effect of DCP concentration on the efficiency of the method. DCP with 0.1, 0.2 and 0.5 mg/kg dry soil were added to the polluted soil and the samples were kept for 1 month. Based on the breakthrough curves, DCP is found to stabilize heavy metals in the soil. Increasing the concentration of DCP, decreases the concentration of metals in the effluent, means more stabilized metals in the soils. The results also show that 0.2 mg/kg dry soil of DCP is enough to stabilize the metals from the first stages of the tests.

Yano et al (2013) described the problem and mechanism of arsenic contamination of groundwater at the worst contaminated areas at a site. The government tubewells (depth: 30m) are almost contaminated with arsenic and the private tubewsells (depth: 10m) are overall not affected with arsenic. The arsenic contaminated tubewells are under reduced condition and the non-arsenic tubewells are under the oxidized condition, meaning that arsenic is leached out into groundwater under reduced condition. Arsenic concentration has roughly linear correlation with those of iron and ammonia in the groundwater.

Case Studies on Stormwater

Harker and Mahar (2013) described the problem of nutrients release into waterways due to discharge of stormwater without any treatment. Nitrates from fertilizers and petroleum products enter local waterways and ultimately groundwater supplies. Porous concrete is used for stormwater filtering capabilities. The use of scoria (vesicular basalt) in porous concrete to retain petroleum contaminants is being investigated using a physical model consisting of a porous concrete slab made with coarse scoria aggregate over a scoria base. The model is being used to determine the capacity of the scoria to retain water/petroleum fluids. Microbial bacteria, similar to those used to clean oil spills, are also being introduced and studied. A scoria leach field was placed to discharge the collected water. Monitoring wells were placed below the slab and in the leach field to measure water levels. The slab was checked throughout the winter and will be monitored during the next year. To date the porous concrete has performed extremely well, and no additional pavement/curb damage has been observed in the vicinity. By employing scoria with porous concrete, precipitation runoffs from driving surfaces can be re-introduced to local aquifers with less pollution, preserving clean water for future generations.

Hussain (2013) described the problem of toxic and highly contaminated water from different drains devastating and impacting the natural lakes and agricultural lands in a region. The natural flow routes of the flood water have been interrupted at many places which have increased the impact and frequency of the floods in the area. The investigated area is very famous for the paddy and wheat production in the country, but its average production of both crops is reducing. Due to short fall rain, saline water is used, which affected the agricultural productivity immensely. The study demonstrates the need to find a solution to the problem and develop the agriculture in the region.

FINAL REMARKS AND TOPICS FOR DISCUSSION

The papers accepted for the sessions 6a deal with properties and behavior of problematic soils and various methods to improve the soils. Several case studies are presented on the performance of ground improvement methods on a wide range of geotechnical applications. The topics covered are broad and comprehensive and reflect the practices worldwide. Some of the topics suggested for discussion in session 6a could include:

1) Documentation of comprehensive case studies, including both technical and cost information
2) Incorporating sustainability in the evaluation and selection of ground improvement method
3) Forensic analysis of failed ground improvement systems
4) Durability of ground improvement systems
5) Design codes and guidance documents
6) Models and validation

The papers accepted for the session 6b are limited (9 papers), but address a wide range of topics dealing with landfills, soil and groundwater contamination, and stormwater issues. Some papers attribute the chemical effects on some of the geotechnical issues and others deal with geotechnical construction over the difficult geoenvironmental conditions such as wastes or contaminated ground. Some of the topics for discussion in session 6b could include:

1) Stabilization of landfills for post-closure development
2) Remediation of contaminated soils and groundwater
3) Brownfield redevelopment
4) Regulatory and policy issues
5) Sustainable practices
6) Education

LIST OF PAPERS

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