ABSTRACT

Environmental geotechnology is an interdisciplinary science which covers the behavior of soil and rock and their interaction with various environmental cycles including the atmosphere, biosphere, hydrosphere, lithosphere, as well as, geomicrobiosphere, which includes bacterial activities in the ground soil and subsequent response to the engineering behavior of soil/water system.

At present, design and construction of most geotechnical projects is based on test results following Indian standards (I.S.) specifications. These standards are set based on experiments/studies carried out with distilled water as the pore fluid. In addition, conditions tested are under short-term duration but are projected into long-term performance. Since field situations and standard control conditions are significantly different, premature or progressive failures frequently occur. To understand soil behavior under in-situ conditions, it is necessary to examine soil behavior as closely to the actual field conditions as possible.

Most foundation structures require friction or adhesive force between structural members and soil for earth pressure, pile and bearing capacity computation. Unfortunately, this force frequently changes due to ground water table fluctuation and pollution. Soil parameters commonly used in geotechnical engineering such as pore water pressure, cohesion, friction angle and coefficient of earth pressure vary due to zonation or micro-zonation environmental conditions. Therefore, using conventional soil mechanics concepts in difficult
reclaimed land must be carefully considered for a proper analysis and design of foundation structures.

Leachate is a hazardous liquid and is a major cause of concern in landfills. Numerous environmental problems such as soil and ground water contamination occur in unlined landfills due to free flow of leachate. Large quantities of leachate-contaminated soils have been found to occur in the study area. These dump yards receive large quantities of municipal solid waste which includes chemical and industrial as well as domestic wastes. Large areas of land are currently being used for this purpose. An extensive laboratory testing program was carried out to determine the properties of clean and contaminated cohesive soils. Laboratory prepared municipal solid waste leachate was used in this study. Contaminated samples were prepared by mixing the soils with MSW leachate in the increments of 0.1 N, 0.2N, 0.3N, 0.4N, 0.5N, 0.6N, 0.7N, 0.8N, 0.9N and 1.0N by weight to vary the degree of contamination. The results showed that the MSW leachate affects the Atterberg’s limits, shear strength and chemical characteristics of the cohesive soils.

The liquid limit and the plasticity index of the cohesive soils increases with MSW leachate concentration. For samples tested at the Proctor density effective cohesion increases and effective friction angle decreases due to increase in leachate concentration. This is attributed to the increase in clay content of cohesive soil after interaction with the leachate. This leads to increase in cohesion parameter and the friction angle decreases. The pH measurements of cohesive soil contaminated with MSW leachate indicated an increase in pH values. This is
also accompanied by slight increase in the cation exchange capacity of the soil. The change in chemical characteristics of cohesive soil contributed due to addition of leachate may be detrimental to foundation concrete in real field conditions. The present work deals with an attempt to study the effect of leachate on Atterberg’s limits, shear strength properties and chemical characteristics of cohesive soil.

This study indicates that the use of hydraulic conductivity information and the pollution hazard rating for a given landfill leachate are the preferred determinants for landfill design. Chloride, sodium and water soluble organic compounds (COD) were relatively undiluted by passage through the clay columns. Montmorillonite had the most dilution capacity, followed by illite and the kaolinite. The results suggest that pollution from landfill leachate would be reduced if landfill liners of earth materials are designed for higher hydraulic conductivity. The current geologically and environmentally unacceptable sites can thus be physically modified by correct design to eliminate costly long distance transportation of wastes from metropolitan areas (Wisconsin Administrative Code, Chapter NR 502, Department of Natural Resources, updated on April 2013).

Several catastrophic failures have occurred during the past three decades, both in engineered as well as non-engineered landfills. In addition, there are numerous instances of significant deformations although not failure in the sense of significant and rapid downslope mass movement, which may cause sufficient damage to buried gas and leachate collection infrastructure. One such instant was observed near the toe of a 75m high 4H:1V slope at the Brock West Landfill
Ontario, Canada (Long Term Waste Management Strategy Plan, Durham Region, June 1998). Significant distortion of gas collection laterals was observed to this site. The present research is an in-depth study intended to examine deformation in landfills based on a detailed study of the mechanical properties of MSW.

Three research objectives were defined based on identified shortcomings and knowledge gaps in the existing literature pertaining to mechanical properties of MSW viz;

a) To develop a method for obtaining intact samples of MSW and to examine the significance of using intact and recompacted samples in characterizing the stress-deformation behavior of MSW;

b) To characterize MSW shear strength and Young’s modulus of elasticity from interpretation of triaxial test results and to determine the parameters of a non-linear elastic constitutive model as applied to MSW, and,

c) To measure the evolution of compressibility behavior of MSW with degradation and the mechanism of secondary compression in waste.

A comprehensive research program was undertaken to address various research objectives—field monitoring of deformations at the Cremation Ground and Daily Market Place Landfills, Jorhat, Assam, triaxial compression tests on intact and recompacted samples of waste; simulating waste degradation in a laboratory compression cell; analyzing stress-strain data from various published studies and a numerical modeling study.
The stress-strain behavior of MSW is non-linear, that is, it exhibits a fairly rapid drop in stiffness as the stress state approaches failure which is typically assumed at 20% strain. A hyperbolic elastic model has been used for soils as it incorporates both the non-linearity of the stress-strain relationship and the stress dependency of stiffness. It is hypothesized that a hyperbolic elastic model may also be appropriate for describing the stress-strain response of MSW. This study presents the application of hyperbolic elastic model to landfilled MSW. The model parameters were determined using data from six published studies as well as the results from laboratory testing carried out in the present study on samples of MSW from two different landfills in Jorhat, Assam. Based on a statistical analysis of the testing results, three of the five parameters are replaced by constants with upper and lower bounds for a desired degree of confidence. It is proposed that the resulting hyperbolic curves may be used to predict the stress-strain behavior of MSW up to 20% strain. A method for characterising modulus of elasticity of MSW from interpretation of triaxial test results is also described. The work presented in this study addresses in part, the second objective: to characterize Young’s modulus of elasticity of MSW from interpretation of triaxial test results and determine the parameters of a non-linear constitutive model as MSW.

Interpretation of the effective stress paths followed during shearing during triaxial compression tests suggested that recompacted samples may be sufficient to characterize shear strength parameters, there might be a benefit in obtaining intact samples to evaluate the deformation characteristics of MSW. The required
parameters for this model were determined from evaluation of the results of numerous triaxial tests, both from this study and from the published literature.

Observations from the long-term degradation test suggested that degradation has a significant effect on compressibility of waste and further verifies the mechanism of secondary compression in waste. The coefficient of at-rest lateral pressure was observed to maintain an essentially constant value during combined compression and degradation.

This study presents the results of a laboratory test of MSW subjected to accelerated degradation and one-dimensional compression. Incremental vertical stresses were applied to simulate staged construction of a landfill. Degradation was quantified by methane yield, leachate quality and loss of volatile solids. Lateral and vertical stress, pore pressure and vertical settlement were continuously monitored during the 150 days duration of the experiment. Data were collected regarding the evolution of the at-rest earth pressure, the compressibility and the constrained modulus. The results show a significant influence of degradation of compressibility parameters ($C_{ce}$ and $C_{ae}$). The $K_o$ value did not change significantly during degradation and it is proposed that it might be considered a constant regardless of applied stresses or age. The mechanism of compression and development of lateral stresses with time are also discussed.

This thesis consists of six chapters. The introductory chapter (Chapter-1) begins with brief review of earlier work, statement and objectives of problem, scope of the present work, organization of thesis is explained.
Chapter 1, aims at giving a brief rationale behind the importance of strength and deformation behavior of reclaimed land MSW dumping landfill sites. The different procedures adopted towards evaluation are also summarized in this chapter. However the procedures adopted in different phases of work are elaborately summarized in the respective chapters as organization of thesis, sampling procedure and methodology along with results and critical comments.

Chapter 2 provides the content of this research work. The results of Atterberg’s limit, hydraulic conductivity using the leachate contaminated soils are compared with the published works.

Shear strength characteristics of MSW are summarized in Chapter 3. A method for obtaining intact as well as recompacted sample of waste from the landfill is also carried out. Shear strength parameters of MSW obtained from triaxial and direct shear tests are compared with those available in the literature.

Engineering properties of MSW are attempted to evaluate stress deformation behavior of MSW and are presented in the Chapter 4. This chapter is presented to propose a non-linear elastic constitutive model for pre-failure stress deformation behavior for MSW and providing a method for estimating Young’s modulus. Required parameters of this model are evaluated from results of numerous triaxial tests.

Compressibility behaviour of MSW during degradation and the one dimensional compression mechanism of secondary compression and its effect on degradation is summarized in Chapter 5. The mechanism of compression and
development of lateral stresses with time are discussed. The differential settlements in landfills are also summarized in this chapter.

The Chapter 6 is the final chapter and is entitled CONCLUSION AND SCOPE FOR FUTURE RESEARCH. It brings out a summary of the chapters 1 to 5. Conclusions are drawn along with the summary of the strength deformation behavior of reclaimed land for municipal dumping site. The results are discussed in light of existing literature and an attempt has been made to evaluate the strength parameter of MSW and its significance.

The literature surveyed and used for present work is alphabetically arranged and presented in Chapter 1 through Chapter 5 (Chapter 1 to 5) as reference. It reflects the quantum of work done by different workers and will form a standard reference for any similar work in future.