International Journal of Academic Research and Development
ISSN: 2455-4197
Impact Factor: RJIF 5.22
www.academicsjournal.com
Volume 2; Issue 6; November 2017; Page No. 396-402

Effect of waste disposal in soil produce by society

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Abstract
The solid waste of closed dump site contains various complex characteristics. Different wastes have different decomposition rates, different compact potential and different settlement rates. Differential waste settlement is a major geotechnical problem characteristic of all waste dumps. Buildings and other structures constructed on dump site have large settlements causing damage. The settlement of solid waste is ongoing process and variation in characteristics is attributed to a combination of factors including dump fill age, waste nature, moisture availability, depth of fills and compaction. In past the places for waste deposition in Lucknow were chosen based on convenience and existing characteristics such as low lying areas or just nearby open space in most haphazard and uncontrolled manner. The seven closed dump sites covering the various areas of Lucknow city under this study that characterize the geotechnical properties of dump site are no exceptions. The samples were collected from seven trial pits at depths of 1m; 1.5m and 2m for each selected dump site were used for investigation. The soil samples collected were subjected to specific gravity, natural moisture content, particle size analysis, consistency limits, compaction, permeability and direct shear tests. The results obtained were compared with the control samples taken from the adjoining area of selected dump site. The study recommends the solution to minimize the problem of waste settlement and design of the foundations of structures/civil works on this type of ground.
Urbanization is the physical growth of urban areas as a result of global change. The facilities like education, healthcare system, employment avenues, civic facilities and social welfare are reasons attracting people to urban areas. As the land cost is increasing tremendously and decreasing availability of good construction site is building up pressure on the engineers to utilize even the poorest site either by providing special type of foundation or by improving ground in urban centers. In this context literature is reviewed for use of landfill site for housing. The site exploration for old dump site was carried out to assess subsoil characteristics. The objective was to evolve strategy for economical feasible ground improvement technique to obtain permissible bearing capacity of 150 kPa and settlement not more than 50 mm. The exploration of site was done by DCPT to find the bearing capacity. The site can be used for construction of low rise housing for rehabilitation of displaced persons under TP scheme within city area utilizing old landfill sites.
The impact of leachate from decomposed solid waste at an open dumpsite on the vicinity soil shear strength and California bearing ratio (CBR) and suitability of such site for construction purpose. Soil samples were taken from three sections of an old solid waste dumpsite operated by the University of Ibadan, Ibadan for laboratory study. The properties determined were particle size, Atterberg limits, compaction test, and CBR and shear strength for two seasons. The CBR and cohesion c' at the core areas of dumpsite were found to be higher than those of surrounding soils that were a little far from dump areas. This shows that buildings and roads can be erected upon unused dumpsite; the soil is structurally safe.

Keywords: atterberg limits, compaction, California bearing ratio (CBR), leachate

Introduction

General

Solid waste openly dumped on land in uncontrolled and unmanaged manner generate leachate and landfill gas that pollute the environment and represent a breeding ground for disease bearing animals and microorganisms. Public health and safety issues are also of great concern due to dumping of municipal solid waste in vacant spaces lying within the city. When water passes through the waste in dump site leachate i.e. liquid formed is generated. Dump site leachate have a complex cocktail of chemicals and have detrimental negative impact on ground water quality. Leachate have stronger chemical and microbiological characteristics than sewage. The variation in chemical and microbiological characteristics is attributed to combination of factors including waste nature, moisture availability, and depth of fills.

Gas is one of the products generated as a consequence of the biological degradation of the organic fraction of the waste placed in the landfill. Since there is sufficient oxygen contained in the air entrapped in the waste during the initial period of waste deposition, hence initial phase of biodegradation is primarily aerobic. Within a very short time from initial deposition, the oxygen originally trapped in the wastes is consumed and biodegradation process becomes anaerobic. The identification of this stage is marked by the production of methane and carbon dioxide as well as a variety of trace amounts of reduced carbon and sulphur compounds. The dump site gas mainly contains methane, carbon dioxide

and a lesser extent hydrogen sulphide, hydrogen and nitrogen. The presence of oxygen trapped in the fill at the time of deposition of waste influence the oxidation reaction. Oxidation reaction also consists of the form of chemical reaction that are due to the presence of organic acids and carbon dioxide synthesized in the biological processes and dissolved in water. These produced gases either migrate laterally through the soil around the fill until they reach areas from where they cannot escape, hence accumulated. If the concentration of the accumulated gas is low, they pose a nuisance only but when the concentration reaches a critical point, explosive level of methane is reached. At higher concentration the methane simply burns. There are many factors that affect the amount and rate of leachate generation and gas production in a solid waste disposal site e. g. waste composition (i.e. concentration of carbon, nutrients. inhibitors), degree of pre-treatment (size reduction, recycling, composting, baling), type and degree of compaction, method of operation of dump site, type and thickness of cover material, quantity of refuse, geometry, hydro geologic properties of the land, climatic condition(temperature, precipitation, evaporation, insulation and above all moisture content and water flowing through the deposited waste. Accumulated gases and uncontrolled dispersion and migration of gases can lead to the development of undesirable conditions due to flammability asphyxiating properties and trace organic composition of the gases. The major environmental health hazards due to dumpsite gas are flammability, suffocation, toxicity (like poison or pertaining to poison) and odor. The flammability is due to the presence of methane, which is explosive when mixed with air at certain ratios. Suffocation and toxicity can occur due to minimal amount of oxygen in the gas. The dump site gas also has an adverse effect on the vegetation of the surrounding area. The gas also gives off a strong unpleasant odor. Environmental public health and waste settlements are the two major problems that are associated with social and technical challenges for the redevelopment or construction of building on dump site. The negative impacts on the public health and on the environment (e.g. odours, contaminated water supplies, ground water and soil pollution) are the characteristic features of all dump sites. However meeting all specific aspects may be technologically and economically impractical. Solid waste dump site when subjected to wetting results biological decomposition which ultimately results in volume reduction. Settlements due to volume reduction create cracks in the building or structures constructed on it since settlement can occur within a few days of filling or can extend over many years. Of three physical, chemical and biological processes, the biological processes are the most significant. However the biological processes are strongly influenced by physical and chemical processes. The various forms of physical reactions in the fill are compression or compaction, dissolution and adsorption and absorption. Compaction is an on-going phenomenon that begins with compression and size reduction of particles by the compacting machinery and continues after the wastes are placed due to the weight of waste and that of the soil cover (binding).Shifting of soils and other fines is responsible for some consolidation. Settling of compacted fill is an end result of compression. Water acts as a medium for the dissolution of soluble substances and for transport of unreacted materials. The un-reacted materials contain animate and un-animate particulates. Particle size ranges from colloidal to several millimeters in cross-section. The different variety of component and particle sizes of the wastes provides conditions that lead to an extensive amount of adsorption, which is the adhesion of molecules to a surface.

Absorption is significant in large parts because it immobilizes dissolved particulates by immobilizing water that could transport them and suspend pollutant particulates out of the confines of the fill. Absorption is the process whereby substances are taken in by capillarity. Cellulosic content of municipal waste is responsible for the most of the absorption potential of land. Estimation of waste settlement is very complex since the settlement influences by a number of uncontrolled factors such as composition of solid waste, moisture content of solid waste, precipitation, type of structure constructed on it and above all settlement continues over an extended period of time with a final settlement that can be as large as forty percent of the initial fill height. The potential uses of dump sites in the past were limited to the natural or Recreation Park, animal refuge, parking lot, golf courses, tennis court, commercial and industrial buildings. The construction of buildings on dump sites were not common due to high differential movement in the buildings resulting foundation cracks, heaving and cracking of floor slabs and side walls, jamming of doors and windows, ruptured pipe lines and roads. With the increase of population, larger number of dump site being closed, dump near urban areas and at major transportation routes resulted building foundation development on dump site more common instead of extreme difficulty due to waste differential movement and time consuming settlement process. The central aim of this paper is the geotechnical properties based characterization of dump site in Lucknow city, capital of Uttar Pradesh. Foundation engineers must be able to identify the geotechnical properties of the dump site for the use of dump site for the foundation as a soil and when they are encountered in the field. Although all the problems cannot be solved, preventive measures can be taken to reduce the possibility of damage to structures built on them.

As the land cost is increasing tremendously and decreasing availability of good construction site is building up pressure on the engineers to utilize even the poorest site either by providing special type of foundation or by improving ground. The weak subsoil deposits pose the problems of low bearing capacity and excessive settlement over long period of time. This may be overcome by the recently developed method of ground improvement. It can be effectively utilized to force the soil to behave according to the project requirement rather than having to change the project to meet the limitation due to weak ground. Solid waste disposal in landfills is the most economical form of disposal of waste particularly in the developing country. As the old and closed landfills are having the limited end use in terms of recreational uses like gardens and golf courses, it is now the demand of time to gain some return from the old landfills like infrastructure, commercial and low income residential development. Cost of land in Luknow city has reached to sky. To satisfy need of land Luknow city limits has been expanded and more area is

included by Luknow Municipal Corporation (LMC). LMC is planning to make the city zero slum in forth coming years. For that, slum rehabilitation policy is prepared by LMC (LMC Report, 2008). So for this purpose a large area is required within city limit. If landfill area can be used for the purpose it may be the economical solution. In this context literature is reviewed for use of landfill site for housing. The site exploration for old dump site was carried out to assess subsoil characteristics. The objective was to evolve strategy for economical feasible ground improvement technique to obtain permissible bearing capacity of 150 kPa and settlement not more than 50 mm. The exploration of site was done by DCPT to find the bearing capacity.

Need for the present study

A refuse or solid waste dumpsite is an open land mass where solid wastes are allowed to decompose, burned and probably treated. A large number of adverse impacts occurred from waste disposal operations. These impacts varied from fatal accidents, infrastructural damage, pollution of local environment such as contamination of groundwater and or aquifers by leakage and residual soil contamination during landfill usage as well as after its closure.

The previously used sites are now being used to provide basic infrastructures such as buildings, roads etc. to meet the demand arising from the increasing population. Recently, the three tiers of Government (Federal, State and Local) are making reforms about bringing into use the existing or old dumpsites into productive use while safeguarding the environment, public health and safety. It is important to check if solid wastes will not affect soil geotechnical properties before erecting structures on old dumpsites. The previously used waste disposal sites are vacant with potential for redevelopment. They might have been contaminated and hence there is need to ascertain to what extend the level of contamination would have on soil strength and ability to resist axle loads from vehicles before structures are erected on them. While many researchers have worked on the characterization and management of Municipal Solid Waste in Nigeria and their effect on groundwater, little attention has been given to the effect of these wastes on the geotechnical properties of soils. The study focused on impact of leachate from decomposed solid wastes at dumpsite on soil geotechnical properties.

Objectives of the study

The study on use of waste materials from construction industries in form of recycled crushed material/aggregates in pavement construction consists of conducting laboratory investigations on soil sample prepared by using waste material from construction industries to estimate its suitability for pavement construction. The main objectives of study are:

1. To determine the load bearing capacity of the samples.
2. To determine the shear strength of the samples.
3. Development of useful product from recounted material

Experimental test program

A laboratory test program was undertaken to evaluate the engineering properties of MSW as a function of compaction conditions. The objectives of the test program were to establish the baseline compaction behavior for MSW (variation of dry unit weight with molding moisture content) and the geotechnical parameters associated with that baseline behavior. To ensure that the results were comparable, the test material was generated from the same stock of components mixed in the same ratios. Experimental procedures consisted of the determination of compression characteristics, hydraulic conductivity, and shear strength trends as a function of placement parameters such as molding moisture content and dry unit weight. By holding variables other than the placement conditions constant, it was possible to discern trends in the behavior of the MMSW and attempt to correlate the trends to established principles of soil and waste mechanics.

This chapter details the test program beginning with the description and classification of the test material. Documentation of the compaction testing follows. A brief discussion of the sample preparation methods used for the remainder of the test program is next. Development and description of test instrumentation and apparatuses along with test procedures for constant bearing capacity of soil and shear strength testing completes the chapter.

Results & Discussion

Introduction

Results from the experimental test program are presented in this chapter. The weight-volume relationships for the MMSW test material were established using published and experimentally determined values for specific gravity of individual waste components. Results of the baseline compaction tests are presented. Following, results from compressibility, hydraulic conductivity, and shear strength tests are provided. Test results are discussed within the framework of existing soil and waste mechanics analyses and theories. Finally, the engineering significance of this investigation is presented.

Shear strength test results

Shear strength data were analyzed to determine internal angle of friction from a single test assuming the waste did not have cohesive strength. This section includes analysis of internal angle of friction followed by an analysis of the shear stress-shear strain curves. A discussion of the sample dilation and contraction characteristics concludes the section.

Shear strength data from 5 tests were analyzed with the assumption that the MMSW was a cohesionless material within the range of strains to be tested. Based on that assumption, it was possible to approximate a linear failure envelope from a single direct shear test at each moisture content-dry unit weight combination.

Liquid was expelled during testing of the 85% and 110% moisture content samples and although captured, was not quantified. During sample unloading, it was noticed that the standing liquid that had drained from the shear box was tan/brown in color, turbid, malodorous, and developed a surfacial film.

The friction angle was calculated using the peak value of shear stress and the corresponding normal stress recorded during the test. Shear stresses were corrected for the change in area that occurred during testing. Friction angles varied between 30.4° and 39.7°. The highest friction angle was measured from the 11% moisture content sample and

decreased with increasing moisture content. The calculated internal angle of friction decreased despite increasing dry unit weight as optimum water content was approached from the dry side of optimum.

Tables and Figures

Table 1: Results of direct shear testing

Water content (%)	γd (kN/m^3)	φ (degrees)	Maximum shear stress (kPa)	Corresponding ε (%)
11	4.3	39.7	165.8	14.6
30	5.4	35.9	145.6	14.6
56	5.9	33.9	134.5	14.7
85	5.5	32.5	127.7	14.8
110	4.9	30.4	118.7	14.8

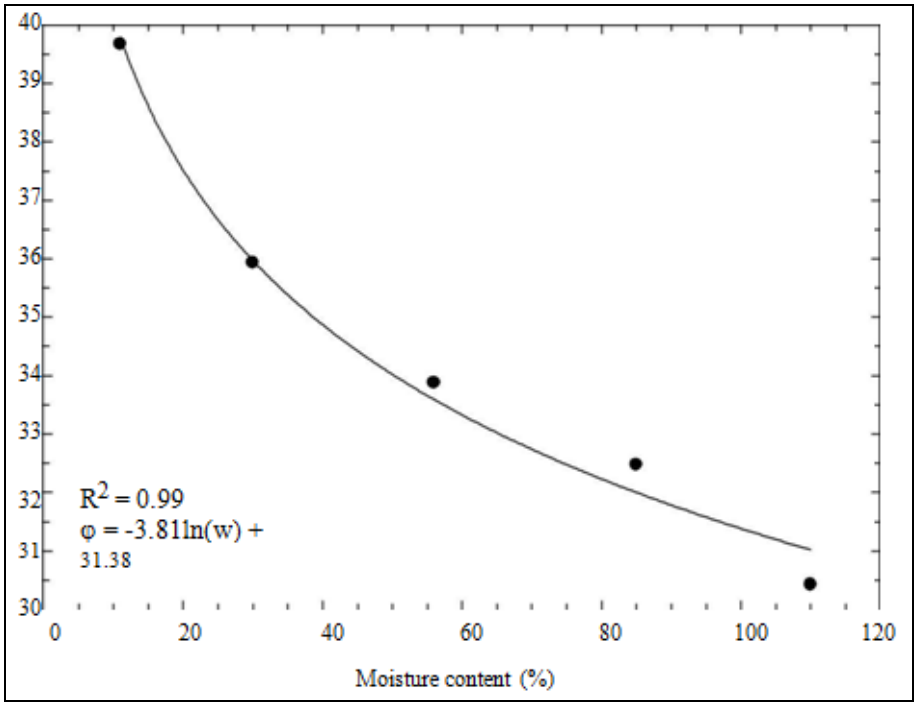

Fig 1: Internal angle of friction as a function of moisture content

The shear stress of each sample was plotted as a function of the shear strain (Figures). The plots were generated based on individual data values and were not based on a data fit. All shear stress-strain curves demonstrated a similar trend of yielding with increased shear stress. The sample at maximum dry unit weight (56% moisture content) developed the highest shear modulus at low shear strains, visible in Figure. At shear strains equal to or greater than 5%, the behavior of the 56% moisture content waste sample appeared to be controlled by the effects of the increased moisture content. The shear stress-strain curve of the 56% moisture content sample flattened out significantly at higher levels of shear strain, crossing through the 11% and 30% moisture content sample curves. This may be attributed to lubrication and breakdown of the waste particles with increasing moisture content and shear strain, despite the increase in dry unit weight.

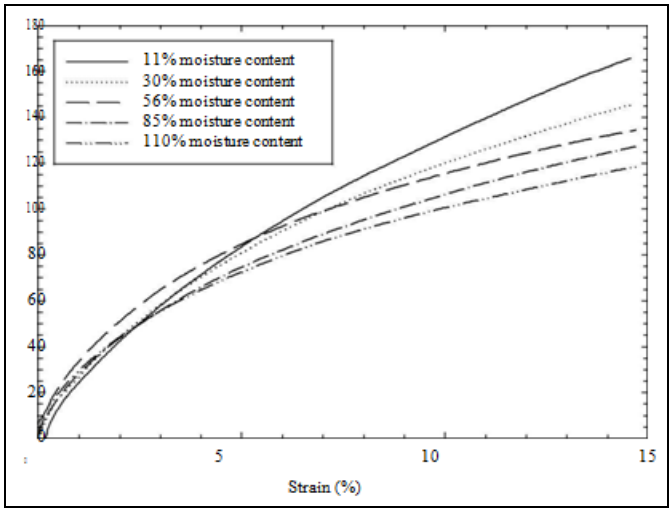

Fig 2: Shear strength as a function of strain

At 1% shear strain the shear modulus of elasticity varied between approximately 2,300 kPa 110% moisture content) and 3,100 kPa, with the peak value at 56% moisture content. At 14.5% strain the shear modulus of elasticity ranged from approximately 700 kPa (110%) to 1,100 kPa (11%), with the 56% moisture content sample in the middle of the range at 840 kPa. The shear modulus was not calculated at exactly 15% strain due to discrepancies in the starting strain reading that resulted in differences in termination strain magnitudes.

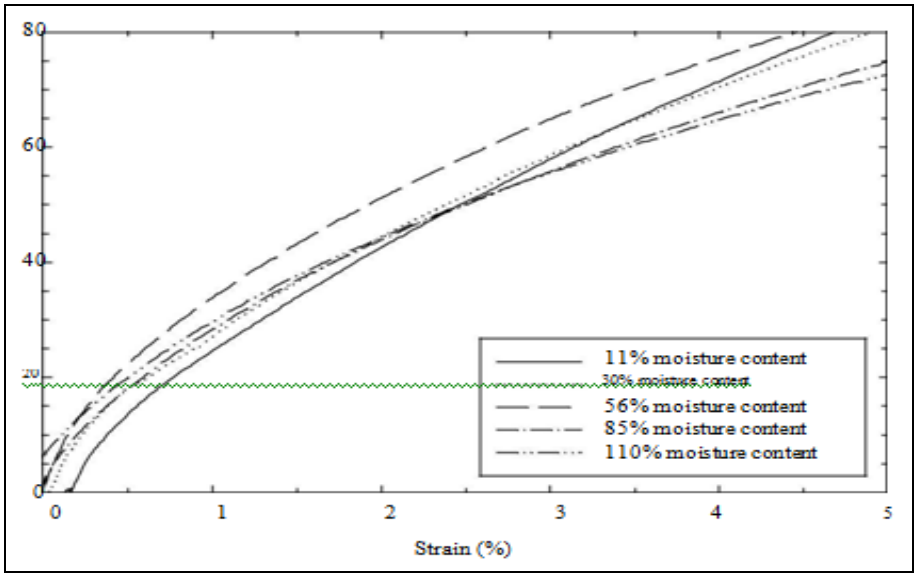

Fig 3: Shear strength as a function of strain enlarged to show detail at low strains

A similar trend was visible for the shear stress curves of the 85% and 110% moisture content samples. The 85% and 110% moisture content curves crossed the 11% moisture content curve at approximately the same strain, indicating that at some minimum moisture content wet of optimum, shear strength is heavily controlled by moisture content. The relatively lower slopes of the 85% and 110% moisture content samples indicates that increases in moisture content wet of optimum resulted in moisture content controlled shear strength behavior at low strains. At high shear strains, the behavior of all the samples was controlled by the molding moisture content.

Table 2: Change in φ based on moisture content

Moisture content range	Change in φ for change in w (degrees/percent)
11% to 30%	-0.197
30% to 56%	-0.079
56% to 85%	-0.048
85% to 110%	-0.082
11% to 56%	-0.129
56% to 110%	-0.064
11% to 110%	-0.094

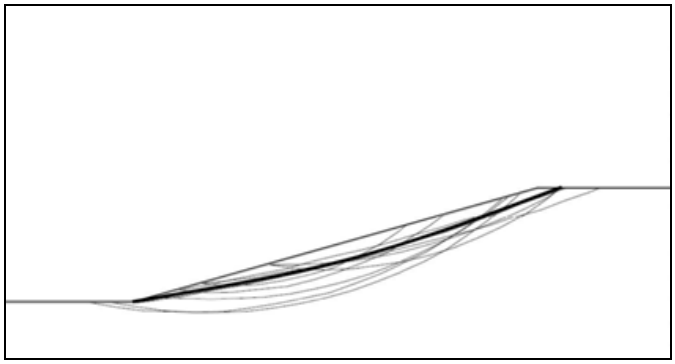

Fig 4: Trial waste slope at 56% moisture content with critical failure surfaces

As land has become scarcer, it has become necessary to vertically expand landfills and re-use landfills after closure for other purposes. Understanding the trends in geotechnical properties of waste based on placement will lead to maximization of reuse options and increased protection of human safety and the environment. Accurate control of waste placement conditions will allow landfill operators, engineers, and planners to effectively control geotechnical properties during operation and post closure. More specifically, understanding and control of placement moisture content in the compaction of wastes will have both immediate and long term effects on the dry unit weight, settlement, leachate recirculation properties, and slope stability.

Increasing the placement moisture content of waste to the optimum moisture content will increase dry unit weight, decrease settlement, decrease leachate infiltration rates, and slightly decrease the factor of safety of waste slopes. Depending on other factors such as landfill life span, waste slope steepness, and financial aspects, the addition of water to waste prior to compaction may be a viable alternative to the operation of conventional bioreactor style landfills.

Equations

They should be numbered consecutively throughout the text. Equation numbers should be enclosed in parentheses and flushed right. Equations should be referred to as Eq. (X) in the text where X is the equation number. In multiple-line equations, the number should be given on the last line.

$$y_i(N) = \sum_{n=0}^{m-1} w_n(N) b_n(N)$$

$$= \sum_{n=0}^{m-1} \overline{b_n^*(N) r_i(N)} \cdot b_n(N) \quad (1)$$

8. Summary, Conclusions, and Recommendations

The test program highlighted the importance of waste placement conditions on the geotechnical properties of waste. Controlling the placement moisture content of the waste had a significant influence on the bearing capacity and shear strength.

A representative, consistent, manufactured MSW was used for the test program. Tests were performed in large scale testing devices and included compaction, constant rate of strain compression, the bearing capacity and shear strength.

Large scale direct shear tests were performed in a 300 mm shear box. Tests ranged in duration from 14 to 15 hours. A single test was performed at each moisture content-dry unit weight combination. Tests were conducted at 200 kPa normal stress and sheared to 15% strain. The analysis of the strength data was based on an assumption of zero cohesion. Based on the data obtained from shear strength testing, the following conclusions were drawn:

1. Initial shear stress-strain behavior was controlled by dry unit weight.
2. Shear strength at high shear strains was controlled by placement moisture content.
3. Internal angles of friction varied between 30.4° and 39.7° from dry (11% moisture content) to wet (110% moisture content) and had the largest decrease in friction angle perincrease in moisture content between 11% and 30%.
4. The samples continued to gain strength with increased shearing due to increased component interlocking and had not reached peak values at test termination.
5. Internal angle of friction decreased monotonically with increasing moisture content.
6. Increasing moisture content (in combination with high shear strains) resulted in particle softening, breakdown of susceptible particles, and slippage between component contacts along the shear plane.
7. Waste samples exhibited volume change behavior similar to soils.

Overall, the results of the tests indicate that the MMSW test material used in this test program was strongly influenced by placement conditions. Molding moisture content had the effect ofsoftening the waste material and lubricating particle contacts in tests where compression or shearing was involved (compaction, compressibility, direct shear). Numerous similarities were found between waste behavior and soil behavior when analyzed as a function of placement conditions including: a bell shaped compaction curve, bell shaped stiffness/moduli of elasticity curves with a peak near optimum moisture content, convergence of stiffness and modulus values wet of optimum, minimized hydraulic conductivity wet of optimum, and decreasing shear strength with increasing moisture content. As well, existing soil data and data gathered in this test program highlighted the importance of material fabric and structure on all geotechnical parameters, and the importance of moisture content in controlling geotechnical parameters.

The values for the varying geotechnical parameters were used to perform a basic study of effects on numerous landfill processes. Increased compaction moisture content would allow for a higher waste density and increased landfill capacity and financial profits while affecting other geotechnical engineering properties. Settlements varied by a factor of 4 based on the varying apparent compression indices, void ratios, and moist unit weights. Increasing placement moisture content would result in more even distribution of moisture throughout the waste as well as increased homogeneity of the waste packing structure despite decreasing hydraulic conductivity. Changes in vertical hydraulic conductivity did not change leachate trench spacing although the changes strongly affected leachate trench infiltration rates and drainage times. The factor of safety of a trial landfill slope decreased 0.49 when moist unit weight and internal angle of friction were varied according to the values as determined in this test program (from 11% moisture content to 56% moisture content values).

Bearing capacity increases with the increase in size of model footing(square footing)on sand. The value of ultimate bearing capacity obtained from performing load test on model footings and that obtained from terzaghi's analysis were found to vary slightly. the value obtained by load test on footing was more than that obtained by terzaghi's analysis. It is possible to perform plate load test on model footings on a particular type of soil and these can be incorporated to the field by considering suitable criteria and foundation for the particular system can be laid

References

1. Alger MS. Polymer Science Dictionary. Elsevier Science Publishers Co Inc., New York, New York. 1989.
2. Al-Thani A, Beaven R, White J. Modelling Flow to Leachate Wells in Landfills, Waste Management. 2003; 24(3):271-276.
3. ASTM. D 698 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, ASTM International, West Conshohocken, PA. 2007a. DOI: 10.1520/D0698-07E01.
4. ASTM. D 1557 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified

Effort, ASTM International, West Conshohocken, PA. 2007b, DOI: 10.1520/D1557-07.
5. Beaven R, Powrie W. Determination of the Hydrogeological and Geotechnical Properties of Refuse in Relation to Sustainable Landfilling, Proceedings of the Nineteenth International Madison Waste Conference: Municipal and Industrial Waste, University of Wisconsin, Madison, Madison, WI. 2012, 435-453.
6. Benson C, Daniel D. Influence of Clods on Hydraulic Conductivity of Compacted Clay, Journal of Geotechnical Engineering, ASCE. 2012; 116(8):1231-1248.
7. Bjarngard A, Edgers L. Settlement of Municipal Solid Waste Landfills, 2012.
8. Proceedings of the Thirteenth Annual Madison Waste Conference, University of Wisconsin, Madision, Madison, WI., 192-205.
9. Bleiker D, Farquhar G, McBean E. Landfill Settlement and the Impact on Site Capacity and Refuse Hydraulic Conductivity, Waste Management and Research. 2012; 13(6):533-554.
10. Boutwell G, Fiore V. Settlement of Clay Cover on Saturated Garbage, 2012.
11. Proceedings of the Specialty Conference on Geotechnical Practice in Waste Disposal. Part 1 (of 2), ASCE, New Orleans, LA., 964-979.
12. Bowles JE. Foundation Analysis and Design - Third Edition, Mcgraw-Hill Book Company, Singapore. 1997.
13. Brandrup J, Immergut H. Polymer Handbook - Third Edition. Interscience, John-Wiley and Sons, New York, New York. 1989.
14. Bray JD, Zekkos D, Kavazanjian E, Athanasopoulos GA, Riemer MF. Shear Strength of Municipal Solid Waste, Journal of Geotechnical and Geoenvironmental Engineering. 2012; 136(6):709-722.
15. Caicedo B, Yamin L, Giraldo E, Coronado O. Geomechanical Properties of Municipal Solid Waste in Dona Juana Sanitary Landfill, Proceedings of the4th International Conference on Environmental Geotechnics: Environmental Geotechnics. De Mell and Almeida. 2012.
16. Capelo J, DeCastro M. Measuring Transient Water Flow in Unsaturated Municipal Solid Waste - A New Experimental Approach, Waste Management. 2007; 27(6):811-819.
17. Carman P. Flow of Gases through Porous Media, Butterworths Scientific Publications, London, United Kingdom. 1956.
18. Chen T, Chynoweth D. Hydraulic Conductivity of Compacted Municipal Solid Waste, Bioresources Technology. 2012; 51:205-212.
19. City of San Diego Environmental Services Department. (2012). Pricing and Pick Up Instructions. Last accessed: 22 June 2012, from http://www.sandiego.gov/environmental-services/miramar/cmw.shtml
20. Coduto D. Geotechnical Engineering: Principles and Practices, Prentice Hall Inc, Upper Saddle River, NJ. 1999.
21. Coduto D, Huitric R. Monitoring Landfill Movements Using Precise Instruments, Geotechnics of Waste Fills - Theory and Practice, ASTM STP. 2012; 1070:358-370.
22. Cokca E, Erol O, Armangil F. Effects of Compaction Moisture Content on the Shear Strength of an Unsaturated Clay, Geotechnical and Geological Engineering. 2010; 22(2):285-297.
23. Cotton Inc. US Cotton Fiber Chart. Last accessed: 4 December 2008, from Cotton, Inc., 2008. from, http://www.cottoninc.com/CottonFiberChart
24. Cowland J, Tang K, Gabay J. Density and Strength Properties of Hong Kong Refuse, Proceedings Sardinia '93, 4th International Landfill Symposium, Eds. T.H. Christensen, R. Cossu and R. Stegmann, CISA, S. Margherita di Pula, Cagliari, Italy, 1993; 1433-1446.
25. Das B. Principles of Geotechnical Engineering - 4th Edition, PSW Publishing Co., Boston, MA, 1997.