

Geotechnical Properties Based Characterization of Closed Dumpsite: A Case Study of Lucknow City of Uttar Pradesh

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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.

KEYWORDS: Closed dump site, compact potential, geotechnical properties, consistency limits, compaction.

I. INTRODUCTION

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

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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 un-reacted materials. The un-reacted materials contain animate and un-animate particulates. Particle size ranges from colloidal to several millimetres 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.

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II. METHODOLOGY

2.1. Measured Characteristics: Some major geotechnical properties of closed dump site wastes in Lucknow city were used to measure the characteristics of the waste. The geotechnical properties determined include specific gravity, moisture content, finer particles percentage, liquid limit, plastic limit, plasticity index, maximum dry density, cohesion, angle of internal friction & permeability. In addition to it some physical parameters observed or determined include appearance, odour, colour etc.

2.2. Collection of Samples: Seven representative closed dump sites were selected in different areas of Lucknow city. The dump sites cut across the various types of wastes in the study area ranging from agricultural, institutional, residential, industrial, commercial nature/type of wastes/areas. Dump site location ranging from 12Kms to 24Kms from Charbaag in different directions having different age groups from 8 years to 22 years were selected. The depth and approximate area range of dump sites were 8m-20m and 30-160 thousand square meters. Sample collection and test performance were carried out in month of December and January nearly after two months closing of the rainy season so that the measured parameters are not influenced by the rain water and may show the stable and true picture. However since the worst condition of the shear strength of the soil is in moist stage the direct shear test was carried out in wet condition.

Table-1 Selected dumpsites studied in Lucknow, U.P.

S.N.	Location of dumpsites	Distances from Charbaag	Age & depth of dumpsites	Approx. area in thousand sq. m.	Types of wastes/Area
1	Near Maniyao gao, Jankipuram	20 Km	16years,20m	160	Agricultural, Institutional
2	Near Race Course, Bahadur Shah Marg, Lko Cantt,	15Km	10years,18m	65	Residential, Industrial
3	Near Bhatamau, Alamganj, Budheshwar Chauraha	22Km	15years,14m	38	Residential, Commercial
4	Near Sainik School Sarojini Nagar	24Km	12years,15m	30	Agricultural, Commercial
5	Near Moti Jheel , Aishbaag	12Km	22years,12m	45	Mixed (Not Distinguishable)
6	Near Naval Kishor Road, Hazaratganj, Gandhisetu	14Km	8years,8m	40	Residential, Commercial
7	Near Bhattha Maidan,Rajni Khand, Sharada nagar	22Km	20years,10m	55	Agricultural, Industrial

The Table-1 represents details of dump sites showing their locations, distances from Charbaag , age and depth of dump sites, approximate area and type of dump-site.

2.3. Laboratory Investigation: Soil samples taken from seven trial pits of each dump site at depths 1m, 1.5m and 2m were used for the investigation. Two of the trial pits were located around each studied dump site to serve as control points, while the five trial pits were located within the dump site to serve as soil solid waste. The soil/solid waste samples used for this study were collected in and around the selected dump sites. Enquiries from residents around the dump site put the ages of the dump site selected as shown in table1and put the information tha dump ssite odor and colour comes to a tolerable standard 5 years after the closing of the dump site. In order for the control the control trial pits to be relatively free from leachate of the de-composting solid waste, they were carefully located so as not to along the direction of the horizontal flow of the leachate. Both disturbed and undisturbed five soil samples at three depths from the trial pits in centre and four corners of dump site in low lying areas and two samples at the three depths from the surrounding area within half km outside the dump area for each dump site were collected. The tests conducted on disturbed samples include natural moisture content test, specific gravity test, sieve analysis, consistency limit test and compaction test. While on the undisturbed samples permeability and direct shear tests were performed.

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III. RESULTS AND DISCUSSIONS

The mean value of parameters of all the seven selected dump sites in Lucknow city are presented in Table-2 below-

Table-2 Geotechnical Properties of dumpsites studied in Lucknow, U.P.

Parameter	Near Maniyao gao, Janki puram	Near Race Course, Bahadur Shah Marg, Lko Cantt,	Near Bhatamau, Alamganj, Budheshwar Chauraha	Near Sainik School Sarojini Nagar	Near Moti Jheel, Aish baag	Near Naval Kishor Road, Hazaratganj, Gandhisetu	Near Bhattha Maidan, Rajni Khand, Sharada nagar
Natural Moisture Content	17.10	16.70	14.00	16.10	15.20	15.80	15.00
Specific Gravity	02.26	02.22	02.28	02.20	02.18	02.24	02.28
Percentage Finer	87.00	92.00	58.00	54.00	68.00	60.00	62.00
Liquid Limit	26.00	26.00	22.00	29.00	28.00	27.00	26.00
Plastic Limit	12.00	16.00	12.00	11.00	13.00	11.00	16.00
Plasticity Index	14.00	10.00	10.00	18.00	15.00	16.00	10.00
Maximum Dry Density	01.72	01.75	01.74	01.76	01.77	01.82	01.86
Optimum Moisture Content	15.60	15.60	15.80	14.20	15.00	14.20	14.40
Cohesion	08.00	10.00	09.00	10.00	08.00	11.00	12.00
Angle of Internal Friction	05.50	05.00	04.50	04.00	04.00	05.00	05.50
Permeability	00.18	00.22	00.20	00.10	00.09	00.05	00.04

These mean value have been compared with the mean values of the control sample i.e. samples collected from the outside dump area within 0.5 km and shown in Table-3 as percentage above/below the mean value.

Table-3. Geotechnical Properties of dumpsites studied in Lucknow, U.P.

Parameter	Mean Value of Control Sample	Near Maniyao gao, Janki puram	Near Race Course , Bahadur Shah Marg	Near Bhatamau, Alamganj, Budheshwar Chauraha	Near Sainik School Sarojini Nagar	Near Moti Jheel, Aishbaag	Near Naval Kishor Road, Hazaratganj, Gandhisetu	Near Bhattha Maidan, Rajni Khand, Sharada nagar
Percentage above the mean value of soil samples collected outside the dump area								
Natural Moisture Content	13.90	23.02	20.14	00.72	15.83	9.35	13.67	7.91
Percentage Finer	44.66	94.81	106.00	29.87	20.91	52.26	34.35	38.82
Optimum Moisture Content	13.45	15.99	15.99	17.47	5.58	11.52	5.58	7.06
Permeability	00.04	350.0	450.0	400.0	150.0	125.0	25.00	00.00
Percentage below the mean value of soil samples collected outside the dump area								
Specific Gravity	02.52	10.32	11.90	9.52	12.70	13.49	11.11	9.52
Liquid Limit	38.66	32.75	32.75	43.09	24.98	27.57	30.16	32.75
Plastic Limit	19.66	38.96	18.62	38.96	47.05	33.88	44.05	18.62
Plasticity Index	19.00	26.32	47.37	47.37	5.26	21.05	15.79	47.37
Maximum Dry Density	1.60	07.50	09.38	08.75	10.00	10.63	13.75	16.25
Angle of Internal Friction	7.16	23.18	30.17	37.15	44.13	44.13	30.17	23.80
Cohesion	15.83	49.46	36.83	43.15	36.83	49.46	30.51	24.20
Average Difference (Percentage)		61.19	70.83	61.46	33.93	36.21	23.10	20.57

Out of the total eleven parameters, it was observed that four parameters have values exceeding than mean value of control sample while seven parameters have values less than the mean value of the control sample. The mean values of

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parameters determined at depths 1.00 m, 1.50 m and 2.00 m have been compared with control sample mean value are presented in Table-4 below-

Table-4. Variation of Geotechnical Properties of dumpsites with depth

Parameter	Control Sample Mean Value	Geotechnical Properties of dumpsites					
		At 1.0 m depth		At 1.5 m depth		At 2.0 m depth	
		Mean Value	% Diff.	Mean Value	% Diff.	Mean Value	% Diff.
Natural Moisture Content	13.90	16.90	21.58	15.10	8.63	15.00	7.91
Percentage Finer	44.66	89.50	100.40	60.00	34.34	57.00	34.35
Optimum Moisture Content	13.45	15.60	15.99	15.00	11.52	14.30	6.32
Permeability	00.04	00.20	400.00	00.13	225.00	00.05	25.00
Specific Gravity	02.52	2.20	12.70	2.22	11.90	2.24	11.11
Liquid Limit	38.66	24.00	37.92	26.50	31.45	28.00	27.57
Plastic Limit	19.66	12.00	38.96	13.50	31.33	14.00	28.79
Plasticity Index	19.00	12.00	36.84	13.00	31.58	14.00	26.31
Maximum Dry Density	01.60	1.84	15	1.76	10.00	1.74	8.75
Angle of Internal Friction	07.16	4.17	41.76	5.25	26.67	5.25	26.67
Cohesion	15.83	9.00	43.15	9.00	43.15	11.50	27.35

The mean value of all the parameters along with standard deviation and mean values of control sample are shown in Table-5 below-

Table 5. Comparison of Geotechnical Properties of dumpsites and Control Sample in Lucknow, U.P.

Parameter	Control Sample Mean Value	Mean Value of the geotechnical properties of dumps	Standard Deviation of the geotechnical properties	Difference in geotechnical properties in percentage
Natural Moisture Content	13.90	15.70	01.06	12.95
Percentage Finer	44.66	68.71	14.89	53.85
Optimum Moisture Content	13.45	14.97	00.71	11.30
Permeability	00.04	00.14	00.07	250.00
Specific Gravity	02.52	2.24	00.04	11.11
Liquid Limit	38.66	26.29	02.21	31.99
Plastic Limit	19.66	13	02.16	33.88
Plasticity Index	19.00	13.29	03.30	30.05
Maximum Dry Density	01.60	01.77	00.05	10.63
Angle of Internal Friction	07.16	04.79	00.64	33.10
Cohesion	15.83	09.71	01.50	38.60
Average	16.04	15.51	2.42	47.04

The results show that difference between the values of the natural moisture content of the soil samples collected from nearby the dump site within 0.5 km from the dump site i.e. control sample at corresponding depths is generally lower to those of dump site sample at corresponding depths. This observed trend could be attributed due to dump msw is generally expected to be more damp(moist), since it contains more fine particles than the soil outside the dump area and fine soil particles have more affinity for water. Dump soil has lower specific gravity, contains more fine particles, lower maximum dry density with higher optimum moisture content, both lower cohesion and angle of internal friction and higher the coefficient of permeability than the nearby soil Higher value of finer percentage, permeability and optimum moisture content indicate that the nature and behaviour of the soil may be like collapsible or expansive soil. This is also evident from the undulating topography & vegetation as observed from the physical observation of the dump site. The specific gravity of the soil dump site is relatively low and greatly discrete because of higher organic content when compared to soil sample. The difference in the geotechnical properties exhibited by the soil at dump site as depicted by test results that reduces with depth. The last two dumpsites show the overall difference in parameters studied as compared to control sample very near whereas the first three dumpsites show far away. The remaining two

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sides show moderate variation. This could be attributed due to the area and depth of the dump sites. The liquid limit of dump site samples varies from 22% to 28% and all samples exhibited non-plastic behaviour. The liquid limit value of the control sample is showing less compressibility than that samples obtained from the dump yard. The plasticity index also shows the similar trend. The control sample is low plastic while samples collected from the dump yard fall in moderate plastic category. Lesser value of cohesion and angle of internal friction indicate that shear strength and bearing capacity of the dump site soil is lower than the nearby soils.

IV. CONCLUSION

1. The characteristic of dump site soil will pose a problem of settlement due to high differential movement and construction of residential building and foundation is extremely difficult without proper preventive measures.
2. As the development of dumpsite has been carried out at different times and the different dumps show the different characteristics due to the nature of waste, depth of dump site and overall to a large extent the uncontrollable factor moisture, all uses of dump site are subject to certain constraints and limitations that remain in force until the biodegradable fraction of the buried waste has been almost completely decomposed and chemical and physical processes going on in fill have reached a relatively high degree of stability the depth of dump fill should not be more than 10 m as evident for the last two dump sites from the comparative study table.
3. Identification of the part of the areas of a closed dump having characteristics of collapsible or expansive soils and concentration of methane gas accumulation is essential so as proper preventive measures for settlement reduction and gas control may be adopted.
4. The design of foundation should be done assuming the ground as unstable ground as shear strength and bearing capacity of dump site is quite low as evident from both low cohesion and angle of internal friction of dump site as compared to the nearby area outside dump site.

REFERENCES

- [1] Ikem A., "Environmental Impact of Two Waste Dump-sites in Ibadan and Lagos on Groundwater Quality," Ph.D. Thesis, University of Ibadan, Ibadan, 1998, pp. 30-40.
- [2] B.S.1377 (1990). "Methods of testing soil for Civil Engineering Purposes", British Standards Institute, London, England.
- [3] Calvert C. K., "Contamination of Groundwater by Im-pounded Garbage Waste," Journal of American Works Association, Vol. 24, No. 2, 1932, p. 266.
- [4] Edward J. M., James H. J.Jr, (1987). Hazardous Waste Management Engineering, published by Van Nostrand Reinhold Company Inc. New York.
- [5] Nabegu, A. B. (2010). "An Analysis of Municipal Solid Waste in Kano Metropolis, Nigeria" Electronic Journal of Geotechnical Engineering (EJGE), Vol. 17(J), pp. 1885-1894.
- [6] Nanda, H. S.(2011).. "Impact of Municipal Solid Waste Disposal on Geotechnical Properties of Soil" Journal of Human Ecology, 31(2) pp. 111-119, Proceedings of Indian Geotechnical Conference December 15-17, Kochi. Paper NoL-183, pp. 715-716.
- [7] Nayak, S., Sunil B. M. and Shrihari, S. (2007). "Hydraulic and Compaction Characteristics of Leachate Contaminated Lateritic Soil", Journal of Engineering Geology, 94, Science Direct, ELSEVIER, pp. 137-144.
- [8] Nkwachukwu, O. I., Chidi, N. I. and Kanno O. C. (2010). "Issues of Roadside Disposal Habit of Municipal Solid Waste, Environmental Impacts and Implementation of Sound Management Practices in Developing Country "Nigeria", International Journal of Environmental Science and Development, 1 (5), pp. 409-418.
- [9] Ogwueleka, T. C. (2004). "Planning Model for Refuse Management", Journal of Science and Technology, 3 (2) Pp. 71-76.
- [10] Ogwueleka, T. C. (2009). "Municipal Solid Waste Characteristics and Management in Nigeria", Iran. J. Environ. Health Sci. Eng. 6(3), pp. 173- 180.
- [11] Schwarz-Herion, O., Omran, A. and Rapp, H. P.(2008). "A Case Study on Successful Municipal Solid Waste Management in Industrialized Countries by the Example of Karlsruhe City, Germany", Journal of Engineering Annals, of the Faculty of Engineering Hunedoara. 6 (3) pp. 266-273.
- [12] SSSA, "Methods of Soil Analysis," Soil Science Society of America, 2nd Edition, 1982, pp. 209-224.
- [13] Sunil, B. M., Shrihari, S and Nayak, S. (2008). "Soil –Leachate Interaction & their Effects on Hydraulic Conductivity and Compaction Characteristics", the 12th International Conference of International Association, for Computer Methods & Advances in Geomechanics (IACMAG), Goa, India, pp. 2380-2386.
- [14] USEPA, "Manual: Groundwater and Leachate Treatment Systems," Centre for Environmental Research Informa-tionk, Vol. 2, No. 9, 1995, pp. 1-64.
- [15] Wright, J. B. (1989). Volcanic Rocks in Nigeria, In Geology of Nigeria, edited by Kogbe, C. A. Abiprint & Pak Limited, Ibadan. Pp. 125-175.210