Impact of Municipal Solid Waste Disposal on Compaction Characteristics and Strength of Red Soil

Shivaraju R.¹, B. V. Ravishankar² and H. S. Nanda³

1. Department of Civil Engineering, C Byregowda Institute of Technology, Kolar 563 101, Karnataka, India

2. Department of Civil Engineering, BMS College of Engineering, Bangalore 560 019, Karnataka, India

3. Department of Civil Engineering, Bangalore Technological Institute, Bangalore 560 035, Karnataka, India

Abstract: The disposal of MSW (municipal solid waste), in most of Indian cities, is to dump on nearby low laying lands. This investigation aims to characterize MSW and assess compaction characteristics and strength properties of contaminated soils at dumping sites in two cities Chickballapur and Kolar of Karnataka, India. Representative solid wastes from selected wards of the city were collected and analyzed. Substantial release of leachate from the dump yards occurred during past few years and the soil at the dump site experience extensive contamination. The test results of contaminated and uncontaminated soil show increase in optimum moisture content and decrease in maximum dry density. The unconfined compressive strength decreased considerably for soil samples obtained at 0.0 m, 0.5 m and 1.0 m depths below waste dump. At depths greater than 1.5 m, compaction characteristics and unconfined compressive strength closely match with the uncontaminated soil. Little variation in pH value, which makes soil slightly alkaline, was observed. From the study, it is inferred that, this investigation is very significant, as the foundation normally at these depths may be affected by this contamination.

Key words: MSW (municipal solid waste), dumping site, contamination, leachate, geotechnical properties.

1. Introduction

MSW (municipal solid waste), a complex refuse composed of various materials with different properties. Some of the components are stable while others degrade as a result of biological and chemical process. Leachate resulted from this, is the most hazardous pollutant [1] for the soil underlying and subsequently ground water. Leaching of nutrients and heavy metals into the soil which leads to soil and groundwater contamination. MSW management is mainly focused on major cities in India [2]. Safe and scientific practice of MSW disposal for any developing city is need of the hour.

The increasing level of solid waste is, nowadays, a serious problem in the urban areas of the world. A high rate of growth of population and increasing per-capita income have resulted in the generation of

enormous solid waste posing a serious threat to quality of soil and water. This is more serious in the case of developing countries where large quantities of solid waste are dumped haphazardly, thereby, putting pressure on scarce land [3] and water resources and at the same time affecting the geotechnical properties of soil [4].

1.1 Study Area

The study area, one of the municipal solid wastes dumping site located near Chickballapur town of Karnataka, the birth place of Bharatharathna Sir. M. Visvesvaraya. The dumping site selected for this preliminary investigation, located between Nimmakalakunte and Ankanagondi village is about seven years old, in which the solid waste dumping in this yard was in practice for a period of one to one and half of year later there was no further dumping in this site since seven years. Another solid wastes dumping site in Moorandanahalli located at outskirts of Kolar

---

Corresponding author: Shivaraju R, M.Tech., research fields: environmental geotechnics and groundwater recharge.

City, the land of gold, in which MSW is dumped adjacent to a state highway since four years and dumping was stopped recently. The present practice of SWM is unscientific, disposing wastes on open space without considering the future environmental consequences

2. Materials and Methodology

In this investigation, the main focus was to determine the extent of leachate effect on soil below [5] the landfill with respect to pH, optimum moisture content, maximum dry density and unconfined compressive strength properties. To attain the study objectives, the following steps were followed:

(1) Characterizing MSW;

(2) Assessing compaction characteristics and shear strength of contaminated soils at various depths.

Representative solid wastes from selected wards of the Chickballapur City were collected and analyzed. Disturbed soil sample was collected immediately below waste dumps site at Chickballapur location, which is seven to eight years old. The soil samples also collected from excavated pits right below the solid waste dump at different depths and were used for characterization. The representative uncontaminated soil samples are also collected adjacent to dumping site for comparisons. Similarly, the contaminated soil and uncontaminated soil samples are also collected from the dumping site which was about four years old at Kolar location for characterization and analysis.

3. Results

The extent of effect of MSW leachate on soil at dumping sites is presented in this paper. This investigation aims to characterize MSW and assess compaction characteristics and strength behavior. Soil samples are obtained right below (0.00 m) and, at a depth of 0.50 m, 1.00 m, 1.50 m from the surface, laboratory tests were conducted for compaction and strength characteristics.

3.1 Characterizing MSW

The solid wastes generated for a period of one week from dwelling houses of selected wards were collected and brought to laboratory. The solid wastes are segregated for characterization. The MSWs consist of materials compostable waste (66%), paper, cardboard (26%), plastic, glass (6%), leather, cloth, textile (1%) and inert material (1%).

3.2 Compaction Characteristics and Strength of Contaminated Soils at Various Depths

3.2.1 Compaction Characteristics

The compaction characteristics of soil at deferent depths were studied in the laboratory using standard proctor test as per IS: 2720 (Part-VII)-1980 [6]. The optimum moisture content and maximum dry density values were established for uncontaminated soil [7]. Soil samples obtained immediately below the solid waste dump, at depths of 0.5 m, 1.0 m and 1.5 m beneath the soil surface were tested in the laboratory. The test results of optimum moisture content and maximum dry density for contaminated soil show an increase in optimum moisture content (26%~36%) and decrease in maximum dry density (10%~18%) comparing with the uncontaminated soil for soil samples of obtained from Chickballapur City. Similar trend was also observed with an increase in optimum moisture content (21%~32%) and decrease in maximum dry density (5%~14%) for soil samples of obtained from Kolar City and are represented in Tables 1 and 2, respectively. This may be due to particle flocculation as a result of soil contaminated with MSW at varying concentration. Fig 1. depicts the variation of optimum moisture content of contaminated soil at different depths and Fig. 2 shows the maximum dry density of same soils at defined depth below MSW dump.

3.2.2 Unconfined Compressive Strength

The unconfined compressive strength tests [8] were conducted on soil samples obtained at defined depths as mentioned in Tables 3 and 4. The results are compared

Table 1 Compaction characteristics of soil samples of Chickballapur City.

Test	Uncontaminated soil	Contaminated soil below natural ground level (m)			
		00.00	00.50	01.00	01.50
OMC (%)	15.00	19.00	24.50	20.50	16.0
ODD (kN/m ³)	19.90	16.18	17.16	17.88	20.0

Table 2 Compaction characteristics of soil samples of Kolar City.

Test	Uncontaminated soil	Contaminated soil below natural ground level (m)			
		00.00	00.50	01.00	01.50
OMC (%)	14.00	17.01	15.78	18.50	15.2
ODD (kN/m ³)	17.80	15.30	16.16	16.90	18.10

Fig. 1 OMC characteristics of contaminated soils. **Fig. 2** OMC characteristics of contaminated soils.

with unconfined compressive strength values of uncontaminated soil. The unconfined compressive strength decreased considerably (61% at 0 m to 32%

at 1.0 m) for soil samples obtained from dumping site of Chickballapur City at 0.0 m, 0.5 m and 1.0 m depths below waste dump. The unconfined compressive strength of soil samples obtained from dumping site of Kolar City also decreased significantly (64% to 7%) at defined depths below waste dump. At depths greater than 1.5 m, compaction characteristics and unconfined compressive strength closely match with the uncontaminated soil. This clearly indicates the effect of MSW on strength behaviour of soil. The variation in unconfined compression strength of contaminated soil at various depth is shown in Fig. 3.

3.2.3 pH value

The pH tests were also conducted on soil samples obtained at various depths and experimental results are compared with pH value of uncontaminated soil. The test results are as depicted in Table 5. The test result shows soil pH value increases resulting in changing from slightly acidic to slightly alkaline in the presence of leachate at different depths. It also shows that in the reduced concentration of leachate below 1.5 m, the pH [9] of soil almost equals to pH value of uncontaminated soil [10].

Table 3 Unconfined compressive strength of soil samples of Chickballapur City.

Test	Uncontaminated soil	Contaminated soil below natural ground level (m)			
		00.00	00.50	01.00	01.50
UCS (unconfined compressive strength) (kN/m ²)	44.00	17.00	22.00	30.00	42.50

Table 4 Unconfined compressive strength of soil samples of Kolar City.

Test	Uncontaminated soil	Contaminated soil below natural ground level (m)			
		00.00	00.50	01.00	01.50
UCS (kN/m ²)	16.50	05.85	13.98	15.27	17.04

Table 5 pH value of soil samples.

Test	Uncontaminated soil	Contaminated soil below natural ground level (m)			
		00.00	00.50	01.00	01.50
pH value	06.60	07.50	07.60	07.30	06.70

Fig. 3 UCS of contaminated soils.

4. Conclusions

The objective of this investigation was to determine the possible effect of leachate on red soil in the solid waste dumping sites which were about four to seven years old, in which solid waste dumping in these sites was in practice for a period of one to one and half years and later there was no further dumping took place in the respective sites. An extensive laboratory testing program was carried out to achieve these objectives. The following conclusions were drawn based on test results:

- Leachate contamination leads to alter the compaction characteristics and strength of soil;
- The influence of leachate decreases with depth and its effect reflects as concentration varies. This is attributed due to chemical reactions with the leachate and soil particles;
- Experimental results indicated that compaction characteristics and strength of soil vary with depth up to 1.0 m below the dump and there is no much changes in its properties beyond 1.5 m depth which implies that leachate influence was limited within this

depth as further dumping of MSW was stopped;

- This investigation also indicates that greater effect to higher depth in the continued dumping site could be expected, as the size of landfill and variety of solid wastes disposed increases, large amount of leachate will be generated and create environmental problems;
- Variation in pH value of soil shows significant impact in the behaviour of soil in the presence of pollutants of different concentration.

Future studies may be carried out to assess the leachate effect on soil and groundwater laterally in the landfill locality.

References

- [1] Martin, E. J., Johnson, J. H. Jr. 1987. *Hazardous Waste Management Engineering*. New York: Van Nostrand Reinhold Company Inc.
- [2] Sunil, B. M., Shrihari, S., and Nayak, S. 2008. "Soil-Leachate Interaction & Their Effects on Hydraulic Conductivity and Compaction Characteristics." In *Proceedings of the 12th International Conference of International Association, for Computer Methods & Advances in Geomechanics (IACMAG)*, 2380-6.
- [3] Lahtinen, P. O., Jyrava, H., and Suni, H. 2000. "Use of Industrial Wastes in the Construction of Low-Volume Roads." *ASCE* 40519 (293): 3.
- [4] Lim, B. M., Stace, L. R., and Zhan, G. 2006. "Index Properties of Soils Rich in Iron Oxides." *ASCE* 40860 (192): 31.
- [5] Abduljawwad, S. N. 2007. "Characteristics & Chemical Treatment of Expansive Clay in Al-Qatif, Saudi Arabia." *Engineering Geology* 30 (199): 143-58.
- [6] Bureau of Indian Standards. 1980. *IS: 2720 (Part-VII). Method of Test for Soils: Determination of Moisture Content Dry Density Relation Using Light Compaction*. Bureau of Indian Standards.
- [7] Nayak, S., Sunil, B. M., and Shrihari, S. 2007. "Hydraulic

- and Compaction Characteristics of Leachate-Contaminated Lateritic Soil.” *Engineering Geology* 94: 137-44.
- [8] Tang, X. W., Ying, F., and Lin, T. S. 2006. “Properties of Clay Mixed with Sticky Rice Juice and Tung Oil.” *ASCE* 40860 (192): 40.
- [9] Torrance, J. K., and Pinnat, M. 1984. “Clay and Clay Minerals, Effect of pH on the Rheology of Marine Clay from the Site of the South National River, Canada, Landslide of 1971.” *Clays and Clay Minerals* 32 (5): 384-90.
- [10] Allam, M. M., Sivapullaiah, P. V., and Gullapalli, S. 2008. “Geotechnical Behaviour of Soil Containing Mixed Layered Illite-Smectite Contaminated with Caustic Alkali.” Electronic Theses and Dissertations of Indian Institute of Science.