Geotechnical Properties of Landfill Solid Waste in Dry Zone of Sri Lanka

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ABSTRACT:In different climatic conditions, Landfill Solid Waste (LSW) exhibits different properties due to variations of composition and decomposition of solid waste. This paper mainly focused to investigate geotechnical characteristics of LSW in dry zone of Sri Lanka.Series of laboratory experiments were conducted on solid waste retrieved from Hambantota waste dump site. Solid wastes were collected representing new waste and old waste. In addition, soils under the waste layer were collected in order to study the effect of leachate on geotechnical properties of soil under the waste. To compare the geotechnical characteristics of solid waste andsoil under the waste layer with intact soil, uncontaminated soil samples were also collected. It can be observed that there is a significantvariation of geotechnical properties of LSW due to decomposition of waste body.Similarly, due to influence of leachate, geotechnical properties of soil under the waste layer have been significantly changed.

1 INTRODUCTION

Due to increase of population, rapid industrialization and urbanization, Municipal Solid Waste (MSW) generation in Sri Lanka is increased significantly during the last decade. However, still the most common method of disposal of solid waste in Sri Lanka is open dumping as it is the cheapest and easiest way of waste disposal. This haphazard method of solid waste disposal creates a lot of environmental, social and safety problems. It is believed that engineering landfill is the most affordable and environmental acceptable way to dispose solid waste (Reddy et al, 2009).

Generally engineering landfills are designed based on empirical correlations. In order to do a conservative design, environmental, social and engineering facts have to be considered all together with higher reliability.

Geotechnical consideration of landfill refuse is timely concept for design of engineering landfills. Several landfill instabilities have been reported in recent years, such as Payatas landfill in Philippines, Rumpke landfill in Ohio USA (Zekkos et al, 2010).Therefore, it is essential to study the geotechnical properties of landfill solid waste in order to make a stable landfill slope. However, evaluation of geotechnical properties of Landfill Solid Waste (LSW) is not an easy task due to heterogeneous nature and time dependent degradation of solid waste (Dixon and Jones, 2005; Reddy et al, 2009). Nevertheless, several studies have been reported on evaluation of geotechnical properties of solid waste (Dixon and Jones, 2005; Gabr and Valero, 1995; Hanson et al, 2010; Landva and Clark, 1990; Reddy et al, 2009; Reddy et al, 2011;Yesiller et al, 2014), very few studies focused to find the variation of geotechnical properties of LSW with respect to burial age, depth and influence of leachate on underneath soil layer. Therefore, in this research study, geotechnical properties of LSW collected from dry zone of Sri Lanka were studied.

2 MATERIALS AND METHODS

2.1 *Waste Sampling*

In order to examine climatic influence on LSW degradation and geotechnical properties,waste samples were retrieved from the Hambantota Municipal Council landfill site, which is located in south arid zone of Sri Lanka. The dump site can be divided in to two areas based on age of waste fill as shown in Fig. 1. The new waste is about2 years old whereasold waste is more than 10 years old. Waste samples were collected from the site by means of box sampling at varying depths of 0.5 m and 1.0 m representing new waste area and old waste area. Further, soil samples under the waste layers were collected to study the effect of leachate on soil contamination. To compare the degree of contamination, uncontaminated soil samples were also collected. In order, to determine the subsurface soil profile at the dump sites, borehole investigations were conducted as shown in Fig. 1.

In this paper, the boreholes aredenoted as BH – 01 (Intact soil), BH – 02(New waste) and BH – 03 (Old waste) whereas test pits are denoted as TP – 01(New waste), TP – 02A (Old waste-location 1), TP – 02B (Old waste – location 2) and TP – 03 (Intact soil).

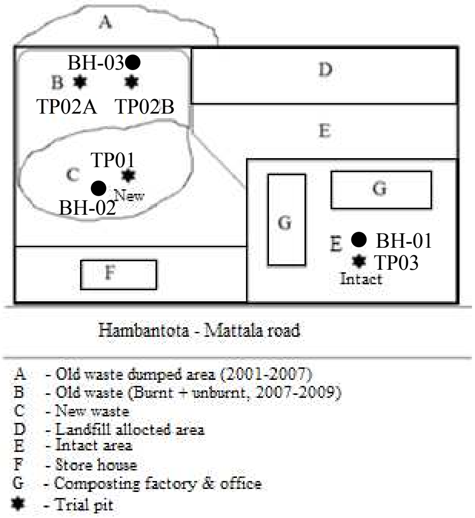

Fig.1 Plan view of Hambantota open dump site

2.2 *Methodology*

A series of laboratory experiments were conducted to determine the physical and chemical properties of LSW according to the standard test procedures.Some incidental modifications were introduced to the experiments as there are no any standard test procedures to determine the engineering properties of solid waste.

3 RESULTS AND DISCUSSION

3.1 *Waste composition*

Waste composition analysis was conducted on materials retained 4.75mm sieve. Waste compositions obtained based on borehole samples in both new waste area and old waste area at different depths are illustrated in Table 1.

Short term biodegradable materials such as food waste, garden waste and paper products take soil like appearance after complete degradation. Based on the data presented in Table 1, it is very clear that all the short term biodegradable materials have completely degraded and as a result fine content has been increased. Only long term biodegradable materials (wood, textile and rubber) and materials that never degrade (plastic, glass and ceramic) are remaining. It can be observed that percentage of long term biodegradable materials slightly low in old waste area than that in the new waste area. Further, it can be noted that percentages of long term biodegradable materials gradually decrease with the depth and age.Higher percentage of waste mainly consists of particles size less than 4.75mm due to the greater degradation of waste. Even though values are different, pattern of waste composition is similar with previously published data (Gabr and Velero, 1995).

According to Waste Amount and Composition Survey (WACS) conducted at Hmbantota Municipal Council in 2014, the average short term biodegradable solid waste was about 89.4 % in residential whereas 83.3 % in commercial. Even though, fresh wastes in Hambantota Municipal Council mainly consists of short term biodegradable waste (more than 83 %), it is realized that these wastes were completely biodegradedat the dump site within a very short period. As a result odor ofthe dump site is less when compared with that in wet zone.

Table 1. Waste composition

Waste Type	Percentage (%)				
	New waste			Old waste	
	0-0.5 (m)	0.5-1.0 (m)	1.0-1.5 (m)	0-0.5m (m)	0.5-1.0 (m)
Food waste	0	0	0	0	0
Garden waste	0	0	0	0	0
Paper products	0	0	0	0	0
Textile	1.17	0.70	2.44	0.40	0.24
Polythene and Plastics	4.56	2.91	0.67	1.40	1.01
Metal and Ceramic	6.26	4.65	5.43	1.91	3.37
Glass	0.84	5.04	4.55	2.23	1.25
Rubber	0	1.54	0	0	0.06
Wood	1.59	0.26	0.71	1.06	0.34
Gravel	15.63	10.45	22.82	34.09	15.92
Particles < 4.75 mm	69.95	74.45	63.38	58.91	77.81

3.2 *Particle size distribution*

Particle size distribution of solid waste in 3 boreholes at different depths is shown in Fig. 2. It can be noted that much larger size particles are presented at new waste area than that of other areas. These observations can be further confirmed when compared with the waste composition illustrated in Table 1 where percentage of textile, polythene and plastic, metal and ceramic, and glass in new waste area are higher than that in old waste area. A significant increment of smaller size particles can be observed in old waste area due to biodegradation of solid waste.

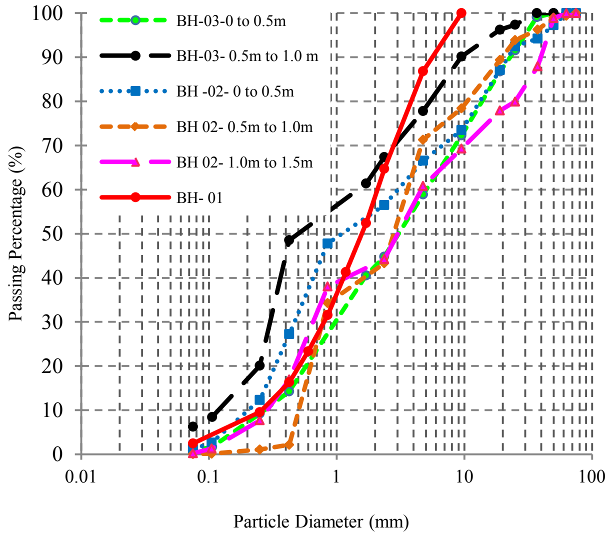

Fig.2 Particle size distribution

3.3 *In situ moisture content*

Variation of in situ moisture content with depth in waste and soil are presented in Fig. 3. It can be observed that moisture content of the solid waste is much lower than that in wet zone due to dry and windy climatic condition. This makes the dump site less odour compared with that of wet zone. Based on the results, generally it can be noted that moisture content in waste on the surface has lesser moisture content than that of bottom.This is mainly due to the very dry climatic condition in the area.It is very clear that, moisture content of waste increases with depth irrespective of the location. Further, it can be noted that moisture content of soil close to the waste layer is higher than that of deeper layers as moisture evaporation from soil is prevented by top waste layer.

3.4 *pH value and Electrical Conductivity (EC)*

Variation of chemical properties such as pH value and Electrical Conductivity (EC) of waste and soil are illustrated in Fig. 4 and Fig. 5 respectively. pH value is a very good indicator to understand the decomposition stage of LSW. It is well known that, micro-organisms are very active if pH is 6 - 9. Based on the results presented in Fig. 4, it can be seen that waste in dump site consists of highly active micro-organisms.

EC is high in the new waste than that of old waste. Also EC of soil under the waste layer is much higher than that of intact soil. It is postulated that, soil under the waste is highly contaminated due to infiltration of leachate. Further, it can be noted that degree of contamination of soil in new waste area is much higher than that of old waste area, which implies the effect of fresh leachate on soil.Based on the result, it can be observed that EC of both waste and soil decreases with time irrespective of the depth; this is a clear indication of the effect of fresh leachate on waste degradation.

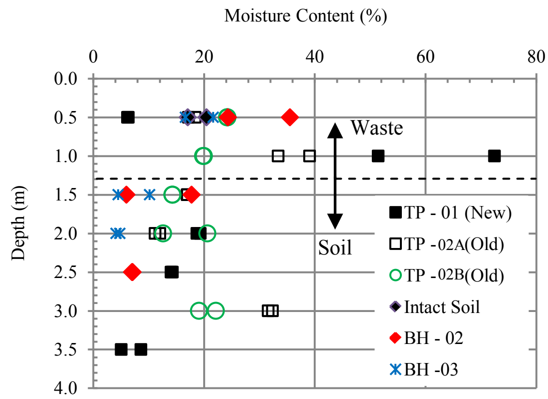

Fig. 3 Variation of in situ moisture content

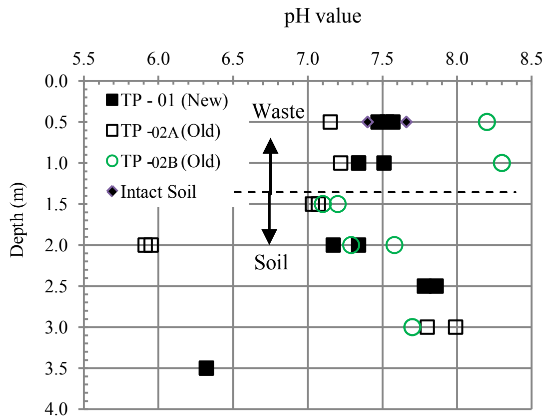

Fig. 4 Variation of pH value

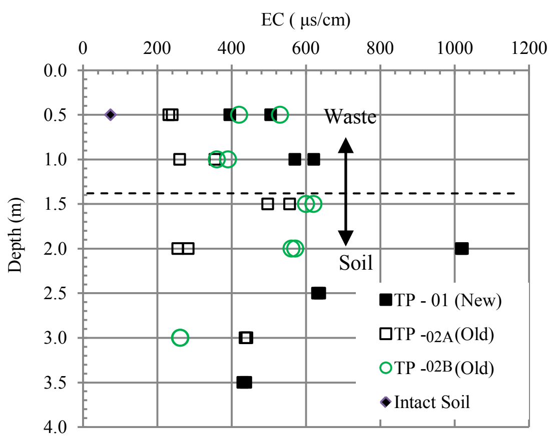

Fig. 5 Variation of EC

3.5 *Consistency limits*

The variation of Plasticity Index (PI) with depth is shown in Fig.6. It was really difficult to perform consistency limit testsfor waste as most of the fine particles in waste layer are non-plastic.

As illustrated in Fig. 6, generally soil at old dump area has relatively lower consistency limits than that of uncontaminated soil. That postulates, soil in old dump area is consisting of more non-plastic fine content than intact soil. Based on these evidences, it is very clear that due to long term effect of leachate interaction, soil becomes more non –plastic. Further, it can be concluded that fines resulting from microbial decomposition are non-plastic. In contrary, soil at shallow depth of new dump area has higher consistency limits than that of uncontaminated soil. Due to influence of fresh leachate, soil under the new waste becomes more plastic.

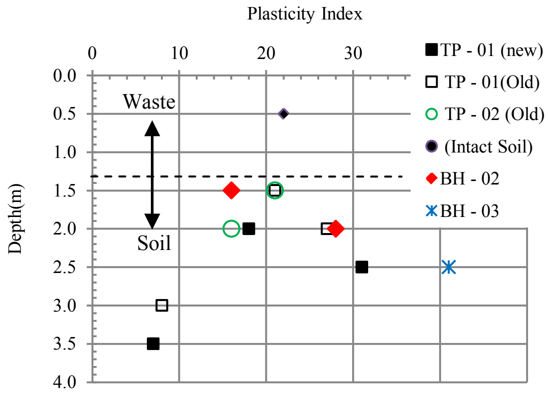

Fig. 6 Variation of Plasticity Index

3.6 *Specific gravity and bulk unit weight*

Specific gravity of LSW highly depends on particle size distribution and waste composition. Based on laboratory experiments, it was found that the specific gravity of particles less than 2.0 mm is between 2.4 – 2.7, whereas the specific gravity of particles between 2.0 - 9.5mm is between 2.1-2.5. Further, it can be noted that specific gravity of contaminated soil is much lower than that of uncontaminated soil.

According to laboratory observations, bulk unit weight of LSW is between 11.11 - 13.69 kN/m^3, which is well agreed with the Dixon and Jones, 2005.

3.7 *Compaction characteristics*

Based on Standard Proctor Compaction test results, it was realized that dry unit weight of new waste is 14.5 – 14.8 kN/m^{3}whereasthat in old wasteis 16.3 – 17.3 kN/m^3. Since old wastes are well-graded than that of new wastes with decomposition, old wastesshow greater compaction characteristics than that of new wastes.

4 CONCLUSIONS

Based on laboratory experimental results, following conclusions can be drawn;

1. LSW in dry zone is highly degradabledue to composition of fresh waste, and thriving environmental and climatic condition for microorganisms.
2. In situ moisture content of LSW is very less in dry zone compared to that of wet zone, as such dump sites in dry zone are less odour compared that in wet zone.
3. The EC values clearly illustrated that soil under the waste layer is highly contaminated due to interaction of leachate with soil.
4. Consistency limits of soil highly depend on the characteristics of leachate. Due to long term effect of leachate interaction, soil becomes more non-plastic. In the contrary, due to the influence of fresh leachate, soil becomes more non-plastic.

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