Geotechnical Properties for Municipal Solid Waste at Open Dumping Sites Located in Wet and Dry Zones, Sri Lanka

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ABSTRACT: Due to rapid urbanization and increase in population, generation of municipal solid waste is increasing in developing countries. The municipal solid waste is mostly dumped in an unsanitary and non-engineering manner, causing serious environmental problems and potential risk of landslide. In this study, buried waste and subgrade soil samples were taken from waste dumping sites under two different climate conditions (wet and dry) and age (new and old) in Sri Lanka and physical, chemical and geotechnical properties were investigated. Results showed buried waste samples were characterized as lower specific gravity and high EC values. Both *In-situ* and maximum dry densities from compaction tests were well correlated with the coefficient of uniformity from particle size distributions. The cohesion and friction angles measured by direct shear tests varied among tested samples.

1 INTRODUCTION

Due to rapid urbanization and increase in population, generation of municipal solid waste (MSW) is increasing in developing countries. However, general disposal practice of MSW in developing countries is unsanitary and open dumping, causing serious social and environmental problems. Those problems cause surface and groundwater pollution in the surroundings and collapse of waste slopes and landslide at disposal sites. Sri Lanka is also facing those problems attributed to the improper MSW management (Sato, et al., 2012), and most of collected MSW is dumped at the disposal sites without any engineering considerations such as ground settlement and slope stability.

Several studies have been done to characterize geotechnical properties for solid waste samples (e.g., Stark et al., 2009; Reddy et al., 2009). However, effects of climate condition and waste age on geotechnical properties are not well understood. This is due to the fact that solid waste characteristics are highly dependent on site-specific factors such as climate, culture, urbanization, and so on. In this study, buried MSW taken from two open dumping sites under different climatic conditions (wet and dry) in Sri Lanka were investigated to understand the effects of climatic conditions and age of waste fill on geotechnical properties of buried MSW.

2 SAMPLE COLLECTION

Core samples taken and box samples of buried MSW and its subgrade were taken from boreholes at two open dumping sites in Sri Lanka: Udapalatha abandoned open dumping site in Central Province (wet zone) and Hambantota open dumping site (which is under operation) in Southern Province (dry zone) (Fig. 1). Annual precipitations are more than 2,500 mm for the Udapalatha site and less than 800 mm for the Hambantota site. At both sites, waste samples were taken from the locations with two different age: One is "new" samples for 3 years after dumping and the other is "old" for 7 to 11 years after dumping. In addition, soil samples intact soil samples were taken from a location away from the influence of waste dumping.

3 TESTING METHODS

Core samples taken from boreholes were used to determine basic physical properties (moisture content, Atterberg limits, specific gravity (G_s), and

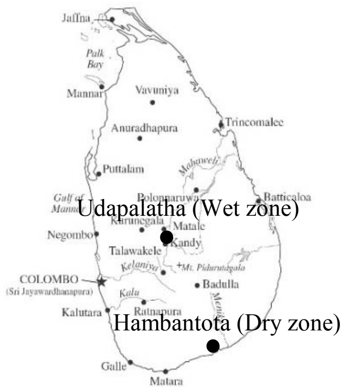

Fig. 1 Location of sampling in wet and dry zones of Sri Lanka

particle size distribution) and chemical properties (loss on ignition (LOI), pH and electric conductivity (EC)). Those tests were carried out conforming to Japanese Industrial Standards (JIS) (JIS A 1202, JIS A 1203, JIS A 1204, JIS A 1205) and Japanese Geotechnical Society (JGS) standards (JGS 0211-2009, JGS 0212-2009, JGS 0221-2009). The compositions for buried MSW were characterized by the waste composition analysis. Standard Proctor compaction test (JIS A 1210) and direct shear test (JGS 0561-2000) were carried out by using box samples. For the direct shear test, a larger shear box with inside diameter of 60 mm and height of 40 mm was used because of coarse and non-uniformity of waste samples. The sample was packed in the shear box to 80% of the maximum dry density, and sheared at a constant strain rate (0.15%/min). The normal stress was set to be 10, 25, 50 and 75 kPa for waste samples and 40, 80, and 110 kPa for soil samples. For all the tests, the maximum particle size of sample was taken to be 2.0 mm for soil samples and 9.5 mm for waste samples. The values of degree of saturation (S_r) for the tested waste samples were around 70-80 % for the wet zone and 65 % for the dry zone. The S_r values for intact soil samples were around 50-60 %.

4 RESULTS AND DISCUSSION

4.1 *Basic physical and chemical properties*

Fig. 2 shows basic physical and chemical properties of boring core samples taken from the disposal sites of Udapalatha (wet zone) and Hambantota (dry zone). The shaded part of the figure represents the region of buried waste layer. Specific gravity (Gs) values for waste samples were less than 2.60, which were lower than that of soil samples. The pH values for waste samples of old site in the wet zone were lower than other samples. Buried waste samples for both wet and dry zones were characterized as high EC and LOI values compared with those of intact soil samples. Especially, EC values in wet zone were greater than those in dry zone. The LOI values for wet zone were higher than those for dry zone.

Fig.3 shows results of particle size distribution (PSD) of buried waste samples and intact soil sample. Compared with the intact soil sample, waste samples, were rich in coarser fraction > 2.0 mm, though to a lesser extent for waste sample from old site in dry zone. There was no significant difference in PSD for waste samples except for that of waste sample from old site in dry zone. Table 1 showed waste compositions for two sites in wet and dry zone. Residue content below 4.75 mm were high for all waste samples, and that for the new site in dry zone exceeding 60%. Based on the results, it can be found that more variety of waste was mixed in the wet zone samples.

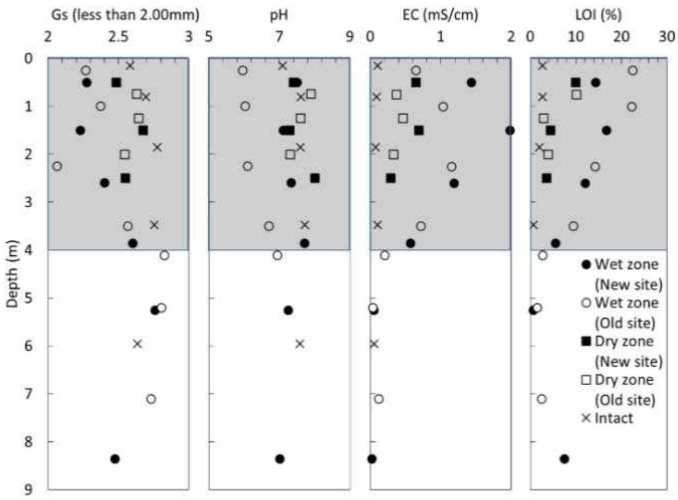

Fig. 2 Basic physical and chemical properties of boring core samples

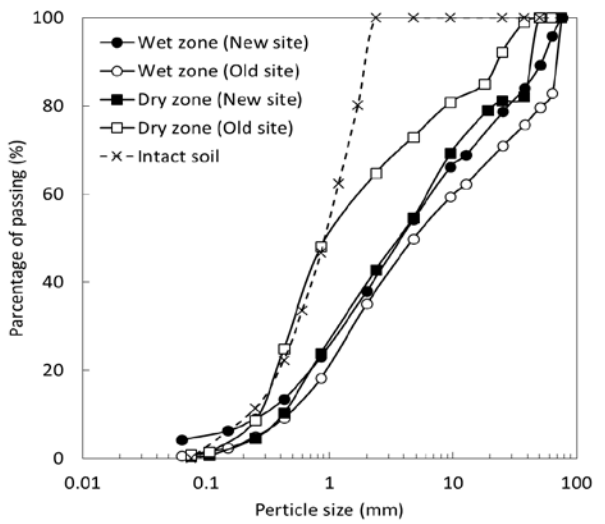

Fig. 3 Particle size distributions for tested samples

Table 1. Results of waste composition analysis

	Wet zone (New site)	Wet zone (Old site)	Dry zone (New site)	Dry zone (Old site)
Paper	0.1	1.7	0.0	0.0
Plasitc	3.2	2.3	0.0	0.0
Vinyl	7.7	6.8	3.6	8.8
Glass, Ceramic & metal	6.7	5.9	3.3	3.4
Leather & Rubber	0.1	2.8	0.0	0.0
Textile	1.0	4.6	1.1	0.4
Grass & Wood	10.8	6.5	0.6	4.5
Cemented material	13.4	4.2	0.0	0.0
Gravel (>9.50mm)	5.7	9.0	17.5	8.2
Aggregated soil	3.9	6.9	12.1	15.5
Residues (2.0-4.75mm)	13.2	14.7	19.4	15.2
Residues (<2.0mm)	34.3	34.6	42.4	44.0
Total	100.0	100.0	100.0	100.0

4.2 *Compaction properties*

Fig. 4 shows results of compaction tests. It can be found that maximum dry densities (ρ_{dmax}) for dry zone were about 1.5 times higher than those for wet zone. Fig. 5 showed correlations between the coefficient of uniformity (C_u) from PSD tests and the *in-situ* and maximum dry densities from compaction curves. Both *in-situ* and maximum dry densities were well correlated with C_u values, the *in-situ* and maximum dry densities decreased with increase in C_u. This implies that compaction properties for waste samples are mainly controlled by PSD of samples irrespective of different waste compositions. Besides, it should be noted that the *in-situ* dry densities for waste samples were lower than maximum dry densities. This indicates that the further compaction would enable to achieve greater densities for the dumped waste ground.

4.3 *Cohesion and friction angles*

Fig. 6 exemplified tested results of direct shear tests under a normal pressure of 75 kPa. For each tested waste sample, shear stress rapidly increased up to 2% of strain, then increased gently with increase in strain compared to intact soil sample. Fig. 7 showed relationships between shear strength and normal stress. Except for the sample from old site in dry zone, there was no significant difference in both cohesion and friction angles for waste samples for wet and dry zones. This difference can be apparent in particle size distributions and compaction characteristics, suggesting the heterogeneity of tested waste samples highly control the shear strength and friction angles. Further tests are scheduled to identify the geotechnical properties for buried waste samples.

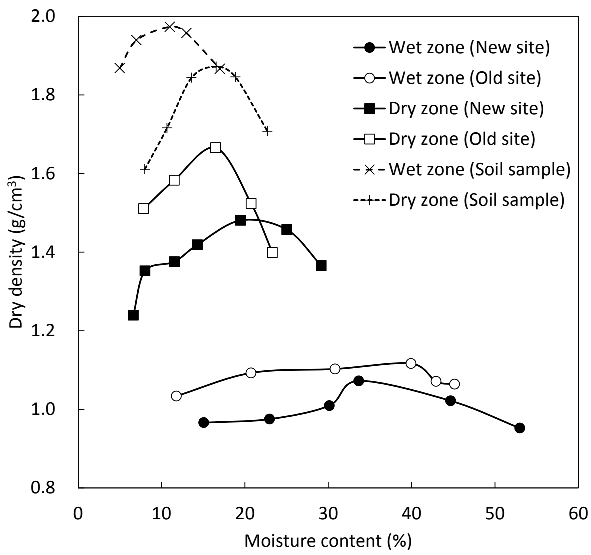

Fig. 4 Results of compaction tests.

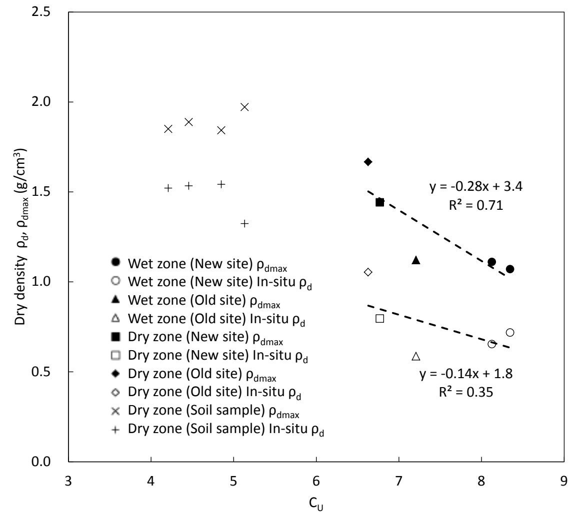

Fig. 5 Relationships between *in-situ* and maximum dry densities and C_u

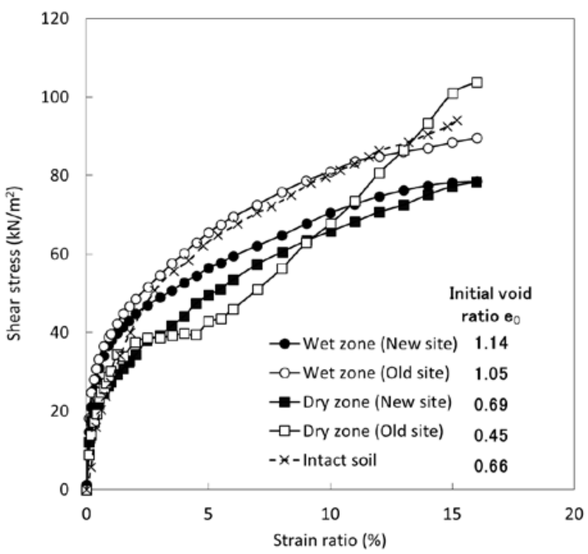

Fig. 6 Results of direct shear tests under normal pressure of 75 kPa

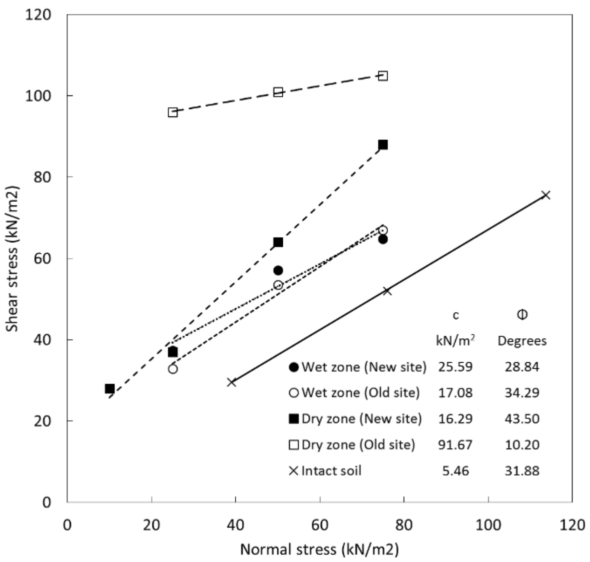

Fig. 7 Relationship for shear stress and normal stress

5 CONCLUSIONS

Using buried waste samples of two different ages (old and new) from wet and dry zone in Sri Lanka, basic physical and chemical properties, and geotechnical properties such as compaction and cohesion and friction angles were determined in the laboratory. Results showed that buried waste samples were characterized as having high EC and LOI values and Gs values for waste samples in both wet and dry zones were less than 2.6, which were a little lower than intact soil. *In-situ* and maximum dry densities for dry zone became higher than those for wet zone, and both densities well correlated with the coefficient of uniformity (C_u) obtained from particle size distribution tests. With increasing in C_u, the *in-situ* and maximum dry densities decreased, implying that compaction properties for waste samples are mainly controlled by PSD of samples as for soils. Further tests are needed to characterize the properties of shear strength for waste samples and effect of climate conditions and waste age.

ACKNOWLEDGMENT

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