Study on Compaction Characteristics of Lateritic Soil/Quarry Dust - Stabilized Municipal Solid Waste

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ABSTRACT: Sri Lanka has faced a huge MSW problem due to dumping in the areas where lots of development activities are being taken place. It is very important to study whether those dumped wastes could be used for different applications as those wastes had been dumped from 30 years and abandoned due to public protests in the last decade. However, there has been limited study on the waste material and this study focuses on the compaction characteristics after improving the MSW with either lateritic soil or quarry dust. MSW alone will provide a low dry density in the range of 1300kg/m^3 and this can be improved by mixing with other locally available materials. Lateritic soils and quarry dust are widely used in the construction industry and it is required to minimize the quantities needed in the construction industry in order to minimize environmental damage as well as the construction cost. With the proposed lateritic soil/quarry dust stabilized MSW will have sufficient densities and also reduce the construction cost considerably.

1 INTRODUCTION

Municipal Solid Waste [MSW] collected in urban areas has been dumped into environmentally very sensitive places causing irreversible negative environmental impacts such as ground and surface water pollution, air pollution. This has further become another problematic concern as the urban public often protests when those are dumped near to their residential areas. There have been several such locations which are eventually abandoned by the authorities due to protests and imitations in their dumping capacity.

Authorities during recent rapid developments too have considered this type of abandoned dumping yards as an area to be improved and used for development activities. However, the amount of dump in those yards has become a serious question with respect to their reuse. Several housing and other development projects faced critical situations as the properties of such MSW are not known. Basic objective of this research is to recognize the improvement of such MSW with the addition of lateritic soil or quarry dust. Use of lateritic/ quarry dust alone in a project will be costly and if the MSW present in an abandoned dump site could be used for such application with lateritic/ quarry dust would be of multi advantageous.

Nawagamuwa and Nuwansiri (2014) have studied the compaction properties of some Sri Lankan MSW and observed that the maximum dry density under standard Proctor compaction on MSW varies in the range from 1200 -1600 kg/m^3.

2 PROPERTIES OF MSW

2.1 *Selection of MSW*

Madampitiya site is open dumping site; that is situated in Colombo Municipal Council area. Industrial and residential waste had been dumped in this dumping site. There was no proper record about the age of this site, and considered as 7-35 years old because of its operational records.

It has to be noted that the average organic content and degree of decomposition were 77.2% and 0%, respectively for fresh wastes and 22.8% and 88.3%, respectively for old wastes as reported by Yesiller et al (2014). The Specific Gravity (G_s) increased with decreasing particle size, compaction, and increasing waste age.

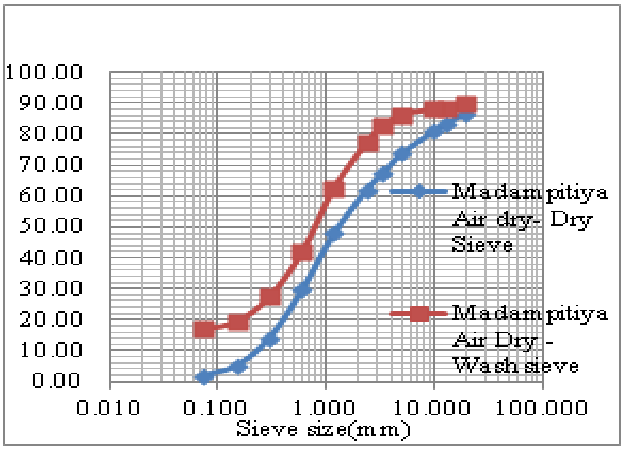

Figure 1. Comparison of Grading Curves of the Air dry - Dry Sieve and Air Dry - Wash Sieve solid waste

2.2 *Properties of MSW in Madampitiya*

Basic soil tests such as grading, Atterberg limits, standard Proctor compaction, specific gravity and organic content tests were conducted on MSW and those are provided in Figure 1 and Table 1.

Table 1. Properties of MSW at Madampitiya

Property	Value
Liquid limit	38.0%
Plastic limit	33.2%
Plasticity Index	5.8%
Specific gravity	1.9-2.1
Organic content	11.8%
Maximum dry density	1326 kg/m^3
Optimum moisture content	27.5%

It has been found that the compaction curves generated from waste material generally are flatter, with a less pronounced peak than that is common in soils. The change in dry unit weight is less sensitive to changes in moisture content. The optimum moisture contents for wastes are significantly higher than for most soils, ranging from 31% to 70% (Gabr and Valero 1995, Hettiarachchi 2005, Itoh 2005, Reddy et al. 2008a). These results too confirm the findings of this research.

3 PROPERTIES OF LATERTIC SOIL/ QUARRY DUST

3.1 *Lateritic soil*

Lateritic soil had a clay/silt content of 32%, sand 52% and gravel 16% according to Unified soil Classification System conducted using wash sieving. Table 2 gives the properties of the selected lateritic soil.

Table 2. Properties of Lateritic soil

Property	Value
Liquid limit	28.3%
Plastic limit	21.7%
Plasticity Index	6.6%
Specific gravity	2.48
Maximum dry density	1845 kg/m^3
Optimum moisture content	14.4%

3.2 *Quarry dust*

Two samples were obtained from two different locations and their properties could be summarized as given in Table 3. All the soil percentasges were claculated according to USCS.

Table 3. Properties of quarry dust

Property	Sample 1	Sample 2
Silt and clay	6%	12%
Sand	62%	88%
Gravel	32%	nil
Maximum dry density	1900 kg.m^3	1865 kg.m^3
Optimum moisture content (OMC)	9.6%	10.2%
Liquid limit (using penetrometer method)	16.8%	22.8%
Specific Gravity	2.63	2.48

Considering these properties mentioned in Table3, sample 1 was selected for the improvement of MSW.

4 COMPACTION CHARACTERISITCS OF IMPROVED MSW

4.1 *Improvement with lateritic soil*

Table 4 provides the summary of compaction characteristics of improved MSW with lateritic soil.

Table 4. Improvement of compaction characteristics with lateritic soil

Lateritic Soil-Solid Waste Combination		Maximum dry density (kg/m^3)	Optimum moisture content (%)
Lateritic Soil %	Solid Waste %		
0	100	1326	27.50
5	95	1395	24.00
20	80	1457	20.50
40	60	1493	20.50
60	40	1675	17.00
80	20	1719	16.00
100	0	1845	14.35

4.2 *Improvement with quarry dust*

Table 5. Improvement of compaction characteristics with quarry dust

Quarry dust and Waste Combination		Maximum dry density (kg/m^3)	Optimum moisture content (%)
Quarry dust %	Solid Waste %		
100	0	1333	27.5
95	5	1336	23.5
90	10	1375	25.0
85	15	1426	21.5
80	20	1423	22.5
60	40	1572	18.0
40	60	1693	14.0
20	80	1764	14.0
0	100%	1900	9.6

Compaction properties of improved MSW with quarry dust are presented in Table 5. This information provided in both Tables 4 and 5 could be used for selection of MSW and percentages of lateritic soil/ quarry dust for a required application.

5 SPECIFIC GRAVITY OF IMPROVED MSW

Since there was a mixture of different sizes of particles in the MSW, it was decided to test the specific gravity using both large and small pycnometers. Summary is presented in Table 6 and 7.

5.1 *Improvement with lateritic soil*

Table 6. Specific gravity of MSW improved with lateritic soil

Lateritic soil %	MSW %	G_s using small pyknometer	G_s using large pyknometer
0	100	1.80	2.10
5	95	1.88	2.23
10	90	1.92	2.25
20	80	1.97	2.27
40	60	2.00	2.30
60	40	2.18	2.37
80	20	2.32	2.42
100	0	2.44	2.48

5.2 *Improvement with quarry dust*

Similar to the data available in Table 6, Table 7 was prepared for quarry dust too.

Table 7. Specific gravity of MSW improved with quarry dust

Quarry dust %	MSW %	G_s using small pyknometer	G_s using large pyknometer
0	100	1.79	2.1
5	95	2.08	2.11
10	90	2.14	2.14
15	85	2.22	2.34
20	80	2.24	2.34
40	60	2.32	2.48
60	40	2.41	2.41
80	20	2.53	2.52
100	0	2.63	2.56

6 STRNEGTH CHARACTERISTICS OF IMPROVED MSW

Strength characteristics were tested using direct shear apparatus under different moisture contents. It was decided to prepare samples for those testing as ±5% OMC and OMC. Corresponding results for OMC are given in Tables 8, 9, 10 and 11. Results of the strength properties are illustrated in Figures 2 and 3.

6.1 *Lateritic soil*

Table 8. Strength properties at OMC

Percentage of lateritic Soil	Maximum dry Density (kg/m^3)	Optimum Moisture Content (%)	*At Optimum Moisture Content*	
			Friction Angle, ϕ	Cohesion (kN/m^2)
5	1395	24.0	4.5	2.55
10	1414	20.1	4.7	2.85
40	1493	20.5	4.5	3.25
60	1675	17.0	5.5	3.65
100	1845	14.3	5.5	3.9

Table 9. Strength properties at ±*5% OMC*

Percentage of lateritic soil	At -5% of OMC		At +5% of OMC	
	Friction Angle, ϕ	Cohesion (kN/m^2)	Friction Angle, ϕ	Cohesion (kN/m^2)
5	2.51	3.8	6.33	2.65
10	3.19	3.7	5.39	3.55
40	5.42	3.6	5.29	0.40
60	3.26	6.2	6.60	1.35
100	3.20	5.55	3.12	3.20

6.2 *Quarry dust*

Table 10. Strength properties at OMC

Percentage of quarry dust	Maximum dry Density (kg/m^3)	Optimum Moisture Content (%)	*At Optimum Moisture Content*	
			Friction Angle, ϕ	Cohesion (kN/m^2)
5	1336	23.5	4.8	3.42
10	1375	25.0	5.1	3.70
40	1572	18.0	5.1	4.54
60	1693	14.0	4.4	4.60
100	1900	9.60	5.8	4.60

Table 11. Strength properties at ±*5% OMC*

Percentage of quarry dust	At -5% of OMC		At +5% of OMC	
	Friction Angle, ϕ	Cohesion (kN/m^2)	Friction Angle, ϕ	Cohesion (kN/m^2)
5	5.11	2.84	6.23	2.98
10	5.83	2.40	6.77	3.13
40	4.71	4.50	6.77	3.16
60	6.23	2.30	5.86	4.60
100	4.61	3.17	5.18	5.04

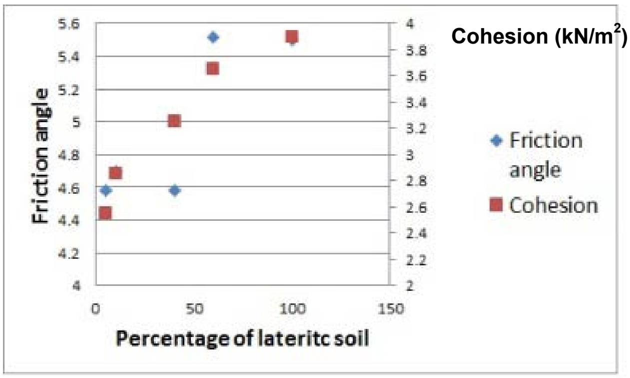

Figure 2. Variation of strength properties with the addition of lateritic soil

7 CONCLUSIONS

Considerable increase in compaction properties and strength could be observed with the addition of lateritic soil/ quarry dust. This application is viable in situations where a need arises to use either lateritic soil or quarry dust. In such situations, these results could be used depending on the compaction and strength requirements. However, it has to be

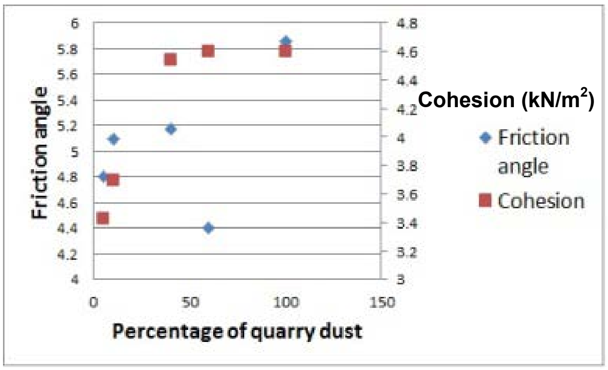

Figure 3. Variation of strength properties with the addition of quarry dust

noted that there could be a certain cost embedded with mixing. Considering the advantages with minimum environmental damages due to mining of lateritic soil or quarry dust and reusing of MSW for engineering applications, this could be treated as a valuable finding for a developing country like Sri Lanka.

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