Development of an Undisturbed Method to Measure Density of Improved Municipal Solid Waste using Heavy Tamping

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ABSTRACT: The core-cutter method can disturb a sensitive municipal solid waste (MSW) sample when measuring dry density of the soil. A mechanism has been developed to reduce this disturbance significantly, thus trying to obtain an accurate value for the dry density. The "resistance to the penetration" parameter of the soil was used as the theoretical background to develop graphical solution. An instrument was developed to measure penetration per blow value and it was calibrated with actual dry densities using Proctor compaction test. This mechanism was used to measure the compaction effect of heavy dynamic compaction, used in a pre-determined grid pattern on a prepared MSW sample.

1 INTRODUCTION

The heavy dynamic compaction (HDC) can be used to improve the mechanical behavior of the soil layers underneath. This technique involves dropping heavy weight on the surface of a land from a selected height, following a pre-defined grid pattern. This compaction method is used in Sri Lanka to improve the ground strength characteristics of MSW in open dump landfills*(Kumar & Vijay, 2001)*

In connection with investigations of the heavy dynamic tamping compaction method to improve the ground condition in abandoned dump sites, this research is carried out to study the feasibility of adopting the Standard Penetration Test (SPT) mechanism to construct relationships between blow count, penetration depth, moisture content and dry density of Municipal solid waste samples (Skempton, 1936).

This method relates to an instrumental mechanism useful in determining dry density of a MSW sample and particularly on undisturbed method to indirectly determine the density of a point located on the sample. Considering the possibility of developing a graph for dry density vs penetration per blow for a known moisture content, the mechanism can be calibrated to measure a significant range of dry densities for a known moisture content.

The instrumental mechanism has been improved by standardizing the energy transferred from the hammer weight to the penetrating rod. For these measurements, energy ratio ER_r is assumed as 45% for a donut shape drop weight to accommodate a correction on blow count (N) to a standard ER of 60% (Yould, Bartholomew, & Steidl, 2008).

This research presents a method to identify an effective grid pattern to carry out a heavy tamping on a predefined MSW sample. The ground improvement can be known by measuring dry density of identified locations of the sample, prior and after the compaction (Warnasuriya & Nawagamuwa, 2015).

2 OBJECTIVE

I. To develop an undisturbed method to measure dry density of a MSW sample

II. To identify the best grid pattern for HDC and comparison of the results obtained from core cutter method

3 METHODOLOGY

After conducting a comprehensive literature, resistance to penetration of a soil sample was considered as the parameter to develop the mechanism.

3.1 *General considerations*

In order to evaluate the above parameter, the procedure of SPT has been adopted to develop an apparatus with following considerations.

a) Composition of MSW
MSW consists of plastic upto 3.2%, 6.7% of glass, 13.4% of cemented material, 5.7% of gravel(>9.5mm) etc.
(Kawamoto, et al., 2015)
b) Energy input and Energy ratio for a donut type drop weight. (Aggour & Radding, 2001)

c) Blow count as N with the total penetration of the rod (Daniel, Howie, & Sy, 2003)

d) Proctor compaction test procedure to calibrate the apparatus readings with accurate density values.

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3.2 *Aspects of the apparatus*

The research with an ancillary objective of developing a graph of dry density against penetration per blow for known moisture content, the apparatus has been made to measure the independent parameter effectively. It consists of two parts as shown inFig.1 and Fig.2.

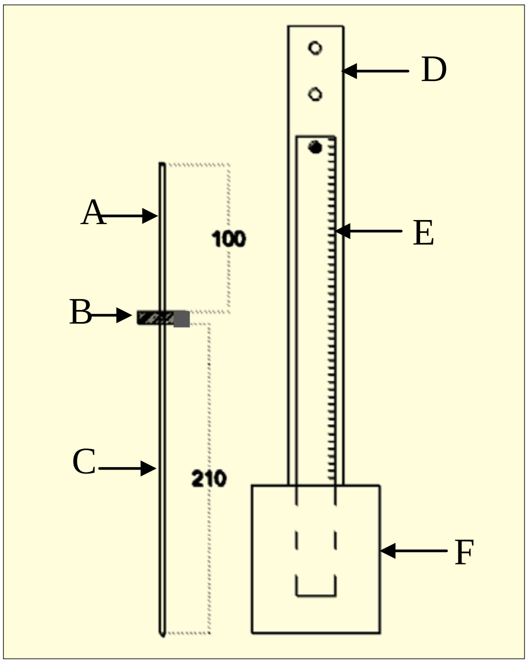

Figure2.Penetration measuring instrument

Drop weight = 57 g
Drop height = 100 mm
Diameter of the rod = 3 mm
Penetrating tip angle = 600
Maximum measureable penetration = 210 mm

A – Drop height
B – Drop weight with anvil and indicator
C – Penetrating length
D – Wooden plate with screws to hold ruler
E – Steel ruler (30cm)
F – Wooden base

Figure 1. Drop weight, anvil and indicator

4 ANALYSIS

4.1 *Adopting Proctor compaction test*

Standard Proctor compaction methodology was adopted to calculate the dry density of the MSW sample. But deviating from the standard methodology, the number of blows per layer were increased without changing the moisture content. This was done using the following procedure.

4.1.1 Procedure for the Test 1

4.1.1.1 Preparation of MSW soil sample

The material percentage of the sample passing through the 4.75mm sieve was 10.8%. The material percentage of the sample passing through 19mm sieve was 2.1% as an average. The SPT(ASTM D698) suggests to use Method C, which is to use 152.4mm diameter mould to carry out the compaction test. Average moisture content of the samples were taken as 11%.The results obtained from the compaction tests are shown in Table 1.

4.1.2 Procedure for Test 2 and Test 3

The Proctor compaction test was done to obtain the results of test 1 by increasing the number of blows of with each sample without much delay since moisture content has to be a constant. Larger particles such as coarse aggregate, plastic, rubber, glass pieces block the penetration of the rod while doing the penetration test. Therefore the remaining solid particles from the 4.75mm sieve is deliberately removed from the sample to reduce the practical difficulties. Table 1 shows the rammer blow count per layer while Table 4 and Table 5 shows the dry density values.

Table 1. Applied blows per layer in Proctor compaction test

Test no.	Blows per layer			
	sample 1	sample 2	sample 3	sample 4
1	25	30	35	40
2	15	20	25	30
3	15	20	25	30

Table 1 shows the number of blows applied by the rammer for each layer in relevant test numbers.

4.2 *Penetration Test*

Penetration test was carried out after every Proctor compaction procedure for a MSW sample, using the developed instrument. Number of blows (drops of hammer) and the penetrated depth was measured. Approximately 1cm length from the surface of the

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soil sample was neglected since the penetration can be disturbed by the inclination of the rod.

Table 2. Penetration readings

Penetration depth reading (mm)	No. of blows
12	7
13	9
14	9
15	9
16	11
17	10
18	14
19	15
20	18
Total Penetration= 80mm	Total blows= 102

Above table shows a specimen of measurements and calculation of penetration per blow value.

Penetration per blow (P/b) $=\frac{80}{102} = 0.78$ mm

This value was plotted against the dry density value obtained by Proctor compaction test in a graph such that the data sets can be separated according to the moisture content.

4.2.1 Results

Table 3. Test 1 results

Avg. moisture content = 11%				
Sample No.	P/b (mm)	M.C. (%)	Bulk density (kg/m^3)	Dry density (kg/m^3)
1	2.75	10.8	1885	1702
2	1.70	10.97	1977.5	1782
3	1.15	11.15	2074	1866
4	0.81	11.3	2171	1951

Table 4. Test 2 results

Sample No.	P/b (mm)	M.C. (%)	Bulk density (kg/m^3)	Dry density (kg/m^3)
Average moisture content = 13%				
1	0.77	12.7	1466.1	1297.4
2	0.56	13.13	1510.6	1336.8
3	0.47	13.02	1554.03	1375.24
4	0.37	12.92	1602.75	1418.36

Table 2. Test 3 results

Sample No.	P/b (mm)	M.C. (%)	Bulk density (kg/m^3)	Dry density (kg/m^3)
Average moisture content = 18%				
1	0.81	17.81	1789.3	1516.1
2	0.49	18.19	1872.0	1586.4
3	0.39	18.09	1923.4	1629.7
4	0.21	18.03	2103.7	1782.2

4.2.2 Penetration vs dry density graph

The data in Table 3, Table 4 and Table 5 were used to plot the penetration per blow against the dry density graph as shown in Fig. 3.

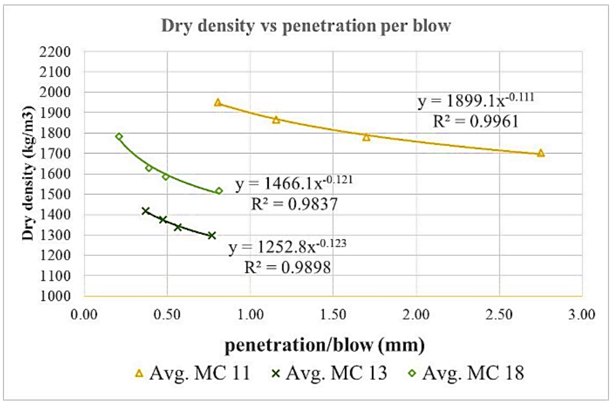

Figure 3. Dry density vs Penetration/blow

4.2.3 Log graph

Graph shown in the Fig.3 is presented as $Y = \frac{m}{x}$ equation. To obtain a linear equation as first degree polynomial of penetration per blow, a log graph is presented as shown in Fig.4 with a linear relationship between parameters.

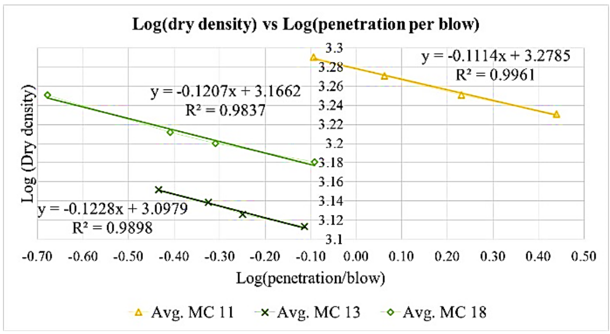

Figure 4. Log(dry density) vs Log(penetration/blow)

4.3 *Compaction test*

As the second objective of the research, the comparison of dry density values obtained from the developed penetration test method and the core cutter method is carried out as follows. (Warnasuriya & Nawagamuwa, 2015)

4.3.1 Preparation of the MSW sample

The sample was prepared by adding water until a familiar moisture was shown in the soil. Later MSW was added to the transparent box as a free fall from 1m height. Then sample was compacted with a roller weight by hand in perpendicular directions.

A 1kg weight with a 50mm diameter was dropped 12 times from a height of 750mm. The grid arrangement and spacing (mm) are shown in Fig. 5

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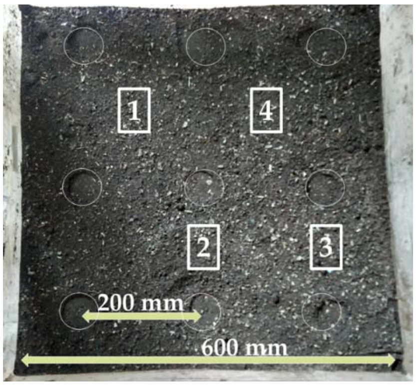

Figure 5. Heavy tamping grid pattern

The test results are shown in the Table 6. The average moisture content obtained was 14.2%. Therefore the equation of the line corresponding to the moisture content 13% was used to calculate the dry density. Figure 6 shows the ratio of dry density of the location after compaction divided by the dry density before the compaction.

Table 3. Density values before and after compaction

Location no.	Penetration/blow value(mm)	Dry density (kg/m^3)
Before dynamic compaction		
1	7.5	978.23
2	7.545	977.52
3	5.714	1011.45
4	7.364	980.43
After dynamic compaction		
1	4.2	1050.43
2	3.88	1060.7
3	4.25	1048.9
4	4.17	1051.35

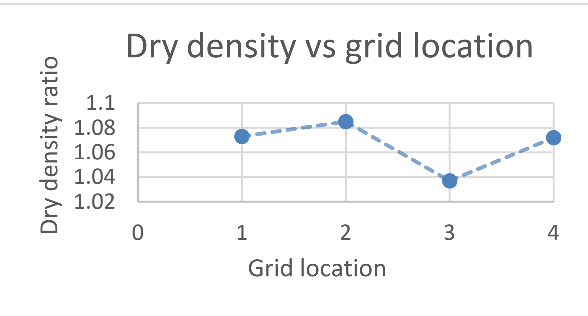

Figure 6. Dry density ratio vs location number

5 CONCLUSION

Test data of this research show “the resistance to the penetration” parameter of the soil can be used to obtain the dry density of the soil in a preferred location.

After the calibration of the developed instrument to a specific soil type, the graphs can be used to calculate an unknown density. This method gives reliable output only to a range of density and moisture content values. When the density is very low and moisture content is high, satisfactory Penetration per blow values cannot be obtained.

The heavy dynamic compaction on the tested grid pattern shows a higher compaction at the grid location number 2 and the least improvement on location number 3. A higher accuracy could be achieved if initial layer compaction was done with a better method than the roller compaction. A Penetration per blow value falls between 0.5- 4 (mm) can give an accurate value as the dry density.

Whatsoever, calibration graph should be improved with more data sets to accommodate more moisture content values to make assumptions more satisfactory in dry density calculation.

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