MSW-leachate-soil-interactions and its effect on shear parameters using admixture

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ABSTRACT: Reclaiming the MSW from landfill sites as soil has become a necessity in this modern era. With modernization, the complexity of the waste generated along with its interactions with surrounding geosphere has become a major issue. The various complex interactions between MSW surface and leachate constituent depend upon the chemical and physical features of both MSW and leachate. This paper, with its laboratory investigations has tried to gain an insight on shear response of dumped MSW from Pirana landfill, Ahmedabad. Since last 31 years the MSW disposed at Pirana landfill, in the city of Ahmedabad, India has grown to become mountains of waste of 15 – 20 meters creating an alarming issue to the health and safety aspect of the local environment. The potential cementitious properties of such MSW is tried to enhance by addition of leachate. Variation in the shear parameters are studied by using its own leachate in proportions of 25%, 50%, 75% and 100% of OMC and tried to enhance the shear parameters with addition of chemical admixture on trial and error basis. Shear parameters are compared with and without leachate and it is observed that increase in leachate proportion increases cohesion value and angle of internal friction. Soil-leachate-MSW interaction plays vital role in changing shear parameters and same is reflected by post chemical analysis.

KEYWORDS: Shear parameters of old dumped MSW, leachate re-use, MSW – leachate interactions.

1 INTRODUCTION. FIRST LEVEL HEADING

The vaious complex interactions between MSW-Leachate –Soil basically depends upon the chemical as well as physical charateristics of each participant. In the presence of different physical and chemical contaminants there is always a possibility for interaction between them.

The per capita waste generation rate in India has increased from 0.44 kg/day in 2001 to 0.5 kg/day in 2011, the total MSW generated in urban India is estimated to be 68.8 million tons per year (TPY). India, one of the fastest growing economies in the world, faces a challenge of municipal solid waste (MSW) management when it comes to finding suitable locations for final disposal. MSW is known to be a heterogeneous material of varying constituent types and dimensions, containing large quantities of highly degradable organic and inorganic waste contents. The Pirana landfill in Ahmedabad is one of the biggest dump yards in the city being spread over an area of 65 acres of land and having three huge mountains of dumped waste scaling to heights of 15 to 20 meters. To utilize these huge quantities of waste which contains large amount of soil in the form of highly degraded organic and inorganic contents, as a Quality controlled engineering material becomes a practical solution to the geo-environmental problems. To use this as mentioned 'Quality controlled geo- material' few of the parameters which play crucial role are the physical composition, MSW maturation, chemical characteristics and its shear parameters. Over the past few years there has been many studies pertaining to use landfill as bio-reactors by re-introducing leachate and moisture and accelerating the decomposition rate. Leachate addition leads to the modification of physical, chemical and biological properties of the MSW. The MSW-leachate interactions have impact on the physico-chemical parameters such as density, void ratio, specific surface area and cation exchange capacity. Even though there has been researches done on the shear strength of municipal solid waste by Kavazanjian et al. (1995), Gabr and Valero (1995), and Kavazanjian (2001), K.R Reddy (2009), none attempted to explain the changes in shear strength of the waste with leachate re-use, relating it to the interactions between the dry MSW and leachate, which brings about a physical and chemical transformation in both the partners.

In this study, dumped MSW of more than 20years was collected form Pirana Landfill in Ahmedabad city. It was analysed for geotechnical properties and shear parameters by direct shear test. Most importantly it involves re-use of the leachate obtained from the lysimeter in the laboratory into the MSW at different amounts and to study its effect on shear strength parameters.

2. MATERIAL AND METHODOLOGY

2.1 Procurement of MSW from pirana landfil

MSW was collected from Pirana dumpsite, at Ahmedabad city of Gujarat. For the past 30 years the 84 acres of landfill site is maintained by the local municipal body for dumping.

Figure 1. Excavating and screened MSW from Pirana

A sample of 1 kg was immediately taken into an airtight plastic container to find the in-situ water content. The rest of the material was then sieved with a fabricated simple screen of sieve size 12 mm with specific dimensions (l=90cm, b=65cm, d=15cm). Big stones, torn cloth pieces and plastic sheets were segregated in the screening process. Around 23 bags of 35 kg each such segregated MSW sample was collected and brought to the Soil Lab of L.D Engineering College.

2.2 Tests Methods

The MSW which was screened and collected was tested for the index properties in the laboratory according to the IS codes. Leachate was thereafter collected from the lab scale lysimeter.

The shear tests were conducted by preparing samples at OMC and MDD with different proportions of leachate in total moisture content added.

2.3 Index Properties of MSW

The mechanical behaviour of MSW are strongly influenced by the particle size distribution of waste. This was carried out as per IS 2720 (Part 4): 1985. It was classified as well graded sandy soil. This gave an encouragement for using MSW as geo material and to go further with the testing.

Table 1. Index Properties of MSW

Index Properties	*Description*
Onsite water content (IS 2720-2)	31.4%
Specific gravity (IS 2720-3)	2.53
Sieve analysis (IS 2720-4)	Cu=7.132 Cc=1.03
OMC (IS 2720- 7)	18.1%
MDD (IS 2720- 7)	16.16 kN/m^3

2.4 *Laboratory setup for Leachate Collection*

There were two identical reactors (columns), loaded with un-shredded solid waste each. A 5 cm thick layer of gravel was placed at the bottom of each column to simulate a leachate collection system, and to prevent clogging of the leachate withdrawal outlets.

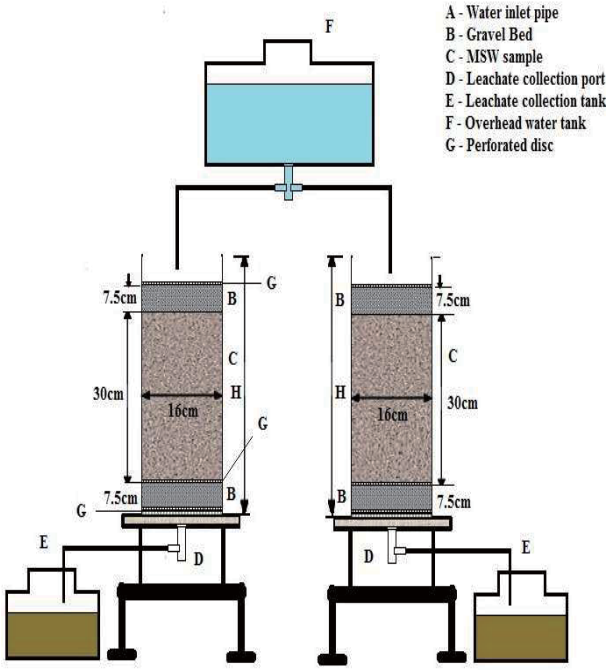

Figure 2. Schematic diagram of lysimeter (leachate collection system)

A pair of perforated discs with filter papers was placed at top and bottom of this gravel layer. Solid waste was loaded in layers and compacted using a hammer. A second gravel layer was placed on top of the waste to simulate an upper drainage layer and further to provide an even distribution of the recirculated leachate. The nominal size of the gravel used for both filter layers range from 10mm passing and retained in 4.75 mm sieve. Finally perforated disc was placed on top of each cell.

2.5 Pre - chemical analysis of MSW and leachate

Proximate analysis was carried out according to ASTM standards E790 (ASTM 2004a), E 830 (ASTM 2004b), and E897 (ASTM 2004c) to determine moisture content, % ash content, % volatile matter content, and % fixed carbon. The ultimate analysis was conducted to determine carbon, hydrogen, nitrogen, sulphur content in dry samples by a CHNS analyser according to ASTM D3176-09(ASTM2002).The pH of MSW was determined according to IS 10158-1982.

Leachate samples were analysed for pH, total solids (TS), total dissolved solids (TDS), chemical oxygen demand (COD), and biological oxygen demand (BOD) and heavy metals (Fe, Pb, Cr, Cd, Cu, Ni, Al, Mn and Zn).

2.6 Shear Test on MSW

Shear parameters were determined by box shear test according to IS 2720 (Part13):1997. In this, sample of 6cm x 6cm x 2cm size was prepared obtained by remoulding the sample to the maximum dry density (MDD) and at optimum moisture content (OMC). Samples were prepared by replacing the amount of water from the moisture content added with 25%, 50%, 75% and 100% leachate. The MSW soil taken was oven dried at 60◦ C passing through 4.75mm sieve and retained of 0.075mm sieve.

2.7 Post - chemical analysis of MSW and leachate

In post chemical analysis EDAX test were conducted for seven samples which included sample without leachate, samples with 10%, 25%, 50%, 75% and 100% leachate in MSW.

3. RESULTS AND DISCUSSIONS

In this study the dumped waste is around 20years old. The moisture content was 31.4% and organic content was 18.44%. Moisture content was determined at 60°C temperature to avoid combustion of volatile matter. The organic content was determined by heating MSW sample in muffle furnace for about 440°C according to ASTM D2974.

The specific gravity is inversely proportional to the organic content therefore the increase in specific gravity indicates reduction in organic content in landfilled MSW (K.R. Reddy, 2009). The specific gravity was found out to be 2.53. It was not possible to conduct liquid limit and plastic limit tests.

The compaction test was carried out as per IS2720 (part 7): 1986 and the Specific gravity was found out by IS: 2720 (Part 3/Sec 1) – 1980. Compaction test were conducted without leachate and then by varying leachate proportions in the total moisture i.e. 25%, 50%, 75% and 100% of moisture content. Also tests were conducted by adding 2% $CaCO_3$ into the leachate which gave maximum dry density.

The maximum unit weight in the present study sample without leachate was 16.16kN/m^3. Increase in unit weight is due to the decrease in particle size, breakup of particles due to recirculation of leachate. In field this increase can be attributed to the confining pressure or reduction in particle due to degradation at greater depths. The dry density increased to 16.5kN/m^3 when the moisture added during the compaction test contained 25 % leachate. This proportion of leachate showed the maximum value among other proportions of leachate added to MSW.

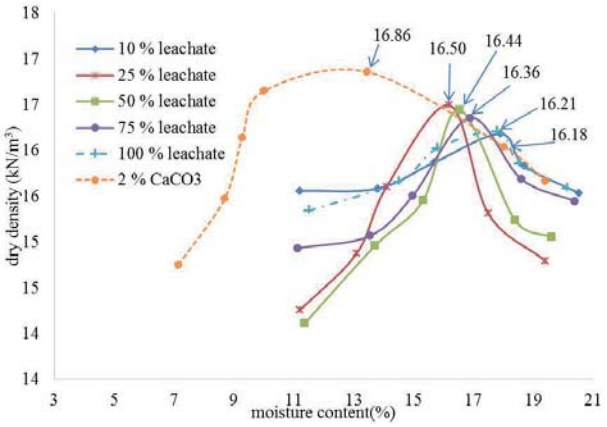

Figure 3. Compaction curve for MSW + leachate (various proportions) and MSW + Leachate + $CaCO_3$

The dry density of MSW + Leachate mixture reduced thereafter for 50%, 75 %, and 100% replacement of water from leachate. Results shows that for 100% replacement of water with leachate was least but it still was slightly more than that for which no leachate was added (i.e. to say 100% water as moisture). Furthermore when 2 % of $CaCO_3$ (by dry weight of MSW) is added into leachate with 25% leachate content it increased the unit weight 16.86kN/m^3.

The results of Pre-chemical analysis of MSW was found out in terms of % ash content, % volatile matter content, % fixed carbon, carbon, hydrogen, nitrogen, sulphur content to be as 6.55%, 18.44%, 14.83,% 11.99%, 0.04%, 1.28%, 0.042%. The results of Elemental analysis done by Inductively Coupled Plasma test showed the presence of Fe (1.9107mg/l), Cr (0.0304 mg/l), Al (0.4024mg/l), Mn (0.2332mg/l), Zn (0.0316 mg/l), Ni (0.3351 mg/l), Cu (0.0633 mg/l), Pb (not detected), Cd (not detected).

The results of the direct box shear tests show that the cohesion ranged from 1.2kPa – 28 kPa. The cohesion in the soil can be attributed to the organic materials. The friction angles in this study ranged from 36-43°. The higher value of internal friction can be firstly attributed to its well graded sandy nature. Also these are higher than the other researcher, which can be due to the matrix of material (soil-waste). Landva and Clark, 1986 have found the value of internal friction and cohesion of old refuse to be 42° and 19kPa respectively. Gabr and Valero (1995) have suggested that the shear parameters of waste are dependent on the composition, age, size and density. R. Reddy (2008) has showed cohesion value ranging from 31 to 64 kPa and friction angle from 26 to 30°. The friction angle increased to the initial increase of leachate content but it then decreased when the leachate addition was 100%.

As the MSW is in dry condition the value of internal friction is more and cohesion is very less. But as moisture is added at OMC, the particles of MSW come close to each other, thus increasing the value of cohesion to nearly 6 times for the MSW sample passed through 10mm sieving and about twice for MSW passed through 4.75mm sieve. By addition of leachate there is again an increase seen in the cohesion. This can be attributed to the MSW and leachate interactions. When leachate is added into MSW, the metal ions (electron pair acceptor) present in leachate binds with MSW (having organic ligands- electron pair donor). As organic content is less in our study, with more addition of leachate, there is a deficiency of enough ligands to interact and so cohesion decreases comparatively as the water of OMC is replaced with leachate. The value of cohesion and internal angle decreases with addition of leachate in 50%, 75%, and 100% proportions.

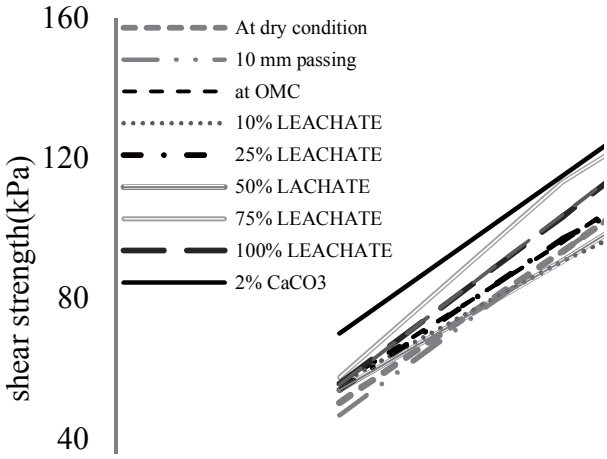

Figure 4. Comparison of shear stress v/s normal stress for different conditions

But still the value of cohesion for 50%, 75%, and 100% leachate proportions were 1.64 times, 1.33 times, and 1.24 times respectively for that of MSW without leachate. The optimum value of leachate is studied to be 25 % of the moisture content in this study. $CaCO_3$ as chemical admixture is added which is a cementitious materiel and has a tendency of surface adsorption. Since it binds the particles and causes cementing action, the value of cohesion and angle of internal friction gets enhanced. Thus, addition of $CaCO_3$ as chemical admixture improves the overall shear strength of MSW.

EDAX test were conducted for seven samples which included sample without leachate, samples with 10%, 25%, 50%, 75% and 100% leachate in MSW and MSW with 2% $CaCO_3$ with moisture content containing 25% leachate and MSW without leachate. The results of the test gave microscopic image of the tested samples, graphical representation of the peak intensities of the elements identified during the test and the summary of weight of each element present in the sample tested.

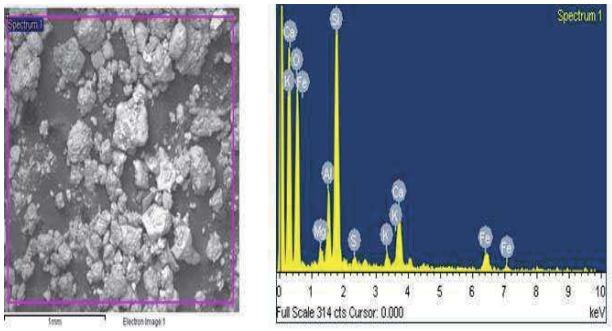

Figure 5. Microscopic image of MSW surface without leachate and its peak intensities of elements

The figures 5 to 8 show the effect of addition of leachate in different proportions into MSW and also addition of 2% chemical admixture ($CaCO_3$) in to MSW. The results of the EDAX test shows that the virgin MSW and MSW after addition of leachate showed the presence of Si, Fe, Al, Mg and K which is the mineral present in any soil. This shows that MSW, though being material which is disposed away, after few years of geological cycles contains minerals such as that of any soil. The images showing peak intensities show that percentage weight of Magnesium (Mg^{+2}), Potassium (K^{+}), Calcium (Ca^{+2}), Silicon (Si^{+4}) increased in different trends when leachate in different concentration was added to the MSW.

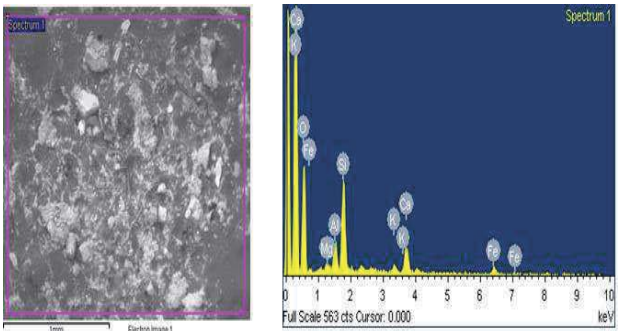

Figure 6. Microscopic image of MSW surface with 25% leachate and its peak intensities of elements

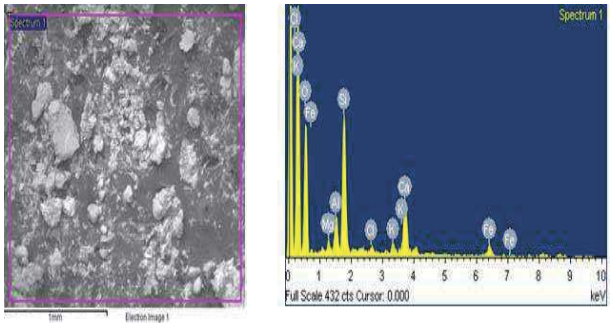

Figure 7. Microscopic image of MSW surface with 100% leachate and its peak intensities of elements

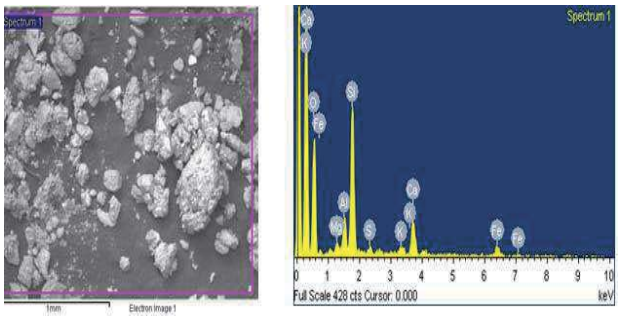

Figure 8. Microscopic image of MSW surface with 2% $CaCO_3$ in 25 % leachate and its peak intensities of elements

When leachate is added to the soil the monovalent and divalent cations such as Ca^{2+}, Mg^{2+}, Na^{+} ions are adsorbed on the surface. This forms covalent bond between the particles and thus decreases the inter pores present between the MSW. These bonds are complex bods which have usually stronger than the electrostatic bonds due to cation exchange process. The Oxygen (O^{-2}) element is found to be 57.56% for MSW without leachate whereas when leachate is added in 25%, 50% and 100% proportion, the oxygen content increased comparatively. Thus anion and cation contents increase with leachate addition, which shows good cation-anion exchange capacity of MSW. The EDAX spectrum result for specimen with $CaCO_3$ clearly shows highest presence of calcium, where calcium reacts with water and leachate. This calcium get adsorbed to the surface of the MSW particles providing cementitious effect.

4. CONCLUSIONS

Based on the tests the following can be concluded:

- The MDD value of the present study sample was 16.16 kN/m^3 and OMC was 18.1% corresponding to 18.44% organic content. With the addition of leachate the maximum dry density of MSW increased to highest value of 16.50kN/m^3 when 25% of the moisture content contained leachate. The MDD value increased to 16.86kN/m^3 when $CaCO_3$ was added as 2% of dry weight of MSW.
- The specific gravity was found to be 2.53 which is less compared to the sandy soils having values ranging between 2.6-2.9.
- The pre-chemical analysis of leachate showed the presence of heavy metals such as Iron (Fe), and Aluminium (Al), and Nickel (Ni) dominated. The high value of suspended solids is expected to also be responsible in increasing the cohesion of the material.
- The cohesion (c) of the MSW increases with addition of the leachate initially but decreased for samples with 50%, 75% & 100% leachate addition. But still the value of cohesion for 50%, 75%, and 100% leachate proportions were 1.64 times, 1.33 times, and 1.24 times respectively for that of MSW without leachate. The increase in cohesion by adding 25% leachate is 1.75 times that in case at OMC without leachate. In comparison with the shear parameters in case of OMC without leachate, the addition of chemical admixture $CaCO_3$ in 2% of the dry MSW sample for leachate solution of 25% showed twice the amount of increase in the cohesion.
- The values angle of internal friction (ϕ) value showed increase in the value at 25% and 50% leachate concentration, but a decrease in value was seen at 75% and 100% leachate addition. The value of angle of internal friction for 25 % leachate addition showed the best result and this indicates that the addition of 25% of optimum moisture content with leachate improved the shear parameters of MSW.
- EDAX results indicate that certain constituents of MSW have strong chemical interaction with the soil mineral.

5 ACKNOWLEDGEMENTS

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