# GEOTECHNICAL PROPERTIES OF AN OLD WASTE DUMPSITE: A CASE STUDY OF SURAT

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***Abstract***— ***Land cost in urban area is increasing day by day as a result of urbanisation, industrialisation and population explosion in developing countries like India so it became a challenging effort to put out a strong engineering solution for the sustainable structural stability at the costly places in the urban areas of covered land filling. Considering the vision of a sustainable development, the challenge of the geotechnical community is to supply more environmental friendly construction techniques, reduce the use of natural resources and promote the use of less harmful products. Solid waste disposal in landfills is the most economical form of disposal of waste particularly in the developing country as compared to incineration. Landfill Engineering Design Problems involve various aspects like determination of geotechnical properties of waste, land fill settlement, slope stability, field performance of landfill cover and liner systems, seismic behavior of the disposal site during earth quake etc. As the land cost is increasing tremendously and decreasing availability of good construction site is building up pressure on the engineers to utilize even old landfill sites which covers a large area. If it is to planned to develop such landfill site for the purpose of infrastructure it is necessary to determine geotechnical properties of such landfill site. In this study, geotechnical properties of an open waste dump site at Surat city is evaluated to check the feasibility of development of housing for economically weaker section, which otherwise constructed on very costly urban area.***

*Index Terms*—**Landfill, Geotechnical Properties, Urbanisation**

## I. INTRODUCTION

As a result of urbanisation more and more people choose to live at urban area and more and more people continuously migrating from rural area to urban area. Urbanization rate is continuously increasing due to industrialisation. Another major problem for developing countries is population explosion. As a result of this in urban area more and more land is being used for infrastructure development and good construction site utilized rapidly. It became a challenging effort to put out an effective engineering solution for the sustainable structural stability at the costly places in the urban areas like landfill site. Solid waste disposal in landfills is the most preferred solution for the safe disposal of solid waste than any other disposal method. Landfill Engineering Design Problems involve various aspects like determination of geotechnical properties of waste, land fill settlement, slope stability, field performance of landfill cover and liner systems, seismic behavior of the disposal site during earth quake etc. A landfill is a system that is designed and constructed to dispose of discarded waste by burial in land to minimize the release of contaminants to the environment. Till very recent times, landfill technique has been used simply to dump the municipal solid waste, so not ample care was taken in their construction and maintenance. With rapid industrialization the concept has changed its shape. As uncontrolled landfills have caused pollution in environment, regulations have been imposed on landfill location, site preparation and maintenance. Some level of engineering has been made mandatory for landfills. The major disadvantage of landfill is it required large area. If the landfill area can be improved and can be used for dwelling purpose, plenty of area can be available, but it will become a challenge for the environmental geotechnical engineers to put out strong engineering solution and develop new technology so such dump site or landfill site can be utilised. In this direction the first and foremost step is to determine geotechnical properties of landfill site.

Landfills may include internal waste disposal sites (where a producer of waste carries out their own waste disposal at the place of production) as well as sites used by many producers. Many landfills are also used for other waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling). The term 'landfill' can be treated as synonymous to 'sanitary landfill' of Municipal Solid Waste, only if the latter is designed on the principle of waste containment and is characterized by the presence of a liner and leachate collection system to prevent ground water contamination. The term 'sanitary' landfill has been extensively used in the past to describe MSW disposal units constructed on the basis of 'dump and cover' but with no protection against ground water pollution.

Landfill is the ultimate disposal process for Municipal Solid Waste (MSW) management. The quantity of MSW for land disposal can be substantially reduced by setting up of waste processing facilities and recycling the waste materials as much as possible. It is estimated that the inert wastes for landfill occupies 40-55% of the total wastes depending upon type of city.

Waste is an unavoidable by-product of human activities. It may be generated in form of solids, sludges, liquids, gases and any combination thereof. With increasing industrialisation the quantity of waste has increased immensely. Depending upon the sources of generation, some of these wastes may degrade into harmless products whereas others may be non –degradable and hazardous. Municipal solid waste (MSW), also called urban solid waste, is a waste type that includes predominantly household waste (domestic waste) with sometimes the addition of commercial wastes collected by a municipality within a given area. They are in either solid or semisolid form and generally exclude industrial hazardous wastes. Municipal solid waste comprises of wastes from households including garbage and rubbish, sanitation waste and street sweepings. MSW also includes wastes and discarded materials from institutions and commercial complexes and debris from construction and demolition activities. Municipal landfills are heterogeneous mixtures of wastes which are primarily of residential and commercial origin. The composition of the fill material will depend on the type of commerce and industry. Typically, a municipal landfill consist of food and garden wastes, paper products, plastics and rubber, textiles, wood. Ashes and the soil used as cover material. More than 50% of the municipal solid waste, by weight, is paper and yard waste. Most of the waste landfill and the amount of production of MSW is about 1.36 Kg per capita per day. Larger objects such as tree stumps, refrigerator, automobile bodies and demolition waste may also be present in MSW. The proportion of these materials may vary from one region to another. The household hazardous waste is mostly landfill or discharged into sewer or septic systems. Such waste may include cleaners, automotive products, paints and garden products. The constituents of the landfill may vary considerably when wastes from different countries are considered. Typical composition of MSW is as per table-1

## II. COMPOSITION OF MSW

Table 1 Typical Municipal Waste Composition Percentage by Weight

| Component | Country or City | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* | *9* | *10* | *11* | *12* | *13* | *14* | *15* | *16* | *17* | *18* |
| Metals | | 1 | 1 | 9 | 9 | 3 | 3 | | 3 | | 5 | 7 | | 2 | 8 | 10 | 7 | 5 |
| Paper, and paper board | 37b | 25 | 5 | 45 | 42 | 33 | 3 | 38 | 10 | 14b | 22 | 32 | 14b | 8 | 3 | 37 | 54 | 31 |
| Plastics | | | 1 | 2 | 2 | | | 8 | | | | 3 | | | | 7 | 2 | |
| Rubber, Leather, Wood | | 7 | 1 | | 3c | 7 | 2 | 12 | 4 | | 3c | 7 | | 3 | 1 | 6 | 2 | 4 |
| Textile | | 3 | | 1 | 1 | 10 | | | | | | 4 | | 4 | 2 | 2 | 2 | 2 |
| Food and Yard waste | 45d | 44 | 45 | 5 | 34 | 15 | 60 | 18 | 74 | 56d | 20 | 36 | 50d | 25 | 16 | 26 | 23 | 16 |
| Glass | | 1 | 1 | 11 | 8 | 10 | 2 | | 7 | | 6 | 4 | | 3 | 8 | 10 | 5 | 13 |
| Non-Food inorganic | 18e | 19 | 46 | 7 | 1 | 22 | 30 | 24 | 2 | 30e | 43 | 7 | 21e | 55 | 35 | 2 | 5 | 29 |
| 1, Australia; 2, Bangkok. 3, Beijing; 4, Berkeley, California; 5, Cincinato, Ohio; 6, Hong Kong; 7, Jakarta, Indonesia; 8, Japan; 9, Korea; 10, Madras, India; 11, New York City; 12, Singapore; 13, Spain; 14, Taiwan; 15, UK; 16,USA; 17, Wayne, NJ; 18, West Germany | | | | | | | | | | | | | | | | | | |
| b. Metal is included under paper and paper board. c. Wood only. d Includes wood, bones, etc, Sources: Sargunan et al., 1986;Aziz, 1986; Hillenbrand, 1986; Waste Age, 1986. | | | | | | | | | | | | | | | | | | |

The composition of garbage in India indicates lower organic matter and high ash or dust contents. It has been estimated that recyclable content in solid wastes varies from 13 to 20% and combustible material is about 80-85%. A typical composition of municipal solid waste is given below.

Table 2 Typical composition of solid waste of India

| Description | Percent by weight |
|---|---|
| Vegetable, leaves | 40.15 |
| Grass | 3.80 |
| Paper | 0.81 |
| Plastic | 0.62 |
| Glass, ceramics | 0.44 |
| Metal | 0.64 |
| Stones, ashes | 41.81 |
| Miscellaneous | 11.73 |

http://cpcbenvis.nic.in/newsletter/solidwastejun1997/jun97ii.htm

## III. GENERATION AND COMPOSITION OF SOLID WASTE IN SURAT CITY

Everyday, Surat generates 400 gms per capita per day of waste amounting to roughly 1100 metric tons. This is collected by SMC, private contractors and the rag pickers. About 70 % of the waste generated every day is contributed by households, shops and other commercial establishments. Just over 30 % of the total waste generated is recyclable. This comprises of paper, plastic, metal, brick stone and glass primarily. Combustible waste accounts for 22.75 percent of the total and organic waste is nearly 42 percent.

Table 3 Quantity of Waste Generated

| Source | Percentage |
|---|---|
| Households | 53 |
| Shops and Establishments | 16 |
| Vegetable/Fruit/Meat/Fish market | 14 |
| Construction and Demolition material | 8 |
| Biomedical waste | 1 |
| Hotel/Restaurant waste | 8 |
| Source: Surat Municipal Corporation, 2006 | |

Composition of waste generated depends upon the life style of city dwellers. The composition of waste in Surat city is given below in Table 4

Table 4 Composition of Waste

| Sr. No. | Characteristics | Unit | Result |
|---|---|---|---|
| 1 | Moisture | % | 60 |
| 2 | Calorific Value | Kcal/Kg | 740.4 |
| 3 | pH | - | 6.61 |
| 4 | Ash | % | 20.0 |
| 5 | Wooden Matter | % | 19 |
| 6 | Vegetable, Grass, Leaves | % | 24 |
| 7 | Food Waste | % | 13 |
| 8 | Dirt Sand & Stones | % | 11 |
| 9 | Clothes & Fabrics | % | 10 |
| 10 | Plastic Packing | % | 12 |
| 11 | Paper Packing | % | 8 |
| 12 | Metals | % | 1 |
| 13 | Glass | % | 2 |

Source: Surat Municipal Corporation, 2006

The Surat Municipal Corporation has been efficient in collecting the solid waste from all over the city. Zone wise solid waste generation in Surat city as well as prediction of solid waste generation in next 2 decades is given in Table 5

Table 5 Solid Waste Generation and its Prediction for Surat City

| Zone | Area | Solid Waste Generation | | |
|---|---|---|---|---|
| | *(sq. km)* | *2001 (MT)* | *2011 (MT)* | *2021 (MT)* |
| Central | 8.18 | 150.1 | 139.5 | 116.2 |
| North | 20.54 | 121.7 | 179.1 | 220.6 |
| East | 13.86 | 210.7 | 295.9 | 337.7 |
| West | 19.63 | 90.9 | 166.3 | 224.5 |
| South | 26.01 | 177.6 | 291.45 | 383.1 |
| South East | 9.1 | 59.2 | 97.15 | 127.7 |
| South West | 14.96 | 73.2 | 108.7 | 139.9 |
| Total | 112.28 | 883.5 | 1278 | 1549.7 |

Source: Surat Municipality Corporation, 2006.

## IV. Literature Review

Mylene Palaypayon et al. attempted to estimate the shear strength parameters of wastes and showed the simplified stability analysis of vertical cut slopes of landfilled wastes and gave conservative estimates for shear strength parameters of landfilled wastes. N. Dixon et al. carried out a summary of measured strengths and an assessment of variability are presented for seven generic interfaces common in landfill lining systems. Michael L. Leonard et al. evaluated Waste placement, initial compaction, stockpiling soils above waste, and use of ADCs (alternative daily cover) relative to short- and long-term airspace utilization. A proven method developed for predicting settlement, including the contribution of aerobic/anaerobic refuse decomposition. The decomposition predictions are based on waste composition and landfill gas (LFG) generation rates. Prem Singh measured settlement of refuse intermittently over a period of approximately 17 years at Envirowaste's Greenmount Landfill in East Tamaki, Auckland. Warren Pump's "FILLS" landfill settlement model has considered and its concept applied to determine more accurate long-term settlements at Greenmount. Observations confirmed Pump's prediction that rapid and possibly irregular initial settlement would be followed by a linear long term settlement on log time. also provided recommendations settlement allowance, cover thickness, finished cover grades and desirability of fixing finished levels in consents. Liu Jiangying et al. monitored Composition of refuse and analyzed in a large-scale experimental unit and established empirical formulas between composition and refuse age. It was predicted that half-life is 7 to 11 years for biodegradable matter, 9 to 12 years for organic carbon or volatile solid, 7 to 16 years for cellulose, and 4 to 6 years for total sugar. According to settlement model and empirical biodegradation formulas, it may be predicted that, 79.4% of biodegradable matter, 92.9% of total sugar, 72.7% of volatile solid and organic carbon, and 73.1% of cellulose will be biodegraded and 79% of maximum secondary settlement potential will occur in high stabilization situation,ie, approximately 21 years after final closure Gordon A. D.T. Bergado, et al. presented the case history of laboratory evaluation of the interface shear strength properties of various interfaces encountered in a modern day landfill with emphasis on proper simulation of field conditions and subsequent use of these results in the stability analyses of liner system. Claire Odud focused on the geotechnical aspects of the construction on closed landfill sites. A comprehensive literature review carried out of the current state of the practice of construction on closed landfill sites, typically MSW also addressed such topics as site improvement that is typically done before construction can begin. In addition design issues that need to account for the compressibility and low bearing capacity of the waste material underlying the construction were also discussed.

## V. About the site:

For research work the experimental work was to be carried out at waste dump site. For the research work waste land fill site located in Surat city near Sewage Treatment Plant is selected. The land fill site is on bank of Mithikhadi from Bamroli Road-Hegdevar Bridge to Althan -Bamroli road Bridge. The land is filled by garbage of varying depth of 1.00m to 5.00m at various length of bank. This site is discontinued since 2002. So out of this two landfill site Bhatar landfill site is selected, as dumping at the site is not continue. More details about Bhatar open waste dump site is as under.The filled bank length is approximately 3.00 km length in varying width of 10m to 1000m. The land is filled by garbage of varying depth of 1.00m to 5.00m at various length of bank.The size of landfill site means designed area for waste placement is approximately - 23 Hector. Waste placed in site is approximated at 35,45,040 MT, with depth varying from 1.2 m to 5.0 m. Filling in the site was began in 1991 and it is closed on 24th January - 2002.

Figure 1 Bhatar Waste dump Site

It is very necessary to know the composition of waste of the dump site. Table 6.1 shows typical composition of random sample of solid waste from Bhatar dump site. Which shows moisture present at the site is 18.5 %. pH value of fill material at site is found 8.12.

As dumping at the site was discontinued since 2002, compositions of the site do not show any present biodegradable matter. All the dumped organic matter is decomposed by the time. Dirt stones and sand present in large proportion (42.5 %) in composition. The site content 12.5 % clothes and fabrics. Plastic (thereds) present at the site is 5 %, where as Plastic (poly thelin) is 12.5 %. Metal content at the site is also high, which is 25 %. Glass present at the site is 2.5 %.

## VI. Experimental Work

For the application of ground improvement technique on landfill site it is necessary to know the basic geotechnical properties of site, with help of which method for improvement for the site can be decided. Following field and laboratory test was conducted at the site to explore the properties of fill material.

In order to find basic geotechnical properties of site disturbed samples and undisturbed were collected from the site at 0.60 m depth. The soil samples so collected were logged, labeled and placed in polyethylene bags and taken to the laboratory for the further tests.

As it was not found possible to collect the sample in undisturbed form from the site using split spoon sampler, as drilling was not found convenient at dump site. The Undisturbed samples have been collected from the landfill site at 0.60 m depth using cylindrical core cutter, 100mm internal diameter and 130 mm long at 0.60 m depth at various locations to collect undisturbed samples so that various geotechnical properties of landfill can be determined.

Table 6 Typical Composition of Random Sample of Solid Waste from Bhatar Dump Site.

| Code | Characteristics | Unit | Results |
|---|---|---|---|
| | ***General Analysis*** | | |
| G1 | Moisture | % | 18.5 |
| | ***Chemical Composition*** | | |
| C1 | pH | | 8.12 |
| C2 | Free Chlorine | % | Nil |
| | ***Physical Analysis*** | | |
| $P_1$ | Wooden matter | % | ND |
| $P_2$ | Vegetable, grass, leaves | % | ND |
| $P_3$ | Food wastage | % | ND |
| $P_4$ | Dirt stones sand | % | 42.5 |
| $P_5$ | Clothes & fabrics | % | 12.5 |
| $P_6$ | Plastic (thereds) | % | 5 |
| $P_7$ | Plastic (poly thelin) | % | 12.5 |
| $P_8$ | Paper | % | ND |
| $P_9$ | Metals | % | 25 |
| $P_{10}$ | Glass | % | 2.5 |

Dynamic cone penetration test (DCPT) has been conducted as per (IS: 4968 – Part I – 1976, reaffirmed 1997). It is used for determining the resistance of different types of soil strata to dynamic penetration of a 50mm cone and thereby obtains an indication of relative strength or density or both. The dynamic cone penetration test shows features of both the CPT and the SPT. A dynamic cone test has been performed by using a 50 mm cone without bentonite slurry. The no. of blows for every 10 cm penetration was recorded. The number of blows required for 30 cm of penetration was taken as the dynamic cone resistance.

## VII. Results and Analysis

From the Fig. 2 it can be seen that variation in moisture content is ranging from 12.51 % to 30.95 %. At two spots moisture content is higher having value up to 26 to 31 %, and at other two spots having lower moisture content nearly 12%. Value of moisture content at remaining two spots in nearly 18%. Which is near to its statistical mean value. So average mean value of water content is approximately 17 %.

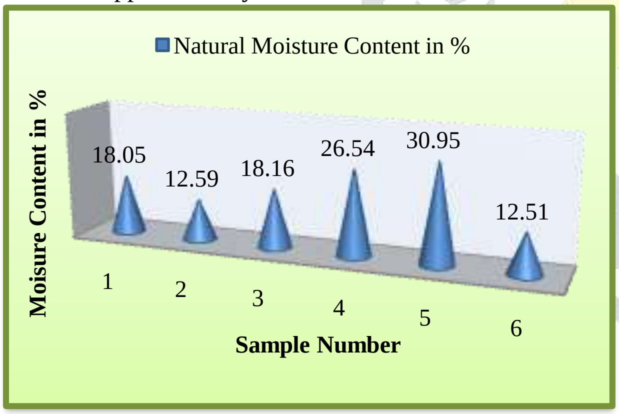


Figure 2 Variation in Natural Moisture Content

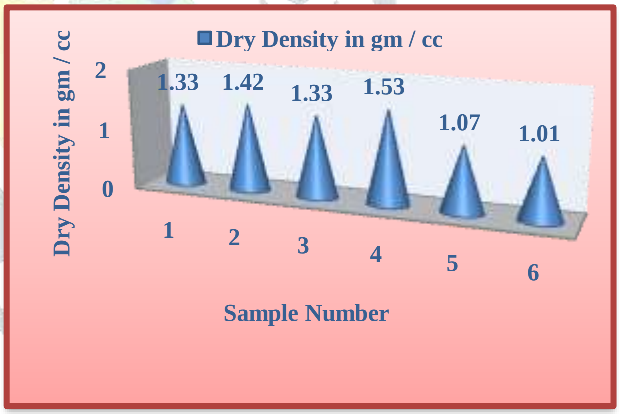


Figure 3 Variation in Dry Density

Dissimilarity in dry density at various spots of landfill site can be well understood from the chart shown in Fig. 3. From the chart shown in Fig. 3 it can be seen that value of dry density at various spots of landfill site study area is varying between 1.01 gm/cc to 1.53 gm/cc. Out of sampling at six spots two spots show the value of dry density as low as 1 gm / cc, while one spot showing the value as high as 1.53 gm / cc. Other three spots showing value of dry density nearly 1.3 gm / cc and at one spot the value is 1.42 gm / cc. The statistical mean value of six random samples is found to be 1.28 gm / cc.

Fig. 4 to 9 shows pie chart of particle size analysis of sample – 1 to sample-6 collected from landfill site. This chart shows the percentage of coarser particles i.e. sand and gravel in sample is 48 % and that is for finer particles i.e. silt and clay is 52 %. So from this percentage of particle, soil can be classified as **clayey sand (SC)**. From the particle size analysis, it can be observed that sample - 2 consists of 44 % of sand and gravel and 56 % of silt and clay. It means that coarser particles are 44 % and finer particles are 56 %. From the analysis of results it can be concluded that soil is **clayey sands (SC).**

Particle size of various samples collected from landfill site can be presented in form of pie chart as under.

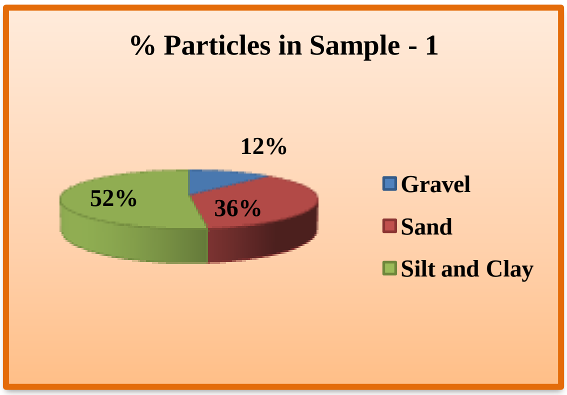


Fig.4 Particle Size Analysis of Sample – 1

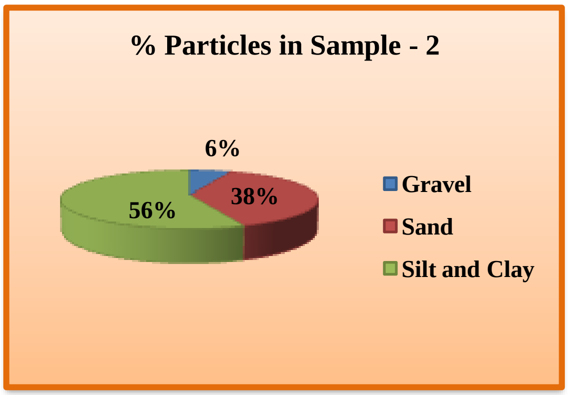


Fig. 5 Particle Size Analysis of Sample – 2

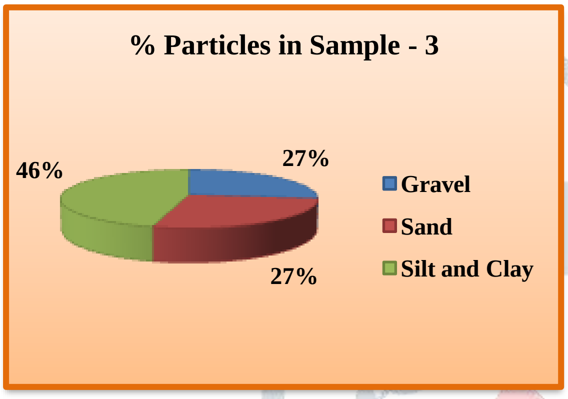


Fig.6 Particle Size Analysis of Sample – 3

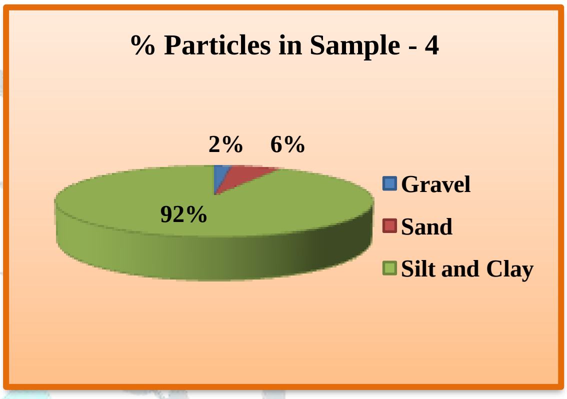


Fig.7 Particle Size Analysis of Sample – 4

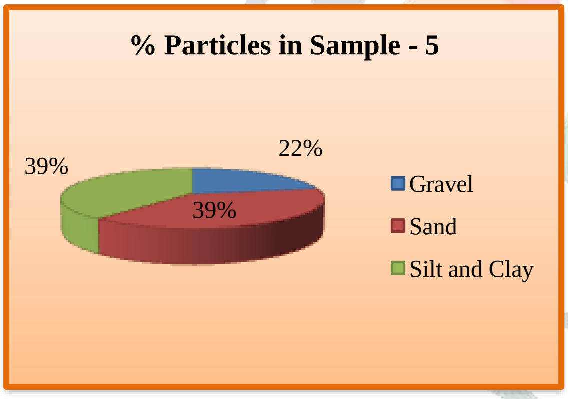


Fig.8 Particle Size Analysis of Sample – 5

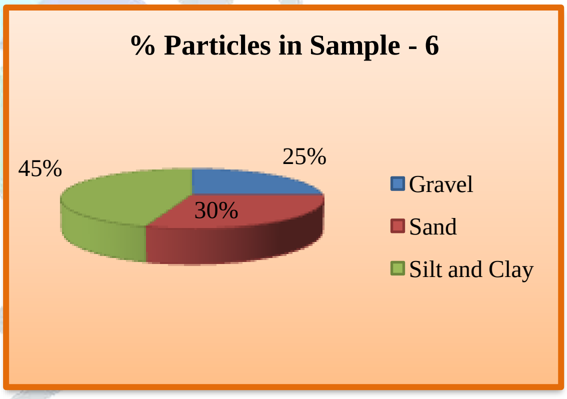


Fig.9 Particle Size Analysis of Sample – 6

It is seen from Fig. 6 that sand particles and gravel particles both are 27 % in the sample, while silt and clay particle available in sample are 46 %. So in sample - 3 proportion of coarser particles is 54 % and that of finer particle is 46 %, which proves that soil is **clayey sand (SC).** Results of tests are plotted in the form of pie chart shown in Fig.7 Pie chart indicates that silt and clay content in the sample- 4 is 92 %, gravel content is 2 % and sand content is 6%. So it consists of more fine particles and only 8 % coarser particles. This soil may be classified as **Silty Clay.** The chart obtained from the results of the laboratory test indicates that the sample-5 is containing 22 % gravel, 39 % Sand and 39 % clay and silt. So it contains 61 % coarser particles and 39 % finer particles. This sample shows very high moisture content 30.95 %, which may be due to presence of organic matter. So the sample-5 is found to be **organic silt (ML).** Pie chart for the sample -6 is shown in Fig. 9, which shows gravel content in the sample is 25 % and sand content is 30 %, so total coarser particles present in the sample are 55 %. While silt and clay content in the sample 45 %, which indicates finer particle. So sample 6 may be classifed as **Clayey Sand (SC).** So, most of samples can be classifed in the range from SC, only one sample has shown clay and one sample shown orgnic silt (ML).

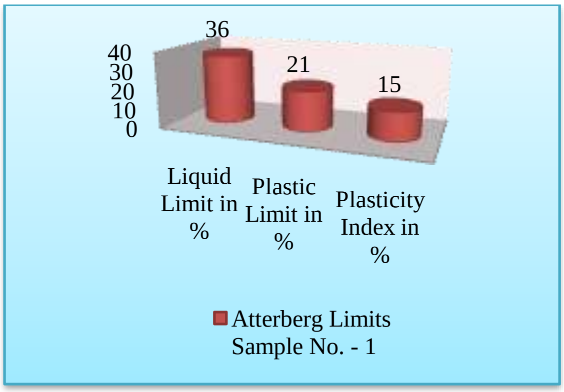


Fig.10 Atterberg Limits of Sample – 1

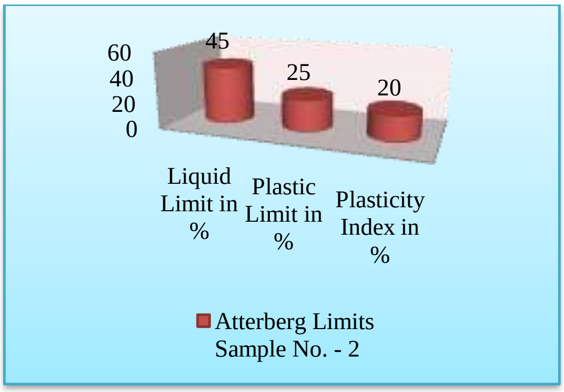


Fig.11 Atterberg Limits of Sample – 2

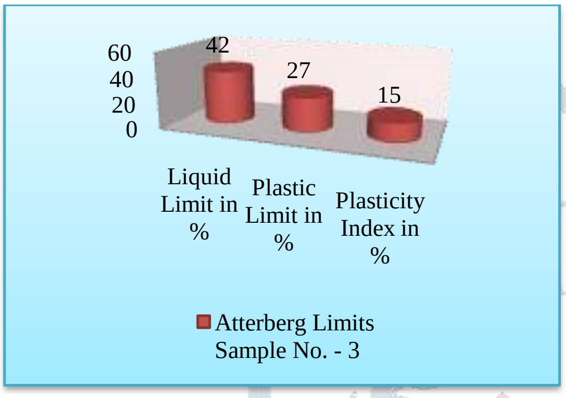


Fig.12 Atterberg Limits of Sample – 3

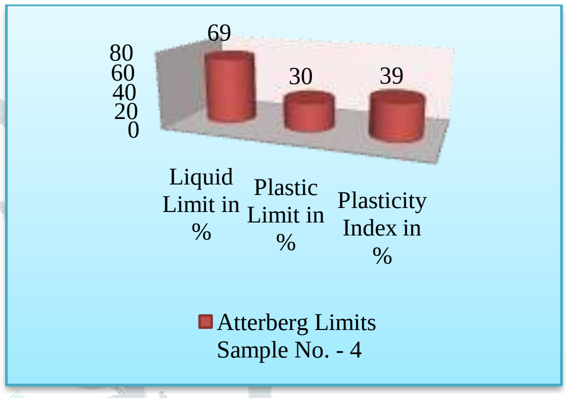


Fig.13 Atterberg Limits of Sample – 4

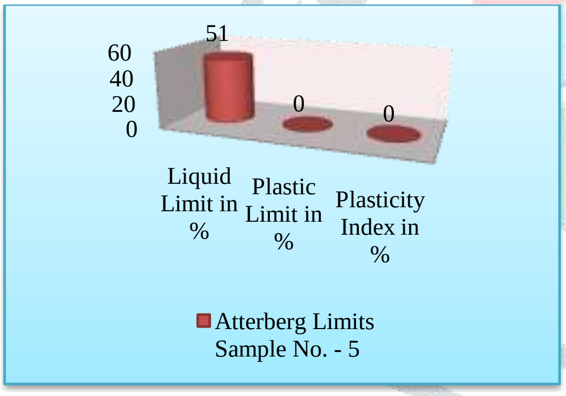


Fig.14 Atterberg Limits of Sample – 5

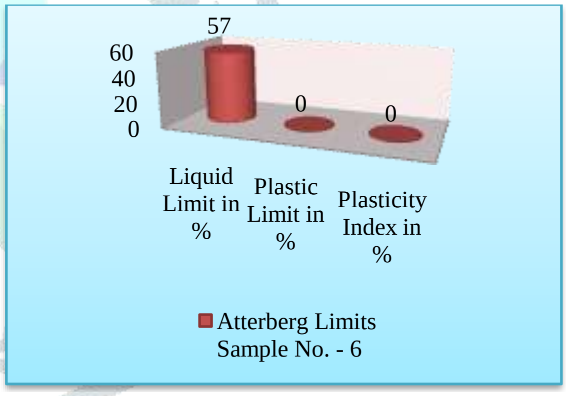


Fig.15 Atterberg Limits of Sample – 6

The results of tests carried out on samples collected from dump site is plotted in form of bar chart as shown in Fig. 10 to Fig. 15 which is very useful for the classification. Fig. 10 shows that liquid limit of sample is 36 %, plastic limit of sample is 21 % and plasticity index of soil is 15 %. From these results the sample can be classified as low plasticity clay (CL). Fig. 11 describes that liquid limit of sample is 45 %, plastic limit of sample is 25 % and plasticity index of soil is 20 %. From these results the sample can be classified as **low plasticity clay (CL).** Fig. 12 narrates that liquid limit of sample is 42 %, plastic limit of sample is 27 % and plasticity index of soil is 15 %. From these results the sample can be classified as low plasticity clay (CL). Fig. 13 recites that liquid limit of sample is 69 %, plastic limit of sample is 30 % and plasticity index of soil is 39 %. From these results the sample can be classified as high plasticity clay **(CH)**. Fig. 14 shows that liquid limit of sample is 57 %, plastic limit of sample is 0 % and plasticity index of soil is 0 %. From these results the sample can be classified as non plastic soil. Fig. 15 shows that liquid limit of sample is 51 %, plastic limit of sample is 0 % and plasticity index of soil is 0 %. From these results the sample can be classified as non plastic soil.

## VIII. Conclusion

From the present study it is found that waste fill material is heterogeneous in nature with variations in various geotechnical properties. In present paper geotechnical properties of the waste dump site is evaluated. Geotechnical properties of waste fill material is site specification it varies from site to site. Site also content spots of loose pockets at random palace in plan and elevation. The average mean value of water content is approximately 17 %. The statistical mean value of six random samples is found to be 1.28 gm / cc. Type of fill when compared to soil, it is found in most of random sample that soil is SC – CL to ML having good value of dry density.

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