IMPROVEMENT OF GEOTECHNICAL PROPERTIES OF MUNICIPAL SOLID WASTE USING GGBS

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Abstract - *Municipal solid waste (MSW) disposal in the cities has become a complex problem worldwide. Improper disposal of solid waste is a very complex problem in India. Segregation of waste is not at all practiced in our country. Bengaluru generates around 5000 tonnes of MSW per month. In the present study, an attempt has been made to study the effect of MSW on the soil characteristics of Kannahalli, an urban area in the Bengaluru northern part which is about 19.5km away from city center. MSW is being dumped in this site since a year. Soil samples were collected by excavation at two different locations in the site, one right below the landfill and the other about 90ft away from the landfill site. The soil samples collected from sites were tested for change in pH, chloride percentage, alkalinity, BOD and COD. Samples were also tested for geotechnical properties such as liquid limit, compaction characteristics, permeability, UCS and shear strength. Analysis results show that there is an effect on both chemical and geotechnical properties of soil because of contamination of soil. Contaminated soil was stabilized by adding different % of GGBS (5%, 10% and 15%). Strength of contaminated soil improved on addition of GGBS* .

Key Words: **MSW, Kannahalli, Chemical analysis, Geotechnical properties, Contamination, GGBS**

1. INTRODUCTION

Managing Municipal solid waste is a complex issue in almost all countries of the world. As the population is rapidly increasing, radius of cities and towns growing at a faster pace, there is also a huge increase of solid waste quantity being generated and hence the solid waste management should be given due importance. Wastes contain various kinds of inorganic and organic contents which may cause damage to environment directly or indirectly.

Implementation of wastes segregation methods in our country is very rare. Unscientific disposal of wastes is one of the major problems in our nation because of which there are many issues such as public ill health caused by various disease causing microbes present in the landfill site, ground water contamination, soil pollution, effect on animal and plant life, pollution of water resources, etc. Currently, Bangalore wastes are being dumped at Kannahalli landfill site. Kannahalli is located in Bangalore North of Bangalore district, Karnataka. Kannahalli is about 16 km from district headquarter. The area of landfill site is 25 acres. The quantity of waste dumped at land fill site is about 500TPD.

2. LITERATURE REVIEW

Harris M R R (1979) [7]: Conducted two compaction tests on wastes collected from landfills in England. Test results concluded average OMC to be 58% and average MDD to be 7.1 kN/m^3.

Korman et al (1987) [8]: Concluded that permeability for old wastes has greater values compared to that of fresh sample.

Krishna R Reddy et al. (2009) [10]: Fresh municipal solid waste samples obtained from orchid hills dumpsite. Compaction test results showed that MDD was 420 kg/m3 and OMC was 70%. However under higher confined stress conditions, MDD was 620 kg/m3. K value of fresh MSW varied between 10^{-8} – 10^{-4}m/s and reduced as density increased. Compression ratio values were between 0.24-0.33. Direct shear test results conducted showed c of fresh municipal solid waste ranged from 31-64kPa and ϕ from 26-30°. Average c and ϕ were found to be 32kPa and 12°. c' and ϕ' were 38 kPa and 16°.

Krishna R Reddy et al. (2015) [12]: Fresh municipal solid waste obtained from dumpsite was degraded in bioreactor cells with leachate recirculation and was tested at several degradation levels to analyse soil properties. Permeability decreased from 10^{-2}cm/s to 10^{-4}cm/s. Compression ratio ranged from 0.24-0.32. Direct shear test results showed angle of friction decreased from 30°-12° for starting stage to high degradation stage. Triaxial test results concluded cohesion range from 14-51kPa and 7°-14° respectively. c' and ϕ' were found to be 14-48kPa and 6°-13° respectively.

Naveen B P et al. (2014) [14]: Investigated the effect of MSW on engineering properties of soil at Mavallipura site. It was observed that permeability, OMC was very high and MDD was low. Direct shear test results showed that c and ϕ values were found to be 10kPa and 26°.

Ramakrishne gowda C et al. (2011) [18]: Investigated how leachate has an effect on pH and geotechnical properties of soil. Soil samples were collected from dumpsite located near Chikballapur. Dumpsite was about 7 years old,pits were excavated and soil samples were extracted right below the dump waste. Some quantity of uncontaminated soil samples were collected very near to the dumping site. Experimental results indicated that MDD, UCS of contaminated soil increased with depth. pH value of contaminated soil decreased with increase in depth. Experimental results of contaminated soil almost matched with that of uncontaminated soil with increase in depth.

Shivaraju R (2016) [19]: Conducted a study by collecting soil samples at different depths at site near Chikkaballapur dumping area and samples were tested for index and engineering properties in laboratory. Results of test showed that at depths greater than 1.5m, compaction characteristics and UCS closely matched with uncontaminated soil.

3. OBJECTIVES

The main objective of the study was to compare chemical and geotechnical properties of soil collected at two locations in landfill site.

4. MATERIALS AND METHODOLOGY

4.1 MATERIALS

SOIL: Excavation was done at two different locations in the landfill site for the collection of soil samples. One sample was collected by excavating right below the landfill. The other soil sample was collected from about 90 ft from the landfill. The samples that were collected from site were disturbed soil samples. The samples were collected in separate polythene bags which were then labeled and transported to the geotechnical laboratory for testing.

Following chemical tests were conducted:

1. pH value determination
2. BOD test
3. COD test
4. Chloride content determination
5. Alkalinity test

Following geotechnical tests were conducted:

1. Determination of specific gravity
2. Grain size analysis
3. Determination of liquid limit and plastic limit
4. Compaction test
5. Unconfined Compression Strength Test
6. Permeability test

GGBS:

Ground granulated Blast furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag from the blast furnace in water or steam, which produces a glassy, granular product that is dried for some days and grounded into a fine powder.

Fig.1.GGBS

4.2 METHODOLOGY

Chemical tests were conducted on soil samples according to IS standards.

Specific Gravity test was carried out using Pycnometer method. The value of specific gravity is used in various calculations. Liquid limit test was carried out using Casagrande apparatus.

Standard compaction tests were conducted according to IS standards on soil samples and stabilized soil too, for the determination of optimum moisture content and maximum dry density.

Direct shear test and unconfined compression strength tests were carried out on soil samples according to IS standards. Stabilized soils were also examined for the same.

After the comparative study of contaminated and uncontaminated soil, the contaminated soil sample was stabilized by adding GGBS in 5% , 10% and 15% respectively.

5. RESULTS AND DISCUSSIONS

5.1 Chemical test reports:

Contaminated Soil:

Table-1: Contaminated soil chemical test report

Sl. No	Parameters	Results	Test method
	Description	Pale brown colored moist soil	Textbook of soil chemical analysis
1	pH (20% suspension)	7.00 at 23.7 °C	
2	Chlorides , as Cl ,%	0.004	
3	Alkalinity , as CacO3 , ppm	18.9	IS: 3025 (part 23)

4	Bio chemical Oxygen Demand (at 27 °C for 3 days)	7.8	IS: 3025 (part 44)
5	Chemical Oxygen Demand	56.6	APHA

Uncontaminated Soil:

Table-2: Uncontaminated soil chemical test report

Sl. No	Parameters	Results	Test method
	Description	Pale brown colored moist soil	Textbook of soil chemical analysis
1	pH (20% suspension)	6.98 at 23.7 °C	
2	Chlorides , as Cl ,%	0.026	
3	Alkalinity , as CacO3 , ppm	14.2	IS: 3025 (part 23)
4	Bio chemical Oxygen Demand (at 27 °C for 3 days)	7.2	IS: 3025 (part 44)
5	Chemical Oxygen Demand	52.5	APHA

Test results showed that there is not much variations in pH. Alkalinity, BOD and COD of uncontaminated soil is less than that of contaminated soil. Chloride content of uncontaminated soil is found to be greater than contaminated soil.

5.2 Grain size analysis:

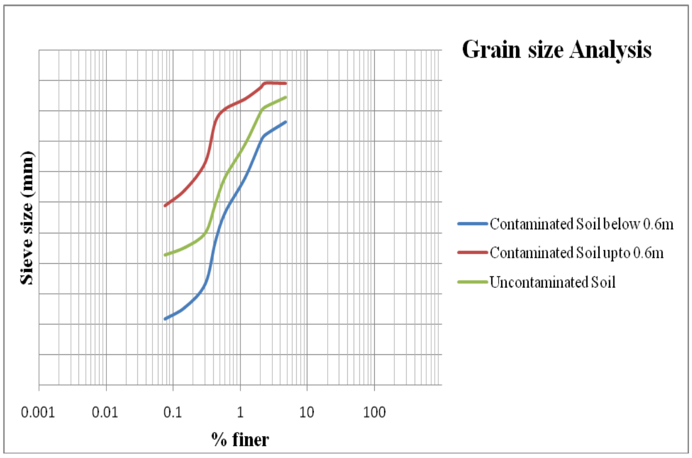

Fig.2.Grain size distribution curve

4.3 Liquid Limit of uncontaminated and contaminated soil:

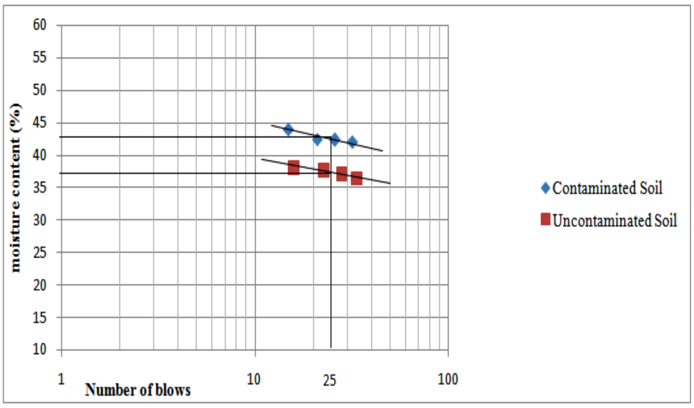

Fig.3.Liquid limit

LL for contaminated soil was found out to be 42.5% and that for uncontaminated soil was found out to be 37.5%.

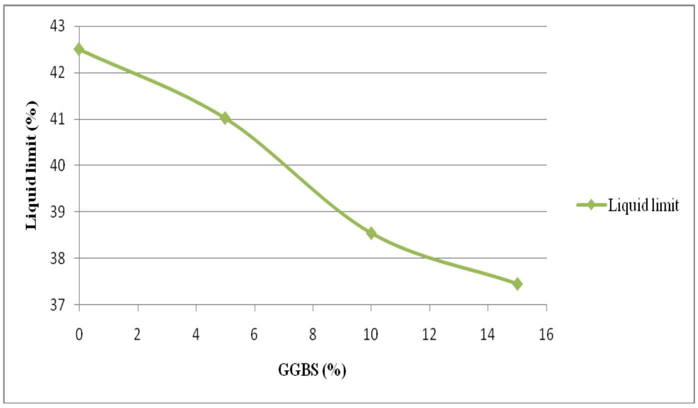

Fig.4.Variation of Liquid limit for different % of GGBS

From the above graph, we can observe that liquid limit is gradually decreased from 42.5% to 37.46% with increase in % of GGBS. Liquid limit was observed to be least when 15% GGBS was mixed with the soil.

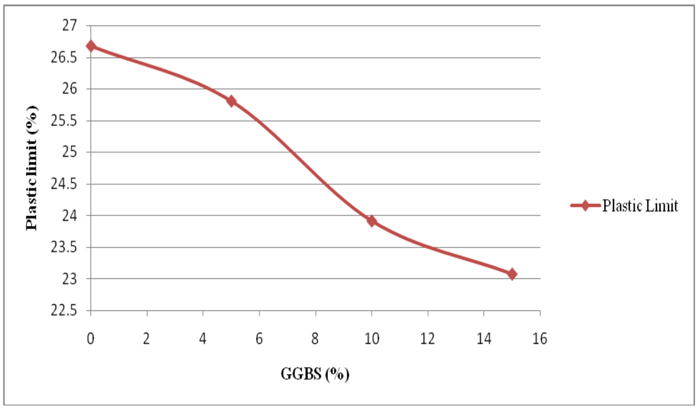

Fig.5.Variation of Plastic limit for different % of GGBS

From the above graph, we can observe that plastic limit is gradually decreased from 26.68% to 23.08% with increase in % of GGBS. PL was observed to be least when 15% GGBS was mixed with the soil.

5.3 Compaction Characteristics:

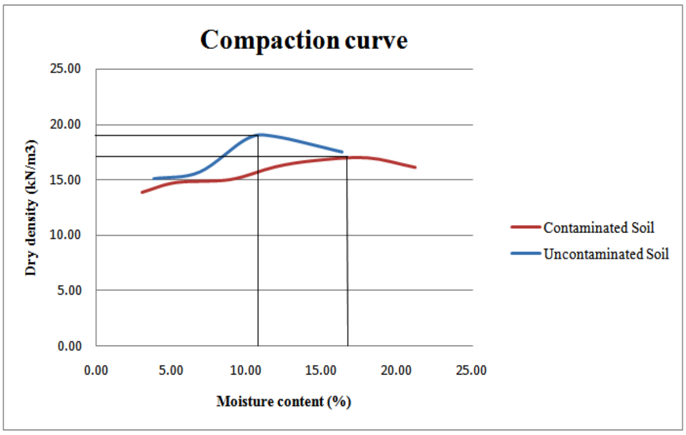

Fig.6.Compaction curve

From the compaction curve, we can observe that OMC for contaminated soil was found out to be 17.75% and that for uncontaminated soil was 12%. MDD of contaminated soil was found out to be 17kN/m^3 and that for uncontaminated soil was found out to be 19kN/m^3.

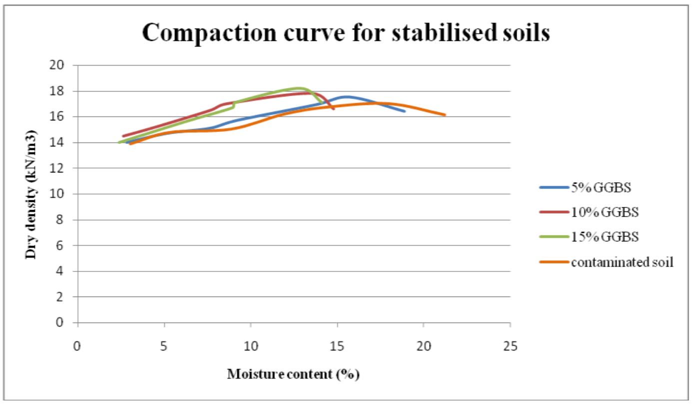

Fig.7.Compaction curve of stabilized soil at different % of GGBS

From the above compaction curve, we can observe that as % of GGBS is increased, maximum dry density has increased and optimum moisture content decreased. OMC obtained on addition of 15% GGBS was 12.5% and MDD was 18.3 kN/m^3.

5.4 Unconfined Compression strength test:

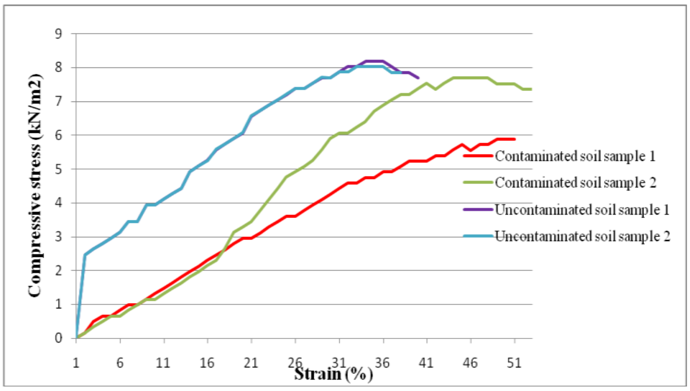

Fig.8.Stress-strain characteristics from UCS test results

From the above graph, we can observe that compressive stress for uncontaminated soil was found higher than that of contaminated soil.

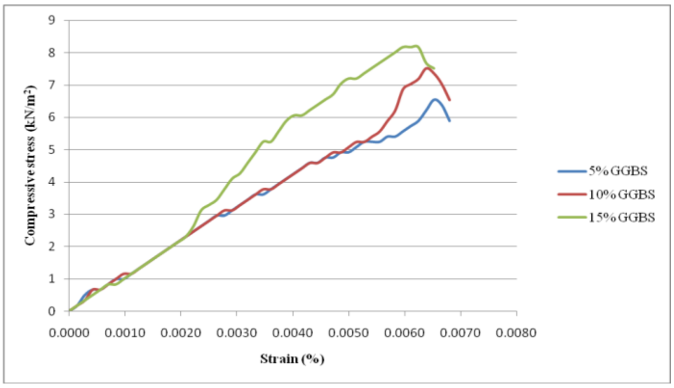

Fig.9.Stress-strain characteristics from UCS test results of stabilized soil at different % of GGBS

From the graph, we can observe that as % of GGBS increased, UCS increased. UCS was highest for 15% GGBS, that is 8.35kN/m^2.

5.5 Direct shear test

5.5.1 Direct shear test for contaminated soil

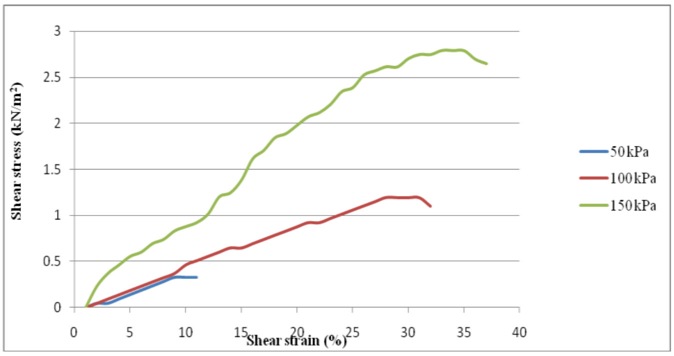

Fig.10.Shear stress v/s strain graph for contaminated soil

5.5.2 Direct shear test for uncontaminated soil

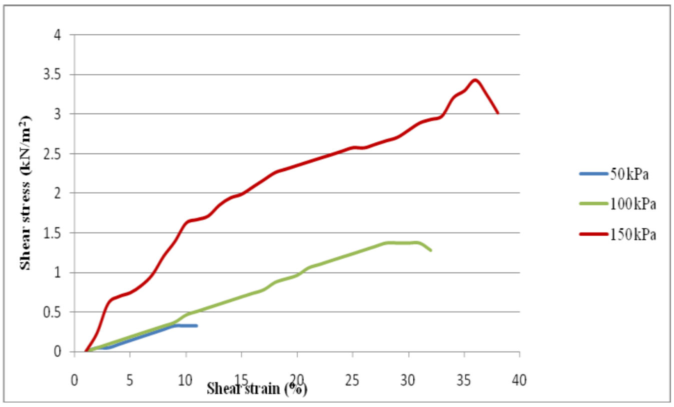

Fig.11.Shear stress v/s strain graph for uncontaminated soil

5.5.3 Direct shear test for stabilized soil

The direct shear tests conducted for both contaminated soil and uncontaminated soil showed that shear strength of uncontaminated soil is higher than that of contaminated soil.

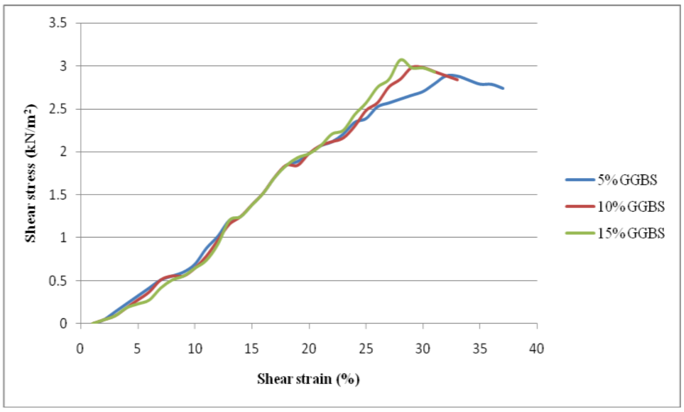

Fig.12.Shear stress v/s strain graph for stabilized soil at different % of GGBS

Direct shear tests were conducted at different loading conditions for different % of GGBS. It was found that strength of soil increased as % of GGBS added to soil also increased.

Table-3: Overall test results

Description	Uncontaminated soil	Contaminated soil
NMC (%)	4.45	17.93
Specific Gravity	1.66	1.7
Liquid limit (%)	37	42.5
Plastic limit (%)	23.31	26.67
Plasticity Index (%)	14.19	15.83
Flow Index (%)	8	8
Toughness Index	1.77	1.978
Soil classification	CI	MI
OMC (%)	12	17.75
MDD (kN/m³)	19	17
Co-efficient of permeability (cm/s)	2.48 X 10^{-4}	3.86 X 10^{-4}
Cohesion, C (kN/m²)	15	10
Angle of internal friction, ϕ (°)	22	19
Unconfined compression strength, qu, (kN/m²)	8.11	6.78
Undrained cohesion, Cu, (kN/m²)	4.05	3.39

Table-4: Overall test results after stabilization

Description	Contaminated soil	Soil + 5% GGBS	Soil + 10% GGBS	Soil + 15% GGBS
Liquid limit (%)	42.5	41.02	38.55	37.46
Plastic limit (%)	26.68	25.81	23.91	23.08
Plasticity Index (%)	15.82	15.21	14.64	14.38
Flow Index (%)	8	7.9	7.8	7.7
Toughness Index	1.978	1.925	1.876	1.867
OMC (%)	17.75	15.5	14.0	12.5
MDD (kN/m³)	17	17.3	17.85	18.3
Co-efficient of permeability (cm/s)	3.86X10^{-4}	3.50 X10^{-4}	3.3 X10^{-4}	3.17 X10^{-4}
Cohesion, C (kN/m²)	10	11	12.5	13.4
Angle of internal friction, ϕ (°)	19	20	22	23
Unconfined compression strength, qu, (kN/m²)	6.78	6.9	7.5	8.35
Undrained cohesion, Cu, (kN/m²)	3.39	3.45	3.75	4.175

6. CONCLUSIONS

The study has been conducted to compare the characteristics of uncontaminated and contaminated soil, the conclusions is as follows:

1. Chemical test results shows that there was not much variations in pH. Alkalinity, BOD and COD of uncontaminated soil was less than that of contaminated soil. Chloride concentration in uncontaminated soil was found to be greater than contaminated soil, this may be due to seasonal variation also.

2. LL for contaminated soil was found to be 42.5% and that for uncontaminated soil was found out to be 37.5%.

3. Co-efficient of permeability of contaminated soil is 3.84 X 10^{-4}cm/s where as that for uncontaminated soil was found to be 2.48 X 10^{-4}cm/s. This indicates the contamination of soil has lead to increase in porosity which in turn increased permeability of soil.

4. Compaction test results shows that OMC for contaminated soil was 12.0% and that for uncontaminated soil is 17.75%. MDD of contaminated soil was found out to be 17kN/m^3 and that for uncontaminated soil was found out to be 19kN/m^3.

5. From Unconfined Compression Strength test, it is observed that UCS for uncontaminated soil is greater than that of contaminated soil. UCS of uncontaminated soil was found to be 8.11kN/m^2 and that of contaminated soil is 6.78kN/m^2.

6. The direct shear test conducted for both soils showed that shear strength of uncontaminated soil is higher than that of contaminated soil.

7. After stabilization with GGBS, it is observed that liquid limit and plastic limit gradually decreased with increase in % of GGBS. Liquid limit and plastic limit was observed to be least when 15% GGBS was mixed with the soil.

8. Co-efficient of permeability decreased with increase in % of GGBS.

9. Compaction test conducted on stabilized soil showed that as % of GGBS is increased, MDD had increased and OMC decreased. The optimum moisture content by addition of 15% GGBS is 12.5% and MDD is 18.3kN/m^3.

10. Due to stabilization with GGBS, it was observed that as % of GGBS was increased, UCS increased. UCS is highest for 15% GGBS and the value was 8.35 kN/m^2.

11. Direct shear test results showed that soil strength increased as % of GGBS added to soil increased.

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