Indian Geotechnical Conference – 2010, GEO*trendz*
December 16–18, 2010
IGS Mumbai Chapter & IIT Bombay

Geotechnical Characterisation of Wastes at Zinc Manufacturing Plants

Reddy, C.N.V. Satyanarayana
Professor
e-mail: cnvsnreddy@rediffmail.com

Sanghamitra, B.
Research Scholar

Department of Civil Engineering, Andhra University, Visakhapatnam

ABSTRACT

Solid waste is present in the form of Slag generated during pyrometallurgical process of secondary Zinc production and contains copper, aluminum, iron and lead. Slag being coarse grained fused material may be considered for utilization as construction material. The waste Jerosite slurry produced during hydrometallurgical process of primary Zinc production is hazardous and cannot be disposed on open land as it leads to environmental pollution. Hence Jerosite waste is to be safely dumped with engineered landfills with appropriate capping. The present paper deals with extensive laboratory investigations done on Zinc Slag and Jerosite waste materials for their geotechnical characterization. The potential of Zinc Slag as construction material has been explored based on its engineering properties. The properties of Jerosite presented in the paper will be useful for design of landfills.

1. INTRODUCTION

The solid waste (fly ash, bottom ash, blast furnace Slag, Zinc Slag, etc.) and liquid waste (Jerosite, pond ash etc.) materials containment is one of the major present day societal problems. The ground and surface water are being contaminated due to improper disposal and/or containment of wastes. It is essential that the waste be handled in such a way that contamination of the ground and ground water is prevented. Most of the wastes are not used and simply dumped near industries. Some of the wastes are hazardous and not decomposed causing environmental pollution with some of the wastes being non- hazardous. The increased construction activity has resulted in scarcity of conventional materials of construction and thereby construction costs have increased. If some of the non-hazardous wastes are found suitable as construction material, not only problem of waste disposal will be solved, but also cost of construction will be minimized.

The efforts of researchers have enabled utilization of several waste materials such as coal ashes, silica fume, and crusher dust in civil engineering constructions. Nawraj Bhatta (2008) has been worked on engineering properties of pond ash and pond ash-sand mixtures. Based on the results of study, pond ash was used as a potential source of embankment / subgrade material in execution phase of NH-6 project. Reddy and Moorthy (2002) have studied engineering properties of waste material produced at Rock Crushing Units namely Rock flour or Stone Dust. The interaction of rock flour with woven and non-woven geotextiles was studied and reported mobilization of higher interfacial friction in comparison to sand. Based on the results of study, it has been recommended to use Rock flour in construction of road sub bases and Reinforced Soil Structures as fill material.

Considerable work (Jewell, 1990; Gatung, 1996) has been done on engineered landfills during last two decades and as a result rational computational design procedures for bund design have been developed. Bund being major component of landfill, it should be constructed at low cost and by occupying least space to contain more volume of hazardous waste. The reinforced bunds may be tried using some granular waste material to minimize the cost. The design of engineered landfill requires the properties of hazardous waste that will be dumped.

The present work is aimed at Geotechnical characterization of Waste materials namely Zinc Slag and Jerosite produced at Zinc Manufacturing units. Hindustan Zinc Limited, Visakhapatnam produces Slag to the extent of 20,000 tons per annum and Jerosite to the extent of 34,000 tons per annum. Hence efforts are to be put in for safe disposal of these waste materials and also to explore their suitability for use as construction material if possible. Detailed discussion has been made to explore their suitability as construction materials and/or for safe disposal without environmental pollution.

2. PROPERTIES OF WASTE MATERIALS

Zinc Slag

The Engineering properties of Zinc Slag procured from

Hindustan Zinc Limited, Visakhapatnam are presented in Table 1. Laboratory investigations have been carried out on slag and segregated slag samples to explore their potential for use as construction material. Segregated Shear parameters of slag samples have been determined from box shear tests by preparing specimens under IS heavy compaction conditions after saturation. The permeability of the slag and segregated slag samples are determined by conducting constant head permeability tests on specimens prepared at M.D.D and Respective OMC obtained from IS compaction tests.

Table 1: Engineering Properties of Zinc Slag

S. No.	*Engineering Property*	*Value*
1.	Specific gravity	2.36
2.	Grain size analysis	
	a) Gravel (%)	48
	b) Sand (%)	51
	c) Fines (%)	1
3.	Gradation characteristics	
	Coefficient of curvature	1.44
	Coefficient of uniformity	7.35
4.	IS Classification symbol	SW
5.	Compaction characteristics	
	a) Optimum moisture content (%)	12.2
	b) Maximum dry density (g/cc)	
	(under IS heavy compaction)	1.6
	(under vibration)	1.65
6.	Shear parameters	
	a) Cohesion (kN/m^2)	5
	b) Angle of internal friction	39^0
7.	Coefficient of permeability (cm/s)	1.5×10^{-3}

The segregated properties of Slag have been mainly assessed for their suitability as filter material with free drainage ability. The properties of segregated Zinc Slag are presented in Table 2.

Table 2: Engineering Properties of Segregated Slag

Engineering Property	*Size of Slag*	
	Passing 10 mm IS sieve & Retained on 1 mm IS Sieve	*Passing 4.75mm IS Sieve*
1. Grain size Analysis		
i) Gravel (%)	57	0
ii) Sand (%)	43	98
iii) Fines	0	2
iv) Coefficient of Curvature	1.1	2.15
v) Coefficient of Uniformity	3.2	5.3
2. IS Classification	GP	SP
3. Dry Density Under Vibration (g/cc)	1.49	1.52
4. Permeability (cm/s)	0.0168	0.004

Jerosite

The Chemical and Engineering properties of Jerosite procured from Hindustan Zinc Limited, Visakhapatnam have been established through detailed laboratory investigations. As Jerosite slurry is a plastic material with large water content in dumped condition, the study is extended to evaluate consolidation characteristics of the material. Consolidation tests are performed in oedometer using Jerosite sludge cake collected from surface of pond after saturation. The properties of Jerosite are presented in Table 3.

Table 3: Properties of Jerosite

Engineering Property	*Value*
1. Specific gravity	2.70
2. Grain size analysis	
a) Gravel (%)	0
b) Sand (%)	2
c) Fines (%)	98
3. Atterberg limits	
a) Liquid limit (%)	45
b) Plastic limit (%)	28
4. IS Classification symbol	CI
5. Compaction characteristics	
a) Optimum moisture content (%)	30
b) Maximum dry density (g/cc)	1.30
6. Consolidation characteristics	
a) Initial void ratio	0.95
b) Saturation water content (%)	52
c) Compression Index	0.53
d) Coeff. of consolidation (cm^2/s)	6.4×10^{-3}
7. Shear parameters at OMC & MDD	
a) Cohesion (t/m^2)	2.4
b) Angle of internal friction	15^0
8. Shear parameters at full saturation	
a) Cohesion (t/m^2)	1.2
b) Angle of internal friction	0^0

Chemical Properties			
Constituent	%	Constituent	%
Iron (Fe)	23 – 25	Sodium (Na)	0.7 – 1
Zinc (Zn)	3 – 4	Potassium (K)	0.6 – 1
Aluminum (Al)	3 – 4	Carbon (C)	0.15
Silica (Si)	3 – 4	Copper (Cu) ppm	1000
Lead (Pb)	1.5 - 3	Cadmium (Cd) ppm	320
		Cobalt (Co) ppm	40

3. DISCUSSION

Engineering properties of Zinc Slag presented in Table 1 indicate presence of mostly gravel and sand size fraction. Thus Zinc Slag is a granular material with good frictional characteristics ($\phi = 39^0$) and better drainage ability (1.5 x 10^{-3}cm/s). Further Slag is having relatively lower density (MDD = 1.65g/cc) compared to moorum soils. As slag has very little amount of fines, it mobilizes higher values of interfacial friction with reinforcing materials. As Zinc Slag is fused material it does not react with soil or water which comes in contact with it. Hence its chemical analysis has not been carried out. Being granular material, it may be also used as fill material with reinforcing materials in different Reinforced Soil Structures and as subbase material in construction of flexible pavements.

The properties of segregated Zinc Slag presented in Table 2 indicate that Slag material passing 10mm sieve and retained on 1mm sieve has good drainage property (1.68 x 10^{-2} cm/s) and hence it may be advantageously used in forming drainage layers of Base Lining System of Landfills. The presence of little or no fines guarantees its good draining ability in long run.

Engineering properties of Jerosite presented in Table 3 indicate that the Jerosite waste slurry is almost in liquid form with density slightly higher than water at the time of disposal into landfill. The chemical properties reveal that Jerosite is hazardous and hence it cannot be used as construction material. Further, it should not be exposed to the atmosphere as well as ground to prevent pollution and associated health hazardous. Being hazardous in nature, it is to be disposed safely with engineered landfills with properly designed capping as per CPCB Norms.

The engineering properties presented in the study are useful for landfill bund and capping design. Further, the composition of the dried Jerosite is found to have the behaviour of Intermediate clay (CI). When Jerosite slurry is dumped in a landfill, it exerts hydrostatic pressure. Hence, the bund used to contain the waste shall be designed for hydrostatic pressure instead of lateral pressure exerted by dried up Jerosite. As the material is found to have the behavior of soft clay in terms of undrained strength and consolidation characteristics in saturated state, the design of capping system will be a challenging task.

4. CONCLUSIONS

Based on the experimental investigations carried out on zinc slag and jerosite samples under study and critically analyzing the evaluated properties of the materials, the following conclusions have been made.

1. Zinc Slag is a granular material with little amount of fines possesses good frictional and reasonable drainage characteristics. Hence it can be advantageously used in construction of embankments. Further the material develops good bond with reinforcing materials.
2. Zinc Slag is well graded coarse grained material. Hence it can be effectively compacted using vibratory rollers in construction of embankment.
3. Segregated Slag (passing 10mm and retained on 1mm) can be used in drainage layers of base lining systems of landfills as the material is free draining in nature (k = 1.68 x 10^{-2}cm /s).
4. Zinc Slag may be used as construction material for Embankments, as fill material for construction of Reinforced Soil Structures and for forming drainage layers of base lining system of Landfills.
5. Hydrostatic pressure of Jerosite slurry should be considered in bund design because drying of the material reduces thrust due to plasticity.
6. As Jerosite is hazardous, it cannot be used as construction material and is to be properly disposed using engineered landfill system with appropriate capping.
7. The consolidation characteristics reveal that it undergoes significant compression under the loads at a slower rate. Being cohesive material, densification is possible only by providing vertical drains.
8. The saturated Jerosite behaves like a soft clay. Hence, the land capping design shall be done using cushions or by planning proper drainage measures to improve its strength.

ACKNOWLEDGEMENT

The authors thank the authorities of Hindustan Zinc Limited, Visakhapatnam for providing the samples for laboratory investigations and for the help rendered by undergraduate students comprising Mr. G. Vikram and his group in carrying out the study.

REFERENCES

Bowles, J.E (1997). *Foundation analysis and design.* Mc Graw Hill Publishing Co., New York.

Central Pollution Control Board (2000). *Criteria for hazardous waste landfills.* Ministry of Environment and Forests, Govt. of India.

Gartung, E. (1996). Landfill liners and covers. *First European Geosynthetics Conference,* Maastricht, Netherlands, Balkema, 55-70.

Jewell, R.A. (1990). Revised design charts for steep reinforced slopes. *Symposium on Reinforced Embankments: Theory and Practice,* Thomas Telford, 1-30.

Koerner, R.M (1986). *Designing with geosynthetics.* Fourth Edition, Prentice–Hall, Eaglewood Cliffs, New Jersey.

Reddy, C.N.V.S and Moorthy, N.V.R (2002). Potential of rockflour for use in reinforced soil constructions. *Journal of South East Asian Geotechnical Society*, Thailand, 148-152.

Vikram, G et al. (2009). Design of reinforced embankment for Jerosite containment plant at Hindustan Zinc Limited, Visakhapatnam. *Unpublished B.E Project work Report*, Andhra University, Visakhapatnam.