GEOTECHNICAL CHARACTERIZATION OF MINE WASTE MATERIALS (ZINC/LEAD MINE) FROM RAJPURA – DARIBA MINE, UDAIPUR

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ABSTRACT

Mine waste material is a residue (refuse) obtained after retrieving the minerals from the ores. The Rajpura – Dariba Mine, Udaipur is operated under the control of Hindustan Zinc Ltd. and is presently one of the largest Zinc mines in India and produces Zinc and Lead. In the present study, the mine waste material from Rajpura – Dariba Mine, Udaipur is characterized by conducting the laboratory tests such as Mechanical Analysis (Grain Size Distribution), Atterberg's Limits, Standard Proctor Compaction Test, Specific Gravity Test, Direct Shear Test, One Dimensional Consolidation Test and Laboratory Permeability Test in order to ascertain the suitability of mine waste material as a construction material for raising the height of the existing tailing dam to increase the storage capacity and it is concluded that mine waste material from the Rajpura – Dariba Mine, Udaipur is gravelly material with silt and clay and is able to achieve very good densities and shear strength. The material has low compressibility characteristics and possesses semi-pervious drainage characteristics.

Keywords: Geotechnical characterization, tailings, mine waste, tailing dam.

Disclaimer: The views expressed in this paper are strictly individual views of the authors and do not, in any way, represent the views of the department/organization where they are presently working.

INTRODUCTION

Mine waste material is a residue (refuse) obtained after retrieving the minerals from the ores. The Rajpura – Dariba Mine, Udaipur is operated under the control of Hindustan Zinc Ltd. and is presently one of the largest Zinc mines in India and produces Zinc and Lead. The ores are extracted from the limestone rock by mechanical and chemical processes that generates the tailing (Quille and Kelly, 2010). This tailing is mixed with the processed waste water and disposed in to the tailing dam having an approximate area 1500x 700 m and 13.0 m height. The tailings after separation of concentrates are pumped to fill plant, where is hydro cycloned to separate the slime (Zinc-Lead tailing of -37 microns) and sand. Slimes are pumped to the tailing thickener where excess water is removed for re-cycling in the plant and underflow is pumped to the tailing dam located three km. away from the Rajpura-Dariba mine.

The geotechnical properties of the mine waste material must be known in order to promote the use of mine waste. In the present paper, the geotechnical properties of mine waste materials from the Rajpura-Dariba Mine, Udaipur have been studied to use the mine waste

material as construction material to raise the height of tailing dam to increase its storage capacity (CSMRS, 2014).

GEOTECHNICAL PROPERTIES

A total 8 nos. samples of mine waste material were collected from the different locations of mine heap Rajpura-Dariba Mine, Udaipur and were subjected to various laboratory tests such as mechanical Analysis (Grain Size Distribution), Atterberg's Limits, Standard Proctor Compaction Test, Specific Gravity Test, Direct Shear Test, One Dimensional Consolidation Test and laboratory Permeability Test in order to ascertain their suitability as construction material for raising the existing tailing dam to increase the storage capacity.

PHYSICAL PROPERTIES
GRADATION

The mine waste material samples were tested for grain size analysis (IS: 2720 (Part-4), 1985) and it was found that clay sizes vary from 0.7 % to 3.9 %, silt sizes vary from 6.6 % to 14.3 %, fine sand sizes vary from 9.3 % to 14.9 % and the medium sand sizes vary from 7.3 % to 12.4 %, coarse sand sizes vary from 5.8 % to 9.7 % and the gravel sizes vary from 57.0 % to 64.3 % respectively. Figure 1 shows the grain size distribution of the mine waste material.

INDEX PROPERTIES

The liquid limit and plastic limit tests on the mine waste material samples (IS: 2720 (Part-5),1985)show that liquid limits vary from 24.4 % to 37.1 % and plastic limits vary from 21.8 to 25.1 for 03 samples and remaining 5 nos. samples shows non-plastic characteristics. The plasticity index values indicate that materials exhibit low plastic characteristics to non-plastic characteristics. The classification of material as per Bureau of Indian Standard soil classification system (IS: 1498, 1970) shows that material in general vary from Silty Gravel to Clayey Gravel.

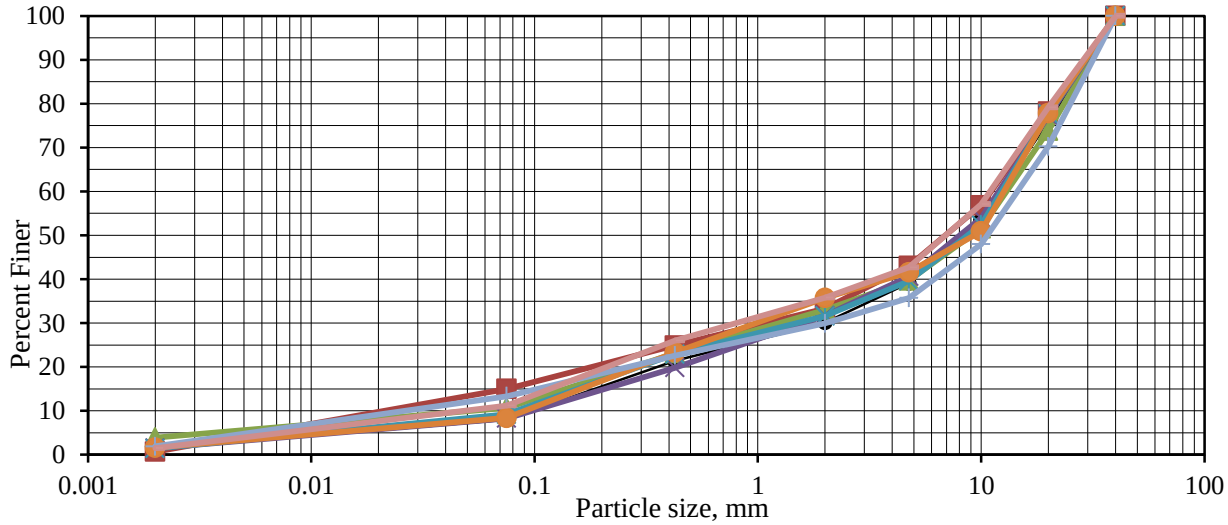


Figure 1 Participle Size distribution of the Mine Waste Material

PROCTOR DENSITY AND SPECIFIC GRAVITY

The dry density of mine waste material was determined using Standard Proctor test (IS: 2720 (Part-5), 1985). The maximum dry density (MDD) of mine waste material vary from 2.01

g/cc to 2.15 g/cc and optimum moisture content (OMC) vary from 6.1 % to 9.1 %. Figure 2 presents the graphical presentation of the dry density and moisture content of the tested mine waste material from the Rajpura-Dariba Mine. The specific gravity of mine waste material vary from 2.90 to 2.96 (IS: 2720 (Part-3), 1980).

DIRECT SHEAR

Direct Shear test was conducted using small size shear box (6 cm × 6 cm) on the mine waste material (material passing through 4.75 mm IS Sieve) (IS: 2720 (Part-13), 1986). The materials was compacted at 98% of the maximum dry density, saturated and sheared under four different normal stresses of 1.0, 1.5, 2.0 and 2.5 kg/cm^2 respectively. The values of angle of shearing resistance (ϕ') of the tested mine waste material (material passing through 4.75 mm IS Sieve) vary from 34.3° to 37.1° respectively. The results of Direct Shear tests (6 cm × 6 cm) of the tested mine tailing materials are shown in Figure 3(a).

Direct Shear test was also conducted using large size shear box (30 cm × 30 cm) on the coarse mine waste material (material passing through 20 mm IS Sieve) (IS: 2720 (Part-13), 1986). The material was compacted at 98% of the maximum dry density (MDD) and sheared under four different normal stresses of 1.0, 1.5, 2.0 and 2.5 kg/cm^2 respectively in dry condition. The values of angle of shearing resistance (ϕ) of the tested mine waste material (material passing through 20 mm IS Sieve) vary from 37.1° to 40.7° respectively. The results of Direct Shear tests (30 cm × 30 cm) of the tested mine tailing materials are shown in Figure 3(b).

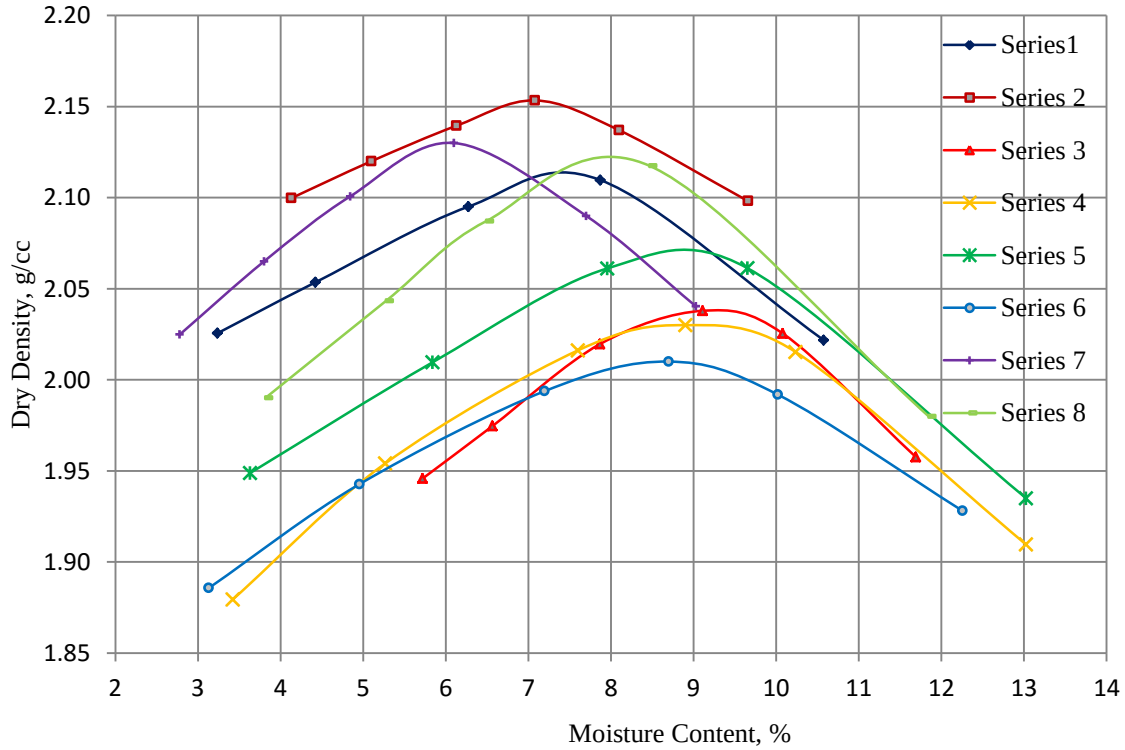
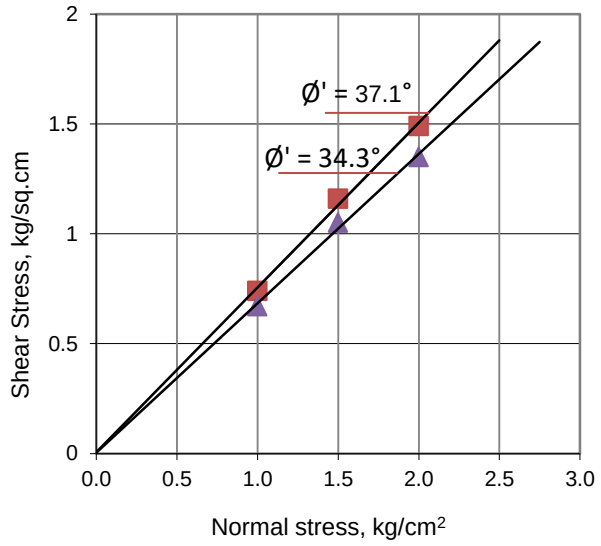
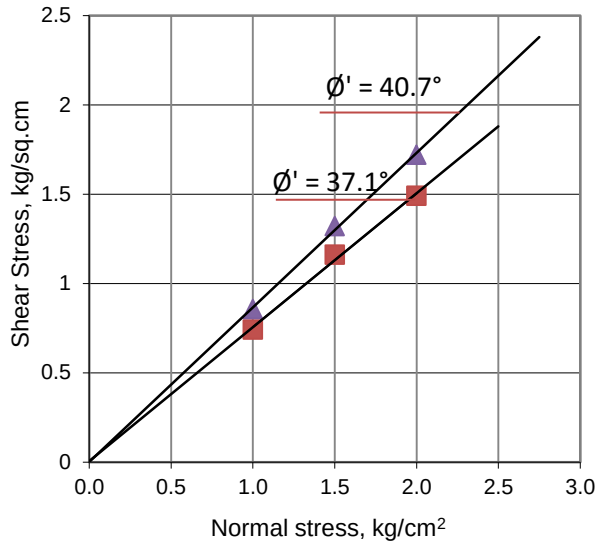


Figure 2 Dry Density vs. Moisture Content



(a)



(b)

Figure 3. Shear Stress vs. Normal Stress (a) Material passing through IS Sieve 4.75 mm (b) Material passing through IS Sieve 20 mm

CONSOLIDATION

The mine waste material was tested for one dimensional consolidation test to determine the compressibility characteristics. The test was conducted on the mine waste materials passing through the 2 mm sieve (IS: 2720 (Part -15), 1986). The mine waste materials were compacted at 98% of the maximum dry density and tested at different stress levels viz. 0.25, 0.5, 1.0, 2.0, 4.0 and 8.0 kg/cm^2 respectively. The test results indicate that the tested materials exhibits low compressibility characteristics. Both coarser (Material passing through IS Sieve 20 mm) and finer material (Material passing through IS Sieve 4.75 mm) consolidated very quickly and the value of axial strain was measured from 5.94% to 8.44%. The value of Coefficient of Consolidation at different stress level are presented in Table 4. The value of Compression Index and Swelling Index were measured 0.0842 to 0.0912 and 0.0133 to 0.0149 respectively. The low values of compression index and swelling index indicates the

low compressibility and swelling characteristics. The effective stress vs. void ratio curves are shown in Figure 4.

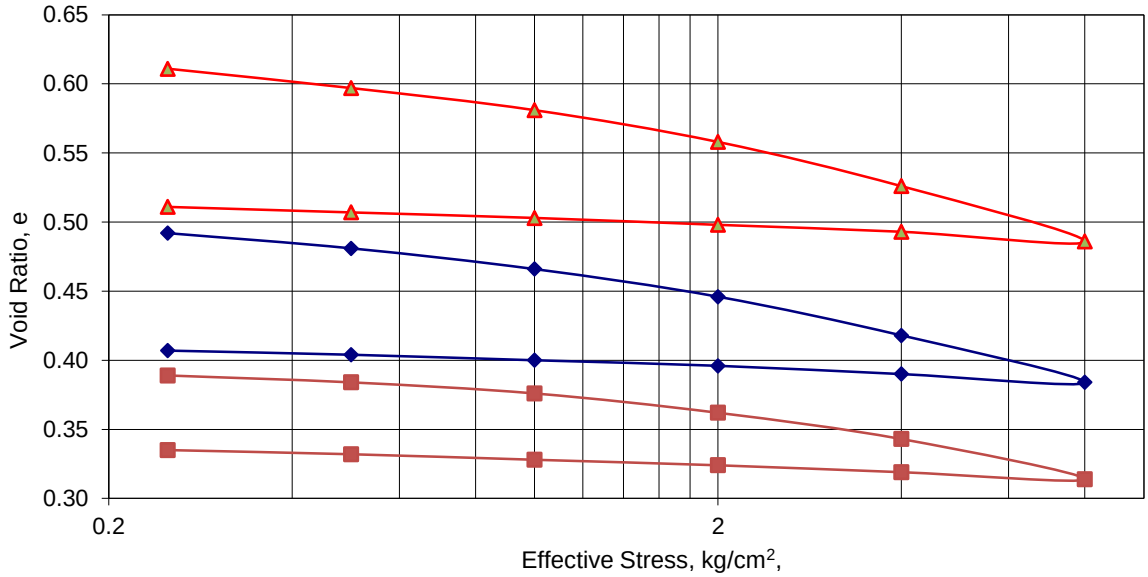


Figure 4. Void Ratio vs. Effective Stress

HYDRAULIC CONDUCTIVITY

The mine waste material (passing through IS Sieve 4.75 mm) was tested for to the hydraulic conductivity test using falling head method (IS: 2720 (Part-17), 1986). The mine waste material was compacted at 98% of the maximum dry density. The value of hydraulic conductivity vary from 4.22×10^{-5} cm/sec to 1.36×10^{-5}cm/sec. The results of hydraulic conductivity test indicate that mine waste material possess semi-pervious drainage characteristics.

Table 4 Value of Coefficient of Consolidation, Compression Index and Swelling Index

S. No.	Stress level	Coefficient of Consolidation (C_v) × 10^{-3} cm^2/kg	Compression Index (Cc)	Swelling Index (Cs)
1	0.25-0.50	23.76-24.60	0.0873-0.0912	0.0133-0.0149
2	0.50-1.00	16.79-20.74		
3	1.00-2.00	16.12-20.37		
4	2.00-4.00	13.32-19.85		
5	4.00-8.00	8.40-14.25		

CONCLUSIONS

The mine waste material from Rajpura –Dariba mine, Udaipur possess predominantly gravel sizes followed by fine sand sizes and medium sand sizes. Based on the results of grain size

distribution and Atterberg limits tests, out of the tested 8 mine waste material samples, 3 samples fall under GW-GM (Well Graded Gravel with Silty Gravel), 2 samples fall under GM (Silty Gravel), one sample each fall under GP-GC (Poorly Graded Gravel with Clayey Gravel), GP-GM (Poorly Graded Gravel with Silty Gravel) and GW-GC (Well Graded Gravel with Clayey Gravel), groups of Bureau of Indian Standard soil classification system. The specific gravity of mine waste material vary from 2.90 to 2.96. The higher value of specific gravity due to higher concentration of zinc and lead. The proctor dry density of material vary from 2.01 g/cc to 2.15 g/cc which indicates that material is capable of achieving the very good density. The value of effective angle of shearing resistance vary from 34.3° to 37.1° for fine material (material passing through 4.75 mm IS Sieve) and 37.1° to 40.7° for coarse material (material passing through 20 mm IS Sieve) which indicates that the material is capable of achieving the very good shear strength. The value of coefficient of consolidation indicates that material will require comparatively less time in consolidation and will go for small compression. The hydraulic conductivity of material vary from 4.22×10^{-5} cm/sec to 1.36×10^{-5} cm/sec which indicates that material has semi-pervious characteristics. On the basis of above study, It can be concluded that that mine waste material from Rajpura –Dariba mine, Udaipur possesses good engineering properties and can be used as construction material for construction of embankment for tailing dams. Mine waste materials can also be used as filling materials in empty mines and open trenches with suitable precautions to avoid the leaching of heavy metals in surrounding water bodies.

ACKNOWLEDGEMENT

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