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INVESTIGATION OF GEOTECHNICAL PROPERTIES OF COAL MINE WASTE: A CASE STUDY FOR BARAPUKURIA COAL MINE

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ABSTRACT

The byproducts generated during mining and processing of coal, generally known as coal mine wastes, are usually dumped near the mining area causing several environmental and aesthetic problems. The present study is aimed to investigate engineering properties of coal mine waste generated from the Barapukuria coal mine, Dinajpur and to evaluate the possibility of using them in the field of geotechnical engineering such as a replacement of road subgrade. Laboratory tests like specific gravity test, grain size analysis, Atterberg limit test, proctor test, unconfined compression test and California Bearing Ratio test were carried out on fresh coal mine waste collected from the Barapukuria coal mine. Test results indicate that the mine waste behaves like a poorly graded inorganic soil which falls in the category "sandy lean clay" with a maximum dry density of 18.13 kN/m3. Unconfined compressive strength was determined as low as 39.99 kN/m2 and hence the waste itself was found to be unsuitable for using as a supplementary engineering material for geotechnical structures. It was concluded that the fresh coal mine waste must be improved with strengthening admixture before using them as an engineering material for structures. In addition, chemical analysis of the waste detected lead content as 0.026 ppm that indicated the requirement of precautions for the areas with high ground water table.

Keywords: *Coal Mine Waste, Barapukuria Coal Mine*

1. INTRODUCTION

Coal is one of the primary sources of energy in Bangladesh and there is an increase in demand for coal production to meet the requirements of the industries. The amount of waste generated from coal mining and processing operation is increasing alarmingly. At present, with the exception of some small scale underground waste disposal operations in abandoned coal mines, most of these wastes are disposed at the surface, which inevitably requires excessive planning and control to minimize the environmental impact of mining. It also results in non-productive use of land, air and water pollution, possible failure of waste embankments, and the loss of aesthetic value of the land. It is high time to find out alternative ways to utilize the coal mine wastes. Before planning such alternate use in the field of engineering, it is essential to know several physical, chemical and engineering properties of the waste. The present study is focussed on investigating the properties of coal mine waste so that they can be used in the field of geotechnical engineering. The Barapukuria Coal Mine, the only natural coal mine reserve that is in operation, is taken under consideration.

Various research and studies on coal mine waste have been conducted in recent years to analyse the possibility of utilization of these wastes, to find out ways to store these wastes safely without causing any pollution and also to find out the methods by which these wastes can be used to prevent various kinds of environmental pollution. A research about Re-Use of

Mine Waste Materials Amended with Fly Ash in Transportation Earthwork Projects revealed that mine waste materials mixed with fly ash can be used in transportation projects bringing some environmental benefits by decreasing energy consumption, raw material use, and greenhouse gas emissions (Christopher, 2013). Another investigation on the use of coal mine refuse for sub-base material and embankment fill in south Dakota showed that coal mine refuse sampled at an abandoned mine site in South Dakota can be used as embankment fill material and can provide limited uses for sub-base applications (Uckert et al., 2006). A geotechnical investigation of coal mine refuse was conducted to assess the fill's ability to act as a ground support material and to study the physical and mechanical properties of coal mine refuse where samples were collected from different mines of Mahanadi Coalfields Ltd (MCL), Hindalco, and South Eastern Coalfields Ltd (SECL). The different tests were performed like triaxial test, slake durability test, liquid limit test, standard proctor compaction test and permeability test. It was found that only coal refuse sample can be used for the purpose of backfilling without much treatment. But all other samples need some treatment such as removal of some fine particles, mixing with some amount of cement or some other binding material so that its strength increases and it does not deteriorate when subjected to wetting and drying cycles (Agarwal, 2009). In another study the physical and mechanical properties of coal mine waste from different sites were described and the effects of these properties on the duty requirements of fill materials were assessed. It was concluded in that study that if improving ground control is the only reason for backfilling, coal refuse alone does not appear to be a suitable stowing material. If coal-refuse disposal is also a consideration, then it may be more attractive stowing and backfilling material (Karfakis et al., 1996). There are also few number of studies carried out on Barapukuria Coal Mine. A research titling "an Assessment of the Underground Roadway Water Quality for Irrigation Use around the Barapukuria Coal Mining Industry" was carried out to investigate the effect of coal mining work on irrigation water (Howladar et al., 2014). The effect of long-wall mining on groundwater for underground coal extraction in Barapukuria was also studied (Kibria et al., 2012). However, the possibility of using Barapukuria coal mine waste as an engineering material was never analyzed by any researchers. The wastes generated from Barapukuria coal mine are not disposed in an authority controlled safe zone. Also they are not generally used for any engineering purpose. Hence, this study about analyzing the geotechnical properties of coal mine wastes collected from the Barapukuria Coal Mine is justified and a well-demanded work.

2. METHODOLOGY

A number of laboratory tests are carried out in order to accomplish this work. Coal mine wastes were collected several times from nearby coal mine. The tests were carried out following the methods and procedures described in ASTM standard.

2.1 Collection of Sample

For this research work, Coal mine waste was collected from Barapukuria coal mine situated at Chowhati village of Phulbari upozilla, Dinajpur. Sample was collected from the dumping site removing the top layers.

Figure 1: Dumped coal mine waste at Barapukuria Coal Mine

2.2 Laboratory Tests of Waste

The entire laboratory testing on coal mine waste was carried out in accordance with ASTM designation. Laboratory tests such as specific gravity test, grain size distribution test (by sieving and hydrometer), standard proctor test, Atterberg limit test, unconfined compression test and California Bearing Ratio (CBR) tests were performed.

2.2.1 Specific Gravity Test

ASTM D 854-00 – Standard test for specific gravity of soil solids by water Pycnometer was adopted for determining specific gravity of coal mine waste sample. The value of specific gravity roughly indicates soil behaviour.

2.2.2 Grain Size Analysis

ASTM D 422 - Standard test method for particle size analysis of soils was adopted for identifying soil type and gradation of fresh coal mine waste.. The Unified Soil Classification System (USCS) was used to classify the waste as a particular soil type based on its grain size analysis data.

2.2.3 Atterberg Limit Tests

ASTM D 4318 - standard test method for liquid limit, plastic limit, and plasticity index of soils was applied for the determination of Atterberg limits of the waste sample. Liquid limit, plastic limit and plasticity index was calculated. Based on the plasticity index and sieve analysis result USCS soil classification was applied in accordance to the plasticity chart.

2.2.4 Standard Proctor Tests

ASTM D 698 - Standard test methods for laboratory compaction characteristics of soil using standard effort (12,400 ft-lbs/ft3) was applied for the determination of optimum moisture content and maximum dry density of the waste sample.

2.2.5 Unconfined Compression Test

ASTM D 2166 - Standard test method for unconfined compressive strength of cohesive soil was adopted for the determination of unconfined compression strength of the waste. This test reveals strength characteristics of the sample. Das (1994) suggested the general relationship between unconfined compressive strength and the quality of the subgrade soils used in pavement applications as in Table 1.

Table 1: Relationship between unconfined compressive strength and the quality of the subgrade (Das, 1994)

UCS value (psi)	Quality of Subgrade
<3.625	Very soft
3.625-7.25	Soft
7.25-14.50	Medium
14.50-29.00	Stiff
29.00-55.10	Very stiff
>55.10	Hard

2.2.6 California Bearing Ratio Test

ASTM D 1883 - Standard test method for determination of California bearing ratio of soil was adopted for the determination of CBR value of the waste. This test evaluates the potential of the waste to be used as a road pavement material.

2.2.7 Chemical Analysis

Standard X-ray Fluorescence chemical tests were performed on fresh coal mine waste to find-out the existence of possible toxic or harmful content in the sample. An EDF3600B model EDXRF (Energy Dispersive X-ray Fluorescence) spectrometer was used. The test result was obtained by ORE work curve method from the attached computer.

3. RESULTS AND DISCUSSIONS

3.1 Specific Gravity

The value of specific gravity was found to be 2.59. This value lies within the range 2.6 to 2.8 which indicates that the fresh coal mine waste resembles like an inorganic soil (Aurora 2006).

3.2 Grain Size

Both sieve analysis and Hydrometer test were carried out for the waste and combining sieve analysis and hydrometer analysis data, a grain size distribution curve is plotted as shown in Figure 2.

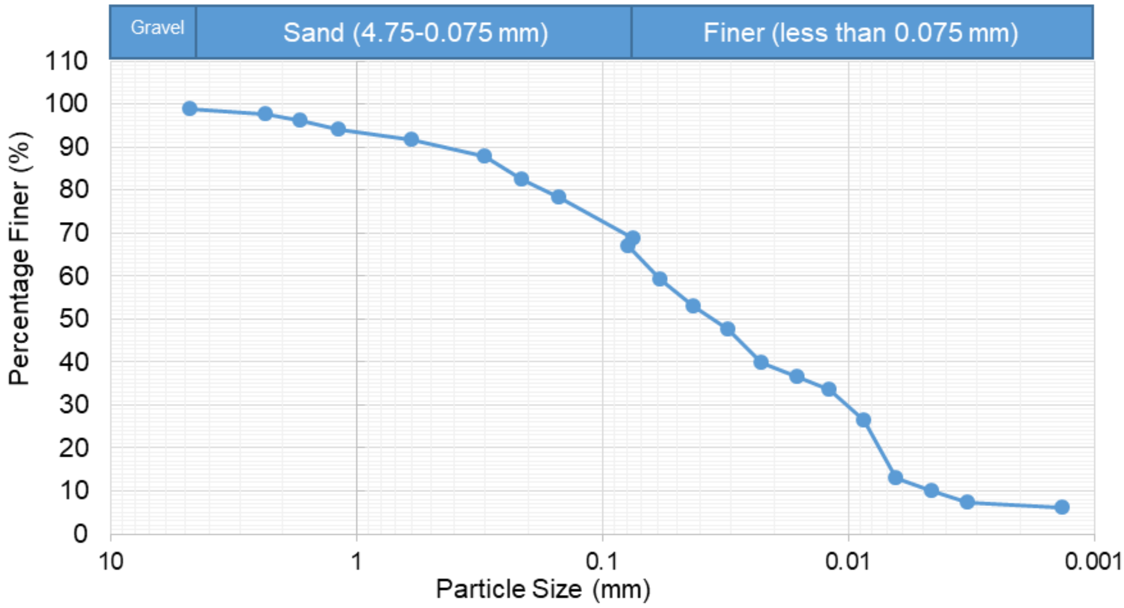


Figure 2: Grain size distribution curve for fresh coal mine waste

Analyzing the grain size distribution curve, the uniformity coefficient (C_u) was found to be 13.33 and Coefficient of Curvature (C_c) was found to be 0.37. A soil sample is said to be well graded if the criteria $C_u \geq 6$ and $1 < C_c < 3$ are satisfied (Holtz and Kovacs 1981). In case of fresh coal mine waste criteria for C_u is met, but C_c lies below unity and hence the soil is poorly graded (Arora, 2006).

3.3 Atterberg Limits and Soil Classification

The liquid limit of waste sample was found to be 32.30% and plastic limit was 13.56%. Plasticity index was calculated as 18.74%. Based on the criteria of the unified soil classification system (USCS), Since in sieve analysis, more than 70% sample Passes No. 200 Sieve and from Atterberg limit test PI > 7 and plots above "A" line in the plasticity chart; So, the sample is of CL group & classified as “Sandy Lean Clay” (inorganic clay of low to medium plasticity). The plasticity chart is shown in Figure 3.

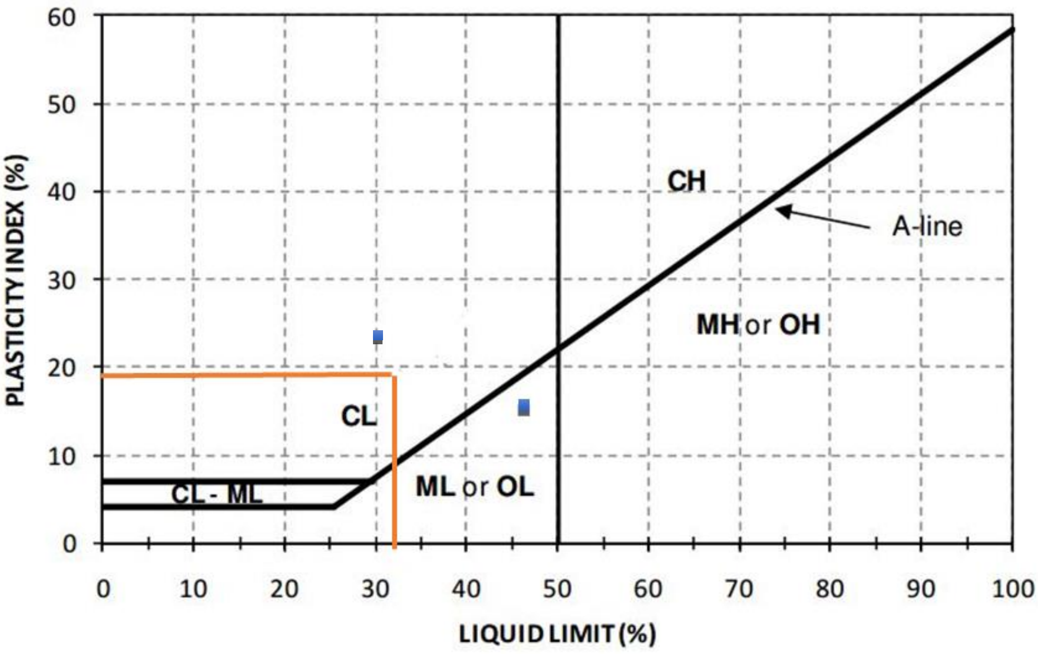


Figure 3: Determination of soil type of waste sample from plasticity chart (USCS)

3.4 Compaction Parameters

By performing standard Proctor test, optimum misture content was found to be 7.5% and maximum dry density was obtained as 18.13 kN/m^3. Corresponding graph for the determination of optimum moisture content (OMC) and maximum dry density (MDD) are presented in Figure 4.

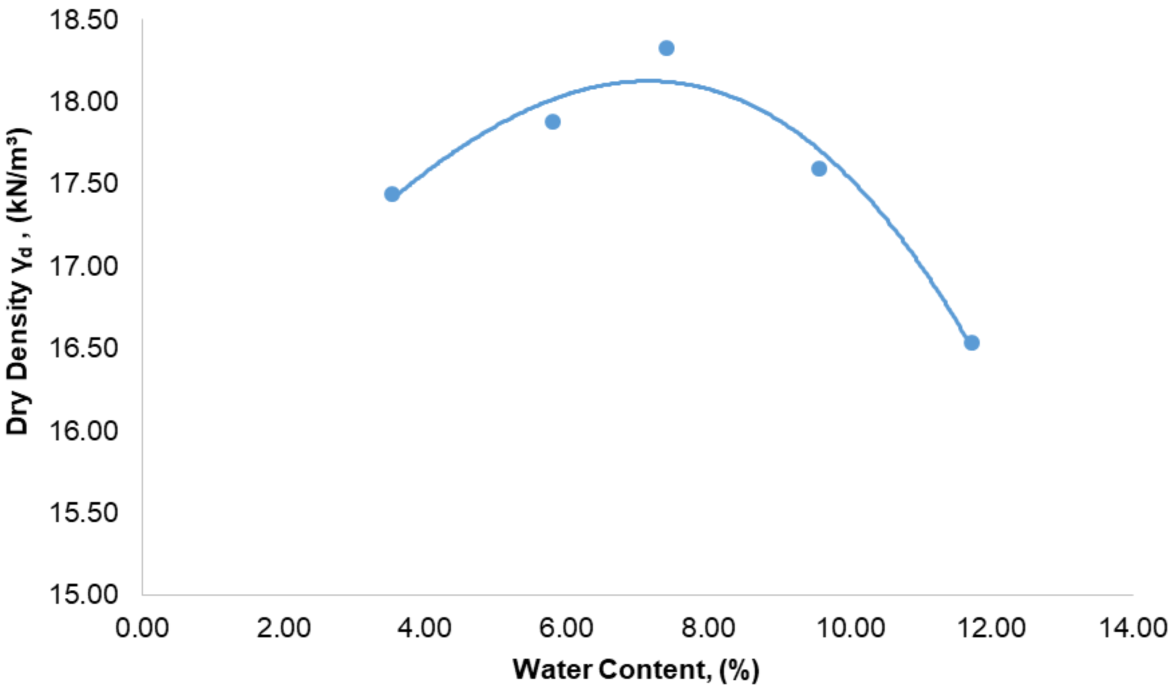


Figure 4: Relationship between dry density (kN/m^3) and water content (%)

3.5 Unconfined Compression Strength

Using unconfined compression test data, the relation between axial stress and axial strain are presented in Figure 5.

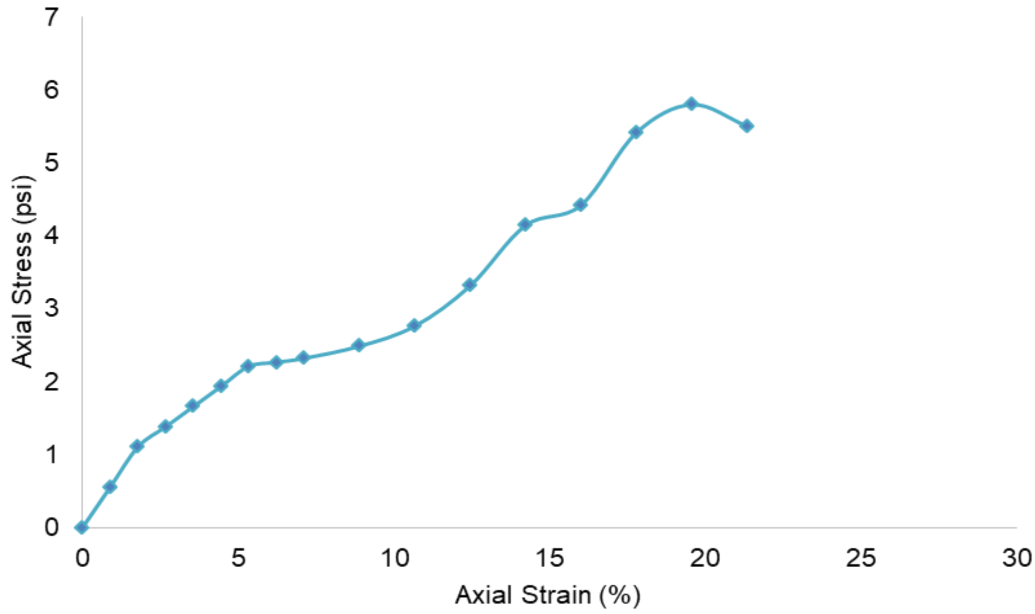
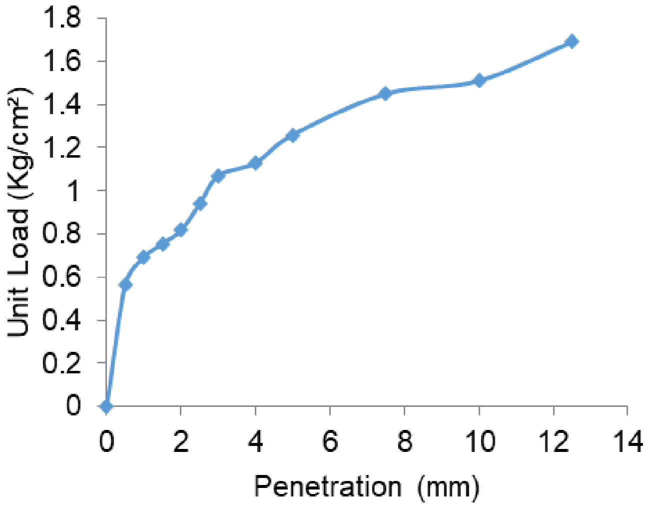


Figure 5: Relationship between axial stress (psi) vs. axial strain (%) for different mixes

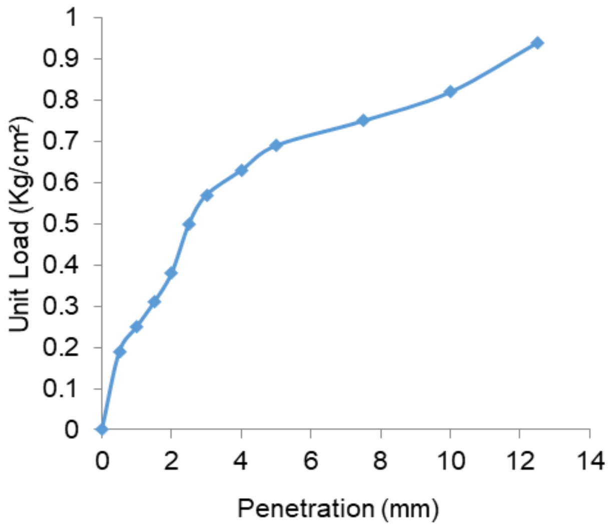
The unconfined compression strength was found to be 5.8 psi only and the waste falls in the category "very soft" according to USCS classification system.

3.6 California Bearing Ratio

The relation between unit load and penetration for both unsoaked and soaked CBR test are shown in Figure 6.



(a) Unsoaked Sample



(b) Soaked Sample

Figure 7: Relationship between unit load and penetration

CBR value and expansion ratio is presented in table 2.

Table 2: CBR test result

Sample Condition	**Penetration**	
	2.5mm	**5.0mm**
Un-soaked	1.34	1.2
Soaked	0.71	0.66
Expansion ratio	1.51	

A large expansion ratio was obtained for the waste sample which indicates its inferiority as a road material.

3.7 Chemical Analysis Report

The chemical analysis report for the waste sample is presented in Table 3.

Table 3: XRF test result for fresh coal mine waste

Element	**Content in Sample-1 ppm**	**Content in Sample-2 ppm**	**Content in Sample-3 ppm**	**Average Content ppm**
Al	1.625	1.287	1.458	1.456
Si	5.570	4.455	4.981	5.002
P	0.002	0.000	0.000	0.001
S	0.055	0.036	0.041	0.044
K	0.297	0.211	0.244	0.251
Ca	0.034	0.022	0.030	0.029
Ti	0.081	0.087	0.067	0.078
Mn	0.010	0.008	0.007	0.008
Co	0.003	0.004	0.004	0.003
Fe	2.669	2.563	2.552	2.595
Cu	0.011	0.011	0.011	0.011
Zn	0.019	0.020	0.021	0.020
Sn	0.046	0.041	0.044	0.043
Pb	0.019	0.024	0.035	0.026
Rb	0.005	0.004	0.004	0.004
Nb	0.001	0.005	0.001	0.002
Mo	0.022	0.015	0.017	0.018

The tested lead level of the waste samples is obtained 0.026 ppm. No level of lead is considered safe in drinking water; although an action level of 0.015 ppm at the tap can be used to identify highly impacted water. Therefore the lead content of waste may be potentially harmful for ground water, if the waste is dumped on ground, particularly in the areas with high ground water table.

4 CONCLUSIONS

The laboratory tests carried out on the coal mine waste sample collected from Barapukuria coal mine revealed its inferior quality as an engineering material. The waste sample possesses very low strengths with a large expansion ratio (>1) which makes it unfit to use even as a road subgrade materials (Road pavement design manual, 1999). The fresh coal mine waste must be improved with proper additives in order to make it usable in an engineering work. Strength and plasticity of the fresh waste can be significantly improved by mixing it with a certain portion of improving agent such as cement. However, extensive study with cost-benefit analysis is recommended for such improvement.

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ASTM D 854-92 – Specific gravity of solid determination.

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