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Strength and CBR Properties of Soil using Coal Dust as an Admixture

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Abstract - *The modified soil developed for the road construction industry would be in a line with the practice of engineering in an environment-friendly and sustainable way. Instead of using conventional materials like aggregates as the various layers, the modified soil is the better option simultaneously reducing cost and utilizing the sub soil, which has been removed otherwise. This research investigate on the use of non-traditional construction materials, specifically coal dust as an engineering material in sub-grade of pavement construction. The specimens were prepared using different proportions of coal dust. Additives are mixed with soil at OMC because the water content adopted at the time of constructions usually around OMC value. The modified soil specimens were subjected to Unconfined compressive strength (UCC) test and California bearing ratio (CBR) test upon 3, 7& 21 days of curing. It was observed that the strength and CBR values of the soil have been increased gradually till 20% of coal dust and no significant improvement thereafter. These values also have been increased with increase in curing period.*

Key Words - *Coal dust, Mine waste, Sub-grade, Unconfined compressive strength, California bearing ratio.*

I. INTRODUCTION

In construction of road and airfield the main objective of stabilization is to increase the strength or stability of soil and to reduce the construction cost by making best use of the locally available materials. Apart from affecting economy in the initial construction cost of lower layer of the pavement such as sub-base course it should be possible to upgrade the low cost roads to high specification without involving appreciable wastage, utilizing the principle of pavement construction in stages. The construction cost can be considerably decreased by selecting local soils for the construction of the lower layers of the pavement such as sub-base course.

The physical characteristics of soil, which determine its usefulness to support traffic or to serve as a sub-grade or foundation material, depend upon the size and shape of the individual grain, the grain size distribution, the specific gravity and the compaction characteristics. Pavement design is based on the premise that minimum specified structural quality will be achieved for each layer of material in a pavement system. Each layer must resist shear, avoid excessive deflections that cause fatigue. Available earth materials do not always meet these requirements and may require improvement in their engineering properties in order to transform these inexpensive earth materials into effective construction materials.

The determining factors associated with soil improvement includes the type of soil to be stabilized, the purpose for which the stabilized layer will be used, the type of soil improvement required, durability of the stabilized layer, the cost and environmental conditions, selection of candidate additives. The present study focus more on use of cheaper and locally available material, undertakes use of coal dust, a type of mine waste in stabilizing clay soil. Coal dust is not generally used for any engineering purposes; rather these wastes mostly are stored as heaps temporarily.

The objectives of the study are,

1. To use coal dust as a stabilizing material and to solve the problem of waste disposal.
2. To evaluate the strength characteristics of clay for different proportions of coal dust.
3. To know the optimum percentage of coal dust that can be used in the stabilization process.

II. BACKGROUND INFORMATION

Long term performance of pavement structures often depends on the stability of the underlying soils. Engineering design of these constructed facilities relies on the assumption that each layer in the pavement has the minimum specified structural quality to support and distribute the super imposed loads. These layers must resist excessive permanent deformation, resist shear and avoid excessive deflection that may result in fatigue cracking in overlying layers. In case of cohesion less soils the strength could be improved by providing confinement or by adding cohesion with a cementing or binding agent. In case of cohesive soil the strength could be increased by drying, making soil moisture resistant, altering the clay electrolyte concentration, increasing cohesion with a cementing agent and adding frictional properties.

2.1 Coal Dust:

Today, world faces a serious problem in disposing the large quantity of mine waste. The disposal of mine waste without proper attention creates impact on environmental health. It disturbs ecosystem, causes air pollution, water pollution etc. The engineers have to take challenge for safe disposal of mine waste.

Coal is a heterogeneous by-product of the mining. Coal rank varies from high to low; high rank coals are generally older, have the greatest fixed carbon, have the least volatile matter, the lowest moisture content, and the highest calorific value, and vice versa. The highest rank coal is anthracite, followed by the bituminous and sub-bituminous coals (hard coals), and ending up with the brown coals and lignite (soft coals). Coal mine dust is a comp1ex mixture containing more than 50 different elements and their oxides. The minera1 content varies with the partic1e size of the dust. The remaining portion consists of a variable mixed dust originating from fractured rock on the mine floor or roof.

Coal mining operation results in two general types of by- products. One is coarse coal refuse and another is fine coal refuse which is also termed as coal dust. In coal mining during the mining process a lot of coal mine dust produce. Proper disposal of this is a great problem. Coal dust is very hazardous and is more susceptible to spontaneous combustion since it is suspended in air. It also causes many lung diseases; if we can try to use coal dust in pavement construction we can reduce its effects. Coal dust suspended in air is explosive coal dust has far more surface area per unit weight than lumps of coal, and is more susceptible to spontaneous combustion. It also results in non-productive use of land, air and water pollution. In the present study, coal dust was introduced to enhance the strength and durability of earth as construction materials.

The presence of a diluted amount of a coal dust concentration (i.e, 15 g.m−3) in the processing industry and/or a hot environment is a potential hazard as a source of ignition. Below a 15 g.m−3 coal dust concentration, auto-ignition was not possible, even when applying higher temperatures [1]. The effects of saw dust, coal dust and iron filling additives at varied proportions on some selected properties of moulding sand were investigated [2]. Consequently, cylindrical specimens with different percentages of additives were prepared based on standard procedures. From the obtained test results, all the experimental additives were found to improve the selected moulding properties of the base (silica) sand.

Cooking coal dust has the potential to replace traditional admixtures used to improve soil properties. The low cost of this coal dust is an added benefit as it can be used either alone or in combination with regular admixtures in the construction of foundations, embankments, retaining walls etc. Disposal of the huge amount of produced coal dust poses a potentially serious environmental threat due to paucity of land for disposal. Therefore, using coal dust in construction can, in addition to reducing expenditures, will also solve the headache of its safe disposal and help in preventing environmental degradation [3].

Coal dust as stabilizer gives satisfactory results in case of soil but showed very poor results in case of concrete. It can be concluded from the concrete specimens prepared by adding coal powder with proportion of 5%, 10%, 15%, and 20%, the pressure strength of coal-added concrete is still unequal to the normal one [4].

III. MATERIALS AND METHODOLOGY

The clay used for the study was brought from Narketpally, Nalgonda district, Telangana. It was dug from a depth of 1.5m from the ground surface. Coal dust for the study was brought from Singareni coal mines, Adilabad district, Telangana. The general constituents of coal dust are shown in Table 1.

Table 1: General constituents of coal dust

S. No.	Constituent	Range (%)
1	Carbon	50 - 65
2	Oxygen	30 – 40
3	Hydrogen	5 - 7
4	Calcium	0.05 – 2.67
5	Iron	0.34 – 4.32
6	Silicon	0.58 – 6.09
7	Aluminium	0.43 – 3.04

The study can broadly be classified into two stages. The first stage determines the properties of the soil and the proportions of coal dust used to the soil. The second stage includes the evaluation of UCC and CBR values of specimens prepared using various proportions of coal dust and determination of the optimum proportion to be used. The CBR test was conducted under unsoaked condition. The general relation between CBR values and bearing capacity of soil [5] is presented in Table 2.

Table 2: Relation between CBR and Bearing capacity of soil

CBR	Bearing capacity of soil
2% -5%	Ugly
6% - 9%	Medium
> 9%	Good

IV. RESULTS AND DISCUSSIONS

Coal dust was mixed with clay soil in proportions of 5%, 10%, 15%, 20% and 25% by weight of soil at optimum moisture content. Tests have conducted on these samples after curing for 3, 7 and 21 days to investigate the relative strength gain in terms of UCC and CBR values. The fraction of coal dust for which maximum strength is obtained was found out.

Tests have been conducted according to IS code specifications. The properties of the clay are presented in Table 3. The results of UCC and CBR tests of clay mixed with various proportions of coal dust at different curing periods are summarized in Table 4.

Table 3: Properties of Clay

S. No.	Properties of Soil	Value
1	Specific Gravity	2.566
2	Natural Water Content	8.2%
3	Gravel	< 1%
4	Sand	37%
5	Fines	62%
6	Liquid Limit	56%
7	Plastic Limit	33%
8	Plasticity Index	23%
9	Swelling Index	50%
10	Optimum Moisture Content	19%
11	Maximum Dry Density	1.77gm/cc
12	P^H	8.2
13	Unconfined Compressive Strength	2.62kg/cm^2
14	CBR	1.87%

Table 4: UCC and CBR values of clay mixtures

Clay Mixture ↓	Name of the test →	UCC (kg/sq.cm)			CBR (%)		
	Curing Period →	3 days	7 days	21 days	3 days	7 days	21 days
Clay + 5% Coal dust		2.52	2.873	3.042	1.785	2.052	2.22
Clay + 10% Coal dust		2.685	3.145	3.402	2.584	4.199	4.86
Clay + 15% Coal dust		2.79	3.281	3.528	3.145	5.32	7.3
Clay + 20% Coal dust		3.12	3.655	4.158	4.811	6.935	7.7
Clay + 25% Coal dust		3.15	3.774	4.158	4.845	7.068	7.92

The relation between percentage of Coal dust with UCC and CBR values are shown in Figures 1 & 3 respectively. The relation between curing period with UCC and CBR values are shown in Figures 2 & 4 respectively. It may be seen from the figures that the UCC values have been increased with increase in percentage of Coal dust up to 20%. The CBR values have increased rapidly up to 15% of Coal dust and have increased further up to 20% of Coal dust. There was no significant increase in UCC and CBR values of soil mixture beyond 20% of Coal dust. Similarly the UCC and CBR values have been increased continuously with increase in curing period. Rapid increase in values is observed from 3days to 7days of curing.

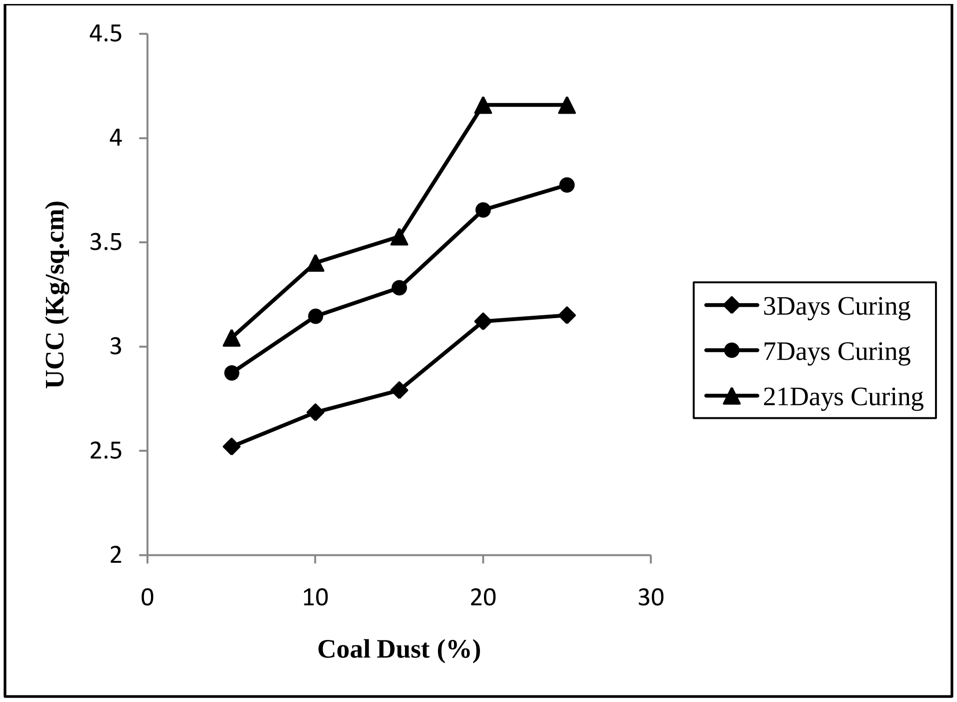

Figure 1: Variation of UCC with percentage of Coal dust at different curing periods

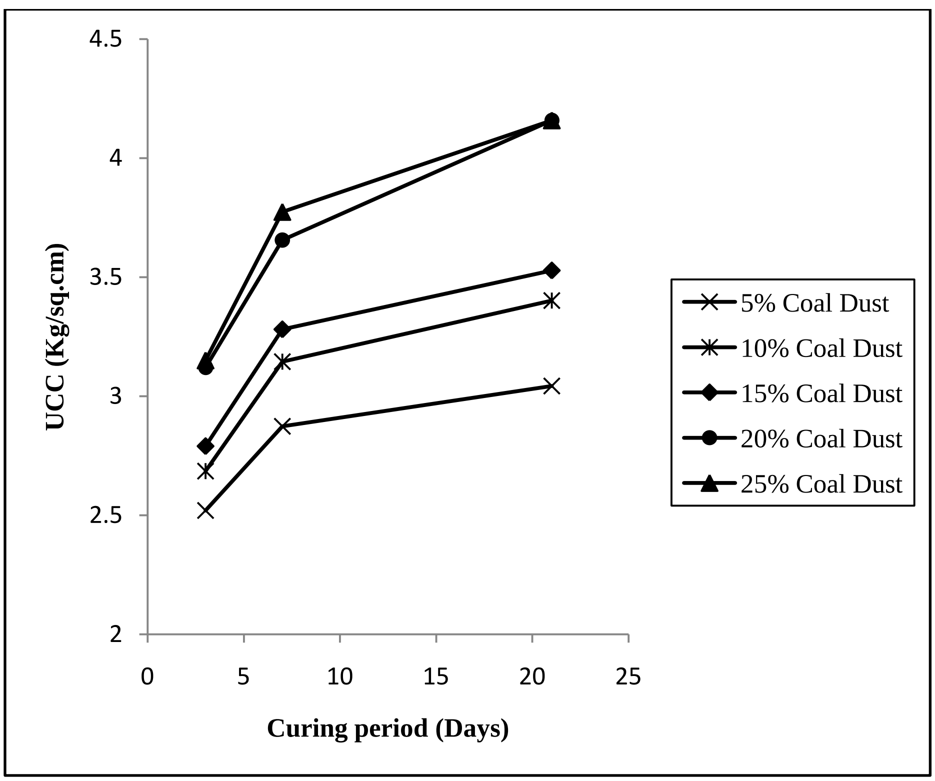

Figure 2: Variation of UCC with curing period at different percentages of Coal dust

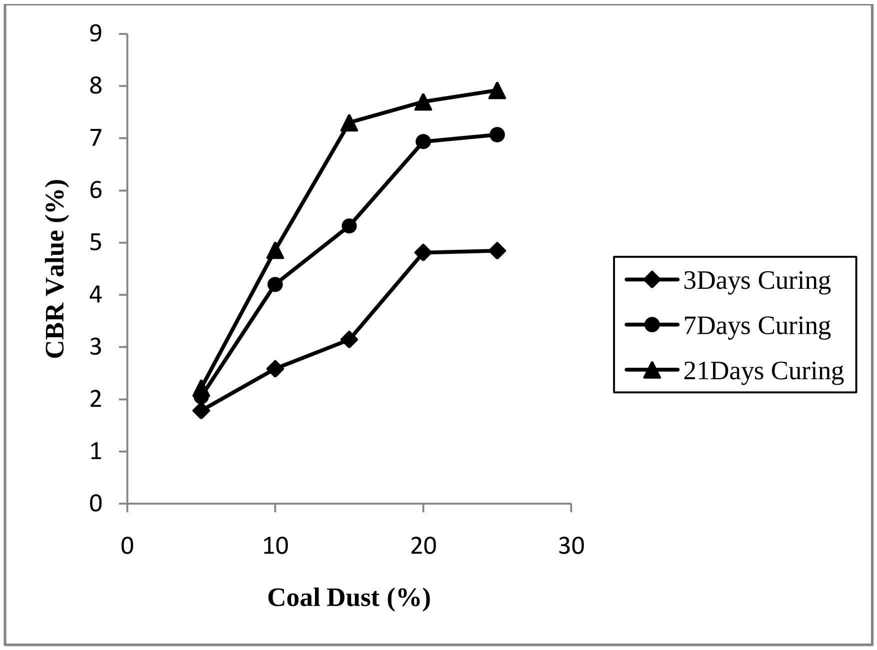

Figure 3: Variation of CBR with percentage of Coal dust at different curing periods

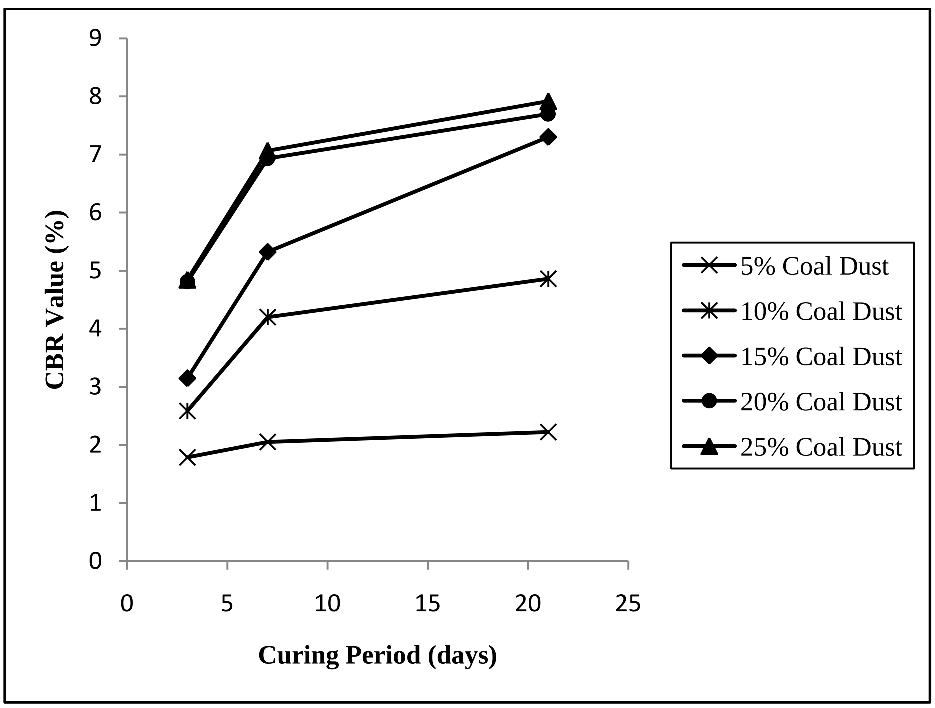

Figure 4: Variation of CBR with curing period at different percentages of Coal dust

V. CONCLUSIONS

1. The use of coal dust, the mine waste improves the properties of clay soil; coal dust can be used up to certain limit to improve the properties of soil.

2. The Unconfined compressive strength and CBR values increased due to curing.

3. The optimum percentage of Coal dust was found to be 20 – 25% for the clay used.

4. The blend suggested from this research is the addition of Coal dust to clay soil, without any addition of cementing or chemical material would be an economic approach.

5. Furthermore if any cementing material is added in suggested blend, then there will be definitely more improvisation in properties of clay soil.

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