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Strength Improvement of Soft Soil Mixed With Pond Ash & Steel Slag

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Abstract: The consumption of coal in thermal power plants produces massive quantities of pond ash which require effective mode of utilization. Steel slag is also one of the valuable industrial by-products which has wide application in the sustainable construction. The present investigation describes about the application of pond ash and steel slag in soil stabilization. Pond ash and steel slag has been blended with soil in different proportions by dry weight. Further, Atterberg's limit, specific gravity, compaction test, direct shear test (DST), and California Bearing Ratio (CBR) tests were used to evaluate the Index characteristics and strength properties of all the mix proportions respectively.

***Index Terms* – Soft soil, pond ash, steel slag, direct shear test, CBR test, compaction.**

I. INTRODUCTION

India now produces nearly 169.25 (MMT) million tonnes of pond ash from the combustion of coal, which is expected to almost double in the next 10 years. According to the analysis, the relative utilization is only about 63.28 percent, or 107.10 million metric tonnes (Central Electricity Authority). This underutilized ash has detrimental effects on the environment, emphasizing the need to boost the pace at which pond ash is utilized. Pond ash may be used as a base material in geotechnical building projects including embankments and filling materials. This is a good way to solve the pond ash problem of waste disposal while simultaneously reducing the construction cost. To use pond ash as a building material, its characteristics and strength/stability, as well as the parent material, must be examined. Apart from experimental work, different scholars have focused on analysis to better understand embankment stabilities of factors of safety. The optimization of slope angles and their stability difficulties with varied proportions of pond ash mixed with soil is now being pursued in this direction. When it comes to the stabilization of soil, it's essential to know every type of stabilizer and how to utilize it effectively, as well as the ideal percentage needed for stability and the approach used. The employment of the optimization method can be used to sort out robust systems to many of the challenges. According to the Antipollution Board's scientific analysis system, all waste is neutral and non-hazardous. This slag is produced in the amount of 24 lacs MT per year by various steel plants. Steel slag can be utilized as a cover liner for landfills. Whenever this are used as a construction material its properties and strength/stability along with parent material need to be check before actual uses. Several extensive research has been investigated the effective utilization of waste for the improvement in the soil characteristics [1]–[7].
Steel slag is used in embankments to reduce significant expansion also but to make use of its good characteristics in providing high stability. Granulated steel slag currently has no uses and therefore is thrown on the expensive land around the facilities. A research was conducted to see if steel slag could be used in embankment buildings. Because it is a non-cohesive substance, that was mixed into local soil and its geotechnical properties were assessed. Steel Slag stability studies were carried out in embankment designs and under different water saturation levels under earthquake as well as traffic loadings. Steel slag technological standards were devised for use in the embankment's construction. As a result, an increase in pond ash and steel slag utilization would lead to a lower rate of disposal, optimum use, and traditional or base material such as soils can be replaced. The results of the above approach would be lead to a cost-effective and enviro-friendly solution.

II. RESEARCH METHODOLOGY

This paper presents a laboratory investigation of soil, pond ash, and steel slag, soil mixes at the various proportion of pond ash and steel slag.

2.1 Soil

The locally available soil was collected from the SSIPMT Raipur Chhattisgarh, India campus for laboratory investigation. The collected soil sample was preliminarily dried for 1 day and with help of an electric oven. The geotechnical properties of soil is presented in Table 1.

Table 1. Geotechnical properties of soil

Sr. no.	Properties	value
1.	G (specific gravity)	2.58
2.	LL (liquid limit %)	30
3.	PL (plastic limit %)	20
4.	Type of soil as per IS code	ML
5.	MDD (Maximum Dry KN/m^2)	18
6.	OMC(Optimum moisture content)	16

2.2 Pond ash

The pond ash sample was collected from NSPCL (NTPC-SAIL Power Company Limited), Bhilai, Chhattisgarh, India. Table 2 presents the geotechnical properties of pond ash.

Table 2 Mechanical properties of pond ash

Sr. No.	Properties	Value
1.	Specific gravity (G)	2.01
2.	LL (liquid limit %)	45
3.	PL (Plastic limit %)	NON PLASTIC
4.	MDD (KN/m^2)	12
5.	OMC (%)	35

2.3 Steel slag

The steel slag sample was collected from BSP (Bhilai steel plant) Bhilai, Chhattisgarh, India. The specific gravity was found as 3.02.

III. RESULTS AND DISCUSSION

The experimental results are presented in the subsequent sections.

3.1 Atterberg' limit and specific gravity

The Atterberg's limits of various soil pond ash and steel slag mixes were estimated according to the IS: 2720 (Part 5) – 1985. Table 3 presents the liquid limit, plastic limit, with various percentages of soil blended with pond ash and steel slag. It was observed that the soil liquid limit has decreased with the increase in the percentage of steel slag. The lowest liquid limit value was observed as 25% for soil mixed with 20% pond ash and 20% steel slag. The soil plastic limit also tended to decrease when the percentage of steel slag increases. The addition of pond ash and GGBS causes reduction in plasticity index.

3.2 Compaction characteristics

Compaction tests were carried out using a light compaction test according to IS 2720. The behavior of pond ash and steel slag is less sensitive to higher air void content than the soil. Normally, soils have 1 to 5% of air voids content at maximum dry density. It was observed that the reduction in the maximum dry density (MDD) and increasing optimum moisture content (OMC). Generally, MDD is influenced by the two major factors i.e., specific gravity and particle size distribution. The increase in pond ash content in soil results in the reduction of MDD and increase of OMC.

3.3 California Bearing Ratio (CBR)

In the construction of pavement, pond ash and steel slag are used as sub-base materials. The CBR method is widely used for pavement design. The CBR values of different soil - pond ash and steel slag mixes were determined according to IS 2720. The CBR samples were prepared for soaked conditions to their given light compaction MDD and OMC and further, their respective values were calculated and presented in Table 5. It was observed that the CBR value of soil is higher for all the proportions of pond ash and steel slag contents. This is mainly due to soil consisting well gradation which gives better packing when placed at 95% of MDD and corresponding OMC, which gives friction-resistant against plunger penetration and exhibits higher capillary force compared to the other proportion of pond ash and steel slag mixes. the decreasing of CBR at this stage could probably be due to the presence of excessive pozzolanic material on clay which could only have functioned as filler to pore space of soil particles and no longer functioned as a binder of soil particles so that cementation processes do not occur.

Table 3: Atterberg's limit and specific gravity

Soil %	PA %	SS %	LL (%)	PL (%)	PI (%)
100	0	0	30	20	10
90	10	0	32	23	9
80	20	0	24	26	8
80	10	10	29	22	7
70	20	10	28	22	6
70	10	20	28	23	5
60	20	20	25	23	2

Table 4: Compaction characteristics

Soil %	PA %	SS%	OMC %	MDD (KN/m^2)
100	0	0	16.00	18.00
90	10	0	18.00	16.50
80	20	0	19.00	16.00
80	10	10	17.50	17.00
70	20	10	18.50	16.80
70	10	20	17.00	17.50
60	20	20	18.00	17.00

Table 5: Soaked CBR values of all mix proportions

Soil	PA%	SS%	Soaked CBR (%)
100	0	0	7%
90	10	0	8%
80	20	0	10.50%
80	10	10	12%
70	20	10	14%
70	10	20	15%
60	20	20	17%

3.4 Direct Shear Test (DST)

The DST was conducted on soil- pond ash and steel slag mix specimen according to IS 2720 , the soil pond ash and steel slag mix specimens were prepared and tested at their respective light compaction MDD and OMC to evaluate the shear strength parameters (cohesion and internal friction ϕ). Table 6.presents shear strength parameters of the different proportions of PA and SS contents. It has been observed that friction angle decreases and cohesion increase with the increase in the percentage of pond ash contents in mix and when we mix steel slag the angle of internal friction increases and cohesion decreases.

Table 6: Shear strength parameters of all mix proportions

Soil %	PA %	SS %	ϕ (Degree)	c (kPa)
100	0	0	24	22
90	10	0	26	21
80	20	0	28	20
80	10	10	28	24
70	20	10	30	23
70	10	20	29	26
60	20	20	31	27

Conclusions:
Based on the present investigations, following conclusions are made:

1. Atterberg's limit of soil, pond ash, and steel mix changes to non-plastic from a plastic state with the replacement of pond ash and steel slag content.
2. As pond ash and steel slag content increases in soil mixes, the reduction in maximum dry density and increasing optimum moisture content.
3. The addition of pond ash and steel slag can increase CBR value which reaches an optimum value 17 % at the variation of 20% pond ash and 20%steel slag.
4. The addition of mix increases the Compaction value which reaches an OMC value of 18% and MDD 17% at the variation of 20% PA and 20% SS.
5. In direct shear test the highest value of internal friction (ϕ) is 31° and the value cohesion (kPa) is 27 at percentage of 20% PA and 20% SS.

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