A Study on the Use of Crusher Dust and Pond Ash as Sub Grade and Fill Materials in Pavement

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Abstract - The construction of civil engineering structures such as roads, embankments, and ground reclamation require large quantities of natural soils and rock materials. However, the presence of plastic materials like silt and clay in these soils often leads to excessive deformations, compromising the durability and increasing maintenance costs. To address these challenges, this study explores the potential use of industrial wastes such as crusher dust and pond ash as geotechnical materials for road and embankment construction, specifically as sub-grade and fill materials. Crusher dust, a by-product of stone crushing plants, and pond ash, sourced from thermal power plant ash ponds, were combined in varying proportions to assess their suitability.

The study evaluated the gradation, compaction, strength, and seepage characteristics of crusher dust and pond ash mixes. The results indicated that the mixes attained high densities (>1.6 g/cc), substantial California Bearing Ratio (CBR) values (>10%), high shear strength parameters (>36°), and maintained adequate permeability (k > 10^-3 cm/sec). Additionally, the mixes were found to be non-plastic and incompressible. Optimal performance was achieved with 30-40% pond ash added to crusher dust, making these mixes suitable for use as sub-grade and fill materials in line with MORTH specifications.

Keywords: Crusher Dust, Pond Ash, Soil Stabilization, Sub-grade, Geotechnical Properties, CBR, Compaction, Permeability, Industrial Waste Utilization.

1.Introduction

Soils are being the cheapest and readily available construction material foe civil engineering structures. Due to its poor performance under saturated condition lost it requirements as a geotechnical material. Embankments, bridges, abutments, retaining structures, sub-grades require good quality of fill material which is free from plastic fines and has good frictional resistance and drainage characteristics. To keep in mind that stabilization of natural soils is difficult and fail to meet the design standards necessitates going for alternate material to meet the above standards. In this connection crusher dust and pond ashes are such materials which are producing abnormal quantities required thousands of acres of land for their disposal. Crusher dust is a waste product obtained from stone crusher plants with annual production of 23 lakh tons whereas pond ash is obtained from burning of coal in thermal power plants and other industrial units which turns about 100 million tons annually.

A number of researchers have made their contributions for the utilization of above said materials in various geotechnical applications, Soosan et al (2000, 2001) identified that crusher dust exhibited high shear strength and beneficial for its use as geotechnical material. Sridharan A et.al (2005, 2006) reported that high CBR and shearing resistance values can enhance their potential use as sub-base material in flexible pavements and also as an embankment material. Praveen Kumar et.al (2006) conducted CBR tests on stone dust as a sub-base material. Wood et al (1993) identified that the physical properties, chemical composition and mineralogy of quarry dust varies with aggregate type and source. Collins RJ et al (1994) studied quarry dust in highway constructions. Studies on pond ash in various applications are Bera A.K. et al (2007), Raju Sarkar et.al (2009) have studied the compaction and strength characteristics of pond ash. Amalendu Ghosh et al (2005), Venkatappa Rao G et al (2011), Kumar. R. et al (2007), Temel Yetimoglu et al (2005) have studied the behaviour of pond ash with Geosynthetics and reinforced with randomly distributed fibers. Kolay P.K. et.al (2011) has used pond ash as stabilizer of peaty soil. Sridharan et al (1996, 1999) studied geotechnical characteristics of pond ash as a structural fill. The results showed that the use of pond ash increase the peak friction angle, peak compressive strength, CBR value.

2. Objectives

The main objective of the present study is the performance of Crusher dust with pond ash and their mixes as a geotechnical material,

1.To know the geotechnical Characterization of Crusher Dust and pond ash.

2.To know the Compaction and strength characteristics of Crusher Dust- pond ash mixes as various percentages of pond ash.

3.Suitability of the mechanically stabilized Crusher dust as Sub-grade and fill material in accordance with MORTH specifications.

4.The primary goal of the present research is to assess the performance of Crusher dust combined with pond ash and their mixtures as a geotechnical material. This study aims to:

5. Investigate the geotechnical characteristics of Crusher Dust and pond ash.

6.Examine the compaction and strength properties of Crusher Dust-pond ash mixtures at varying percentages of pond ash.

7.Evaluate the suitability of mechanically stabilized Crusher Dust as a sub-grade and fill material, ensuring compliance with the MORTH (Ministry of Road Transport and Highways) specifications.

2.1 SCOPE OF THE PRESENT STUDY:

In the present study Crusher dust was collected from crushing stone plants and pond ash from Srikakulam and NTPC, Parwada,Vijayawada respectively. These industrial wastes were tested for Geotechnical Characteristics such as Gradation, Plasticity, Compaction, CBR, etc. To study the performance of Crusher Dust- pond ash mixes various percentage of pond ash was added to these Crusher dust and studied plasticity and strength characteristics. Based on the results of CBR, angle of shearing resistance and compaction the stabilized materials were checked as sub-grade and fill materials in accordance with MORTH specifications.

3. Materials and Methodology

3.1 Material Used:

The materials used in this investigation are:

- Pond ash
- Crusher Dust

Properties of Material

The following tests were conducted on the soil. The index and engineering properties of soil were determined.

1. Grain size analysis confirming (IS: 2720-part 4, 1985)
2. Consistency limits or Atterberg's Limits using Uppal's method confirming (IS: 2720-part 5. 1985)
3. Compaction test confirming (IS: 2720- Part 8: 1983)
4. California bearing ratio test confirming (IS: 2720- Part 16: 1987)

3.2 Laboratory Testing result

PROPERTY	VALUES
Grain size distribution;	
Gravel (%)	5
Sand (%)	87
Fines (%)	8
a. Silt (%)	8
Clay	0
CONSISTENCY	
Liquid Limint (%)	NP
Plastic Limint (%)	NP
I.S Classification	SW
Specific gravity	2.64
Compaction Characteristics	
Optimum moisture content (OMC)(%)	12
Maximum dry density (MDD)(%)	2.02
Shear Parameters:	
Angle of shearing resistance (DEG)	38
California bearing ration CBR (%) (soaked)	10
Coefficient of uniformity (Cu)	23
Coefficient of curvature (Cc)	2.78

Table.1 testing result for crusher dust

3.2.2 Grain Size Analysis

Grain size analysis was conducted using a standard set of IS sieves. The soil sample was oven-dried and placed on the sieves, and the retained weights were recorded after shaking for 10-15 minutes. The fine fraction passing through the 75-micron sieve underwent hydrometer analysis. The results were used to calculate parameters such as D10, D30, D60, and the coefficients of uniformity and curvature, providing insights into soil gradation.

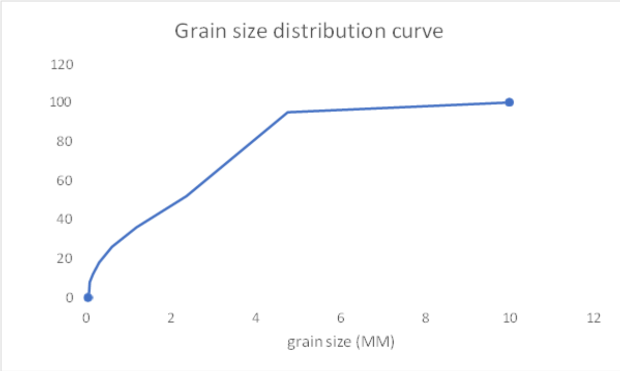

Fig.Grain size distribution curve for pond ash and crusher dust

3.2.3 California Bearing Ratio (CBR)

The CBR test evaluates the penetration resistance of the soil to determine its subgrade strength. Soil samples were compacted at optimum moisture content and cured for different durations. A cylindrical plunger was used to apply pressure, and the loads for different penetration depths were recorded. CBR values were calculated based on the ratio of measured load to standard load, providing insights into the soil's bearing capacity.

Fig.2 CBR

3.2.4 Modified Proctor Test

The Modified Proctor test was conducted to determine the maximum dry density and optimum moisture content of the soil. A heavier rammer and higher compactive effort were used compared to the standard Proctor test. This method simulates field conditions with heavy rollers. The dry density values were plotted against moisture content to derive the compaction curve.

3.2.5 Specific Gravity Test

The specific gravity of the soil was determined using a pycnometer. This test helps assess the density of soil particles by comparing their weight to the weight of an equal volume of water. The specific gravity was calculated using the weights of the pycnometer with and without soil and water.

PROPERTY	VALUES
Grain size distribution;	
Gravel (%)	0
Sand (%)	95
Fines (%)	5
a. Silt (%)	5
CONSISTENCY	
Liquid Limit (%)	NP
Plastic Limit (%)	NP
I.S Classification	SPN
Specific gravity	2.4
Compaction Characteristics	
Optimum moisture content (OMC) (%)	14
Maximum dry density (MDD) (%)	1.4
Angle of shearing resistance (DEG)	34
California bearing ration CBR(%)(soaked)	6
Coefficient of uniformity (Cu)	5.6
Coefficient of curvature (Cc)	0.86
Coefficient of permeability(K)	2.6*10

Table: 2. Geotechnical Characteristics of pond ash

4.Crusher Dust and pond ash mixes

Tale.3 mix proporations of pond ash and crusher dust

Crusher Dust (%)	Pond Ash (%)	Mixes
100	0	M1
90	10	M2
80	20	M3
70	30	M4
60	40	M5
50	50	M6
40	60	M7
30	70	M8
20	80	M9
10	90	M10
0	100	M11

This data represents a series of mixes (M1 to M11) where the proportions of crusher dust and pond ash are varied. In mix M1, the material consists entirely of crusher dust (100%) and no pond ash (0%). As we move through the series, the percentage of crusher dust decreases while the proportion of pond ash increases by 10% increments. For example, M2 contains 90% crusher dust and 10% pond ash, M3 has 80% crusher dust and 20% pond ash, and so on. By the time we reach M11, the composition has completely reversed, with 0% crusher dust and 100% pond ash. This progressive variation allows for analyzing the properties and performance of different combinations of these two materials in the mix.all mixes as shown in table 3.

4.2 Angle of Shearing Resistance:

The angle of shearing resistance, often denoted as ϕ\phiϕ, is a fundamental property used to characterize the behavior of soils and other granular materials under shear stress. It plays a pivotal role in geotechnical engineering, where soil stability, foundation design, and slope stability are critical considerations. As shown in table 4.

The angle of shearing resistance represents the steepest angle of a plane or surface of a material from the horizontal plane under which shear failure occurs. It is primarily determined through laboratory tests such as the direct shear test or triaxial shear test, where the material is subjected to controlled shear stresses under different confining pressures.
The results of the mixes composed of varying percentages of crusher dust and pond ash, measured in terms of their angle of shearing resistance, show a distinct relationship between the mix composition and the material's ability to resist deformation under load.

Starting with mix M1, which consists of 100% crusher dust and no pond ash, the angle of shearing resistance is 38 degrees. As pond ash is gradually introduced in increments of 10%, there is a noticeable improvement in the angle of shearing resistance. For instance, M2 (90% crusher dust + 10% pond ash) increases slightly to 38.5 degrees, and this trend continues through to M4, where the mix reaches 70% crusher dust and 30% pond ash, achieving a peak angle of 40 degrees.

Interestingly, mixes M4 and M5 (60% crusher dust + 40% pond ash) maintain the highest angle of shearing resistance at 40 degrees, indicating that these particular combinations of crusher dust and pond ash provide optimal resistance to shearing forces. This suggests that a moderate proportion of pond ash enhances the strength properties of the mix, likely due to improved particle interaction and compaction.

However, beyond this point, the angle of shearing resistance begins to decline. M6, with a 50-50 mix of crusher dust and pond ash, sees a slight reduction to 39 degrees, and the angles continue to decrease as the percentage of pond ash increases. By the time we reach M11 (0% crusher dust + 100% pond ash), the angle of shearing resistance has fallen to 34 degrees, the lowest value observed in the series.

These results indicate that while the addition of pond ash can enhance the shearing resistance of crusher dust to some extent, excessive amounts of pond ash lead to a significant reduction in the material’s shearing resistance. The optimal mix, based on this data, appears to be around 60% crusher dust and 40% pond ash, balancing strength and resistance effectively.

MIXES	CRUSHER DUST (%) +pond ash	Angle of shearing Resistance (O degree
M1	100+0	38
M2	90+10	38.5
M3	80+20	39
M4	70+30	40
M5	60+40	40
M6	50+50	39
M7	40+60	38
M8	30+70	37
M9	20+80	36
M10	10+90	35
M11	0+100	34

Table.4 angle of shearing resistance

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5.Results and Discussion

5.1 CBR

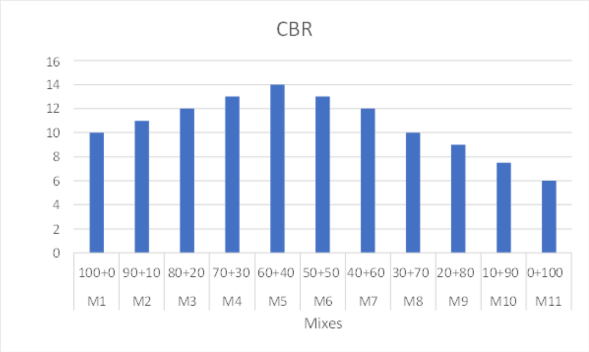

Fig.3The results from the various mixes of crusher dust (CD) and pond ash

The result demonstrate a clear relationship between the material composition and the California Bearing Ratio (CBR), which is a measure of the strength of the subgrade material used in pavement design.

Mix M1, with 100% crusher dust and no pond ash, achieved a CBR value of 10. As the proportion of pond ash increases, the CBR values rise progressively, peaking at mix M5, which consists of 60% crusher dust and 40% pond ash. This combination resulted in the highest CBR value of 14, indicating an optimal balance of the two materials for strength.

Beyond this point, as the percentage of pond ash continues to increase, the CBR values begin to decline. Mix M6 (50% crusher dust + 50% pond ash) shows a slight drop to 13, and the CBR values continue to fall as the amount of pond ash increases further. By the time we reach mix M11, which contains 100% pond ash, the CBR drops to 6, the lowest in the series.

These results suggest that an intermediate mix of crusher dust and pond ash, particularly around 60% CD and 40% PA, provides the best strength performance for pavement applications. Excess pond ash leads to a significant reduction in CBR.

From the experimental data as shown in table-4.8 and fig-4.8, it is observed that the mixes of crusher dust and pond ash have attained high CBR values in the range of 13-14. As the percentage of pond ash is increasing in the mixes, frictional resistance values are increasing reflecting in achievement of high CBR values followed by less penetration against compression.
At higher percentages of pond ash (60%) lower values of CBR were obtained reflecting the behavior of pond ash particles.
Hence a dosage of 60-70% crusher dust and 30- 40% pond ash can be effectively used for sub-grade and fill materials.
California Bearing Ratio (CBR) values are widely used to assess the strength and load-bearing capacity of materials used in subgrade, subbase, and base layers in road construction. A comparison between Crusher Dust and Pond Ash using a bar chart can visually represent their CBR values and highlight their performance differences.

Crusher Dust This fine aggregate, often used as a road base, typically has a higher CBR value. Its good compaction characteristics and angular particles contribute to higher load-bearing capacity, making it a preferred choice for base layers in pavements.
Pond Ash A byproduct of thermal power plants, Pond Ash has lower CBR values compared to Crusher Dust due to its finer and more spherical particles, leading to reduced friction and compaction capabilities.
A bar chart showing these CBR values would depict Crusher Dust with a taller bar, indicating higher strength, and Pond Ash with a shorter bar, reflecting its lower load-bearing capacity.

5.1 conclusion

To study the use of eraser dust and pool ash mixes as geotechnical material in construction of made the following conclusions have been drawn based on the experimental results.

1. Based on the grain size distribution crusher dust has dominated by medium to coarse sand size particles whereas pool ash has dominated by medium to fine sand size particles.
2. Crusher dust attained high dry densities (2.02 g/cc) by maintaining wider variation moisture contents (12%) with high angle of shearing resistance (38 degrees) and high CBR (10%) values, whereas pond ash has fewer dry densities (1.4 g/cc) at 14% moisture content with angle of shearing resistance of 34 degrees and CBR of 6%.
3. As the percentage of pond ash is increasing in the crusher dust and pond ash mixes strength values like angle of shearing resistance (0) as 40 degrees and CBR as 14% are increasing. High strength values are attained due to filling up of formed voids in the mixes by lower sizes of pond ash particles.
4. High values of CBR 10% and high angle of shearing resistance values > 38 degrees at high moisture contents and high densities Da> 16 KN/m² of these crusher dust- pond ash mixes can be used as sub-grade, fill and embankment material.
5. 30%-40% pond ash can is considered as effective utilization in the crusher dust - pond ash mixes by maintaining high strength values against shear and compression.

5.3 Scope for further study:

In the present study Crusher Dust and pond ash were used as materials for construction of roads in place of natural soils as sub-grade and fill material. This study can extend for the use of various other industrial waste materials like slag. Pond ash, Flyash, GGBS etc, as a sub-grade, and fill material in Road construction. It can also extend this study for selection of materials as sub-base and base courses when mixed with stone aggregate.

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