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Optimizing Soil Stability by Using Ash with PVC and GI Pipes for Stabilization

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Abstract: This study investigates the use of Fly Ash, PVC, and GI Pipe to enhance soil stability by refining its physical and chemical properties. The research emphasises the need for a thorough understanding of soil behaviour, especially in addressing challenges like swelling, shrinkage, and settlement. Stabilized soil materials exhibit improved strength, reduced permeability, and compressibility, essential for durable foundations. Systematic tests on soil and Fly Ash revealed that varying proportions of Fly Ash led to decreased optimum moisture content and increased dry density. However, excessive Fly Ash content caused a decline in dry density, highlighting the delicate balance required for effective soil stabilization. PVC and GI pipes with diameters of 5cm and 7.5cm, respectively, were used alongside bottom ash to enhance soil properties. The study's findings suggest that the combined use of Fly Ash, PVC, and GI Pipe offers a promising approach to soil stabilisation, providing improved strength and stability. This approach has practical implications for construction projects, particularly in contaminated areas with challenging soil conditions.

Keywords: Ash, PVC Pipe, GI Pipe, Plasticity, Swelling, Shrinkage, Moisture.

1. Introduction:

In the realm of construction, whether it be for buildings, dams, hydraulic structures, or the like, the soil's bearing capacity emerges as a critical concern in ensuring the structure's ability to withstand imposed loads. A diminished bearing capacity poses a significant threat, rendering the structure incapable of maintaining its position and giving rise to various issues such as liquefaction and compaction problems. Addressing challenges associated with soil-bearing capacity necessitates the implementation of soil stabilization techniques. In this context, soil stabilization is achieved through the utilization of ash, with the complementary use of GI and PVC pipes. This strategic approach aims to fortify the soil, mitigating potential problems and reinforcing the structure's ability to endure external pressures.

Constructing on expansive soils poses considerable challenges due to their significant swelling and shrinking tendencies with fluctuating moisture levels. Structures on such soils are highly prone to collapse, underscoring the importance of avoiding construction on these grounds whenever possible. However, given the rising infrastructure demands and the scarcity of suitable soil, there is a compelling need to devise specific strategies for utilizing certain soil types in foundations. Innovative techniques like soil stabilization and pile foundations have emerged over recent decades to tackle these complex issues effectively. Soil stabilization involves modifying the properties of natural soil by incorporating various admixtures, wastes, or chemicals. Different methods, including traditional stabilizers like lime, have been historically effective. However, lime and similar substances are costly, making them less feasible for widespread applications due to their higher expense compared to other building materials. In recent decades, research projects have explored the use of discarded materials such as fly ash, leading to multiple studies in the field of soil stabilization (Faiqa Farooq and Murtaza Hasan 2019).

Soil is a naturally occurring complex system consisting of solids (minerals and organic matter), liquids, and gases, covering the land surface. It is defined by distinguishable layers resulting from various processes involving energy and matter. Moreover, soil's ability to support plant growth is essential, as stated by Amber Anderson. Apart from providing a foundation for plants, soil plays a crucial role in retaining water and storing carbon. Imagine a scenario where soil lacked the capacity to retain water for plant growth; the management and cultivation of crops would become significantly more challenging. Soil formation occurs through the weathering of rocks, a process that takes place in three main ways:

1. Mechanical Weathering
2. Chemical Weathering
3. Biological Weathering

2. Related Work:

Konstantinos F. Makris (2020)- Over recent decades, Polyvinyl chloride (PVC) has risen to prominence as a primary construction material for sewer systems, acclaimed for its notable advantages. However, current apprehensions regarding the longevity of PVC sewer pipes have surfaced among sewer managers in the Netherlands, particularly due to prolonged operation in harsh environments. This article explores the fundamental factors and mechanisms impacting the lifespan of PVC pipes, providing insights into existing methods for predicting longevity and acknowledging their inherent limitations. An examination of pertinent case studies reveals a gradual, if any, material degradation process, albeit occurring at a sluggish pace. In contrast, inspection data, notably derived from Closed-Circuit Television (CCTV) examinations conducted in three Dutch municipalities, paints a different picture by highlighting severe defects and an unexpectedly accelerated degradation rate. A pivotal factor contributing to this divergence between theoretical expectations and practical observations is the paucity of comprehensive material testing for PVC sewer pipes in existing literature, a critical omission given its indispensable

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role in accurately gauging degradation levels and understanding their sources.

This article underscores the imperative for more rigorous material testing practices to bridge the gap between theoretical expectations and real-world performance. By addressing this disparity, a more precise understanding of the durability and potential challenges associated with PVC sewer pipes can be achieved. This, in turn, facilitates proactive maintenance measures and addresses concerns related to their operational resilience in sewer systems.

Jon E. Schoonover (2015)- Soil stands as a non-renewable and dynamic natural resource crucial to sustaining life. Its significance is evident in its connections with water movement, water quality, land use, and vegetation productivity. This article provides an introduction to key soil concepts, encompassing its development, classification, and properties—encompassing physical, chemical, and biological aspects. It also touches upon soil quality and conservation. A comprehensive grasp of these soil concepts and their intricate relationships is imperative for making informed decisions in land management.

S. ANDAVAN (2018)- Soil, by nature, is a distinctive material, and the incorporation of Fly Ash serves to enhance its stability. This addition contributes to improvements in both the physical and chemical properties of the soil, impacting key factors such as liquidity index, plasticity index, unconfined compressive strength, and specific gravity. Recognizing the pivotal role of soil in supporting any structure, the foundation must be robust, necessitating a careful consideration of the surrounding soil.

3. Methodology:

In the process of assessing the geotechnical properties of soil from a contamination area, a systematic approach was followed, which involved careful sample collection and rigorous laboratory testing. The steps undertaken for the laboratory performance evaluation were as follows:

Sample Collection: Soil samples were meticulously collected from the contamination area and subsequently oven-dried at 105°C in the laboratory before initiating the experiments.

Ash sample was collected from Singrauli, Mirzapur, Uttar Pradesh power plant.

Geotechnical Properties Assessment of soil and ash-

Water Content Determination: The water content of the soil / ash was determined using the oven drying method, following the guidelines outlined in IS: 2727 (part-2)-1973. It is defined as the ratio of the mass/weight of water to the mass/weight of soil solids;

Procedure -

1. Begin by thoroughly cleaning and drying a container, including its lid, and record this weight as W1.
2. Carefully place the moist soil sample into the container and record the weight as W2.
3. Transfer the containers to an oven set at a temperature of 105-110°C for drying.
4. After 24 hours, retrieve the containers from the oven and record the mass of the cans.
5. Allow the samples to cool, and once cooled, reweigh the samples with the container, noting this weight as W3.

CALCULATION- W = Ww/Ws

Where, w = water content

Ww = Weight of water

Ws = Weight of soil solids (mass of oven dry soil).

$$\text{Moisture content (\%)} = \{(W_2 - W_3) / (W_2 - W_1)\} * 100$$

No. of samples	Sample 1	Sample 2	Sample 3	Sample 4
Weight of empty container (W1) gm	0.230	0.290	0.290	0.290
Weight of container + wet soil (W2)	0.670	0.650	0.650	0.680
Weight of container + dry soil(W3)	0.580	0.581	0.575	0.595
Moisture content	25.714	24.642	25.806	27.868

Fig. 1. dry Oven.

Specific Gravity Measurement: The specific gravity of the soil/ ash was determined using a density bottle, following the procedures specified in IS: 2720 (part-3, sec-1)-1980. It is defined as the ratio of mass (wt.) of a given volume of solid to the mass of the equivalent volume of water. The density bottle method can be used to determine the specific gravity of all types of soil. Standard values for Specific gravity of different types of soils;

S.No.	Soil Type	Specific Gravity
1	Gravel	2.65-2.68
2	Sand	2.65-2.68
3	Silty Sand	2.66-2.70
4	Silty Sand	2.66-2.70

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5	Inorganic Clay	2.68-2.80
6	Organic Soil	may fall below 2

Procedure-

1. Start by cleaning the bottle with alcohol and ether, allowing it to drain. Weigh the empty bottle with the stopper and record this weight as W1.
2. Take approximately 10 to 20 grams of the sample and transfer it into the bottle. Measure the combined weight of the bottle and soil and record it as W2.
3. Fill the bottle completely with distilled water, seal it with the stopper, and place it under a constant temperature. Determine the weight of the bottle and its contents (W3).
4. Empty the bottle, ensuring thorough cleaning, and refill it with only distilled water. Weigh the bottle and water at the same temperature, recording this weight as W4.
5. Repeat this process five times to obtain consistent readings, and calculate the average value for more accurate results.

OBSERVATION	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4
Mass of empty density bottle (M1)	18.57	18.50	18.62	18.60
Mass of bottle and dry soil (M2)	28.57	25.50	28.62	28.53
Mass of bottle, soil and water (M3)	90.88	90.20	91.02	90.68
Mass of bottle filled with water (M4)	87.74	84.00	84.83	87.63
Specific gravity of solids	2.59	2.63	2.62	2.73

SPECIFIC GRAVITY = [(M2 – M1)/{(M2-M1) - (M3-M4)}]

Grain (Particle) Size Analysis: The particle size analysis was conducted through sieving, see Figure 4, adhering to the standards set in IS: 2720 (part-4)-1985. Particle size distribution is a fundamental aspect of soil classification, providing crucial information about the soil's physical properties. Based on the size of particles, soils are categorized into various types:

Fine-Grained Soil: If more than 50% of the soil passes through a 75-micron sieve, it is classified as fine-grained soil. These soils include clay and silt particles, which are smaller than 75 microns.

Coarse-Grained Soil: If more than 50% of the soil retains on a 75-micron sieve, it is termed coarse-grained soil. These soils consist of larger particles and can be further classified as follows:

- **Boulder:** More than 300 mm in diameter.
- **Cobble:** Between 80 mm and 300 mm in diameter.
- **Gravel:** Between 4.75 mm and 80 mm in diameter.
- **Coarse Gravel:** Between 4.75 mm and 20 mm in diameter.
- **Sand:** Between 0.075 mm and 4.75 mm in diameter, further categorized as:
    - **Coarse Sand:** 2.0 mm to 4.75 mm.
    - **Medium Sand:** 0.425 mm to 2.0 mm.
    - **Fine Sand:** 0.075 mm to 0.425 mm.

Clay: Particles smaller than 75 microns fall into the clay category. Clay particles are tiny and possess high plasticity, allowing them to retain water effectively.

Silt: Silt particles are smaller than 2 microns in diameter and fall between the size range of clay and sand. Silt soils offer good fertility and drainage properties.

Understanding the particle size distribution is essential in various fields, including geotechnical engineering, agriculture, and environmental science, as it influences soil behaviours, permeability, and suitability for construction or cultivation.

Fig. 2. Sieve shaker

4. Result and Discussion:

SPECIFIC GRAVITY-

The experiment is performed according to the IS code procedure. The specific gravity of ash was determined by density bottle and illustrated below.

Specific gravity	Sample 1	Sample 2	Sample 3
Mass of bottle(gm)	117.3	119.6	120.9
Mass of bottle +soil(gm)	167.13	169.6	170.9
Mass of bottle +soil +water (gm)	394.23	396.5	397.9
Mass of bottle +water(gm)	365.86	368.4	369.95
SPECIFIC GRAVITY	2.303	2.283	2.275

Specific Gravity of Material= 2.28

- Liquid and Plastic Limit: It was not possible to find out the liquid limit and plastic limit of pond ash indicating that ash is non-plastic in nature.
- Grain size analysis: The ash was passed through a test sieve having an opening size of 75µ. Sieve analysis was conducted for coarse particles as per IS:

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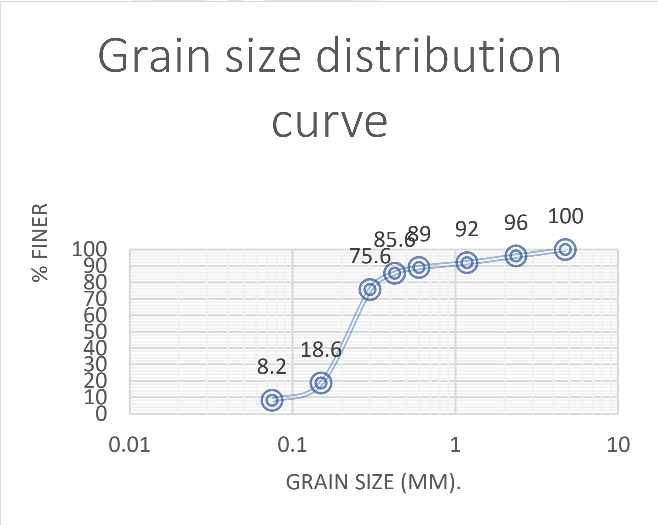
2720 part (IV),1975 and hydrometer analysis was conducted for finer particles as per IS: 2720 part (IV). The percentage of pond ash passing through the 75µ sieve was found to be 36.28%

Grain size distribution

Sample taken=1000gm

IS Sieve No.	% Finer
4.75	100
2.36	96
1.18	92
0.6	89
0.425	85.6
0.3	75.6
0.15	18.6
0.075	8.2
pan	1.2



From graph

Coefficient of uniformity $C_U = D_{60}/D_{10} = 6.94$

Coefficient of curvature $C_C = (D_{30})^2 /(D_{60}*D_{10}) = 3.7$

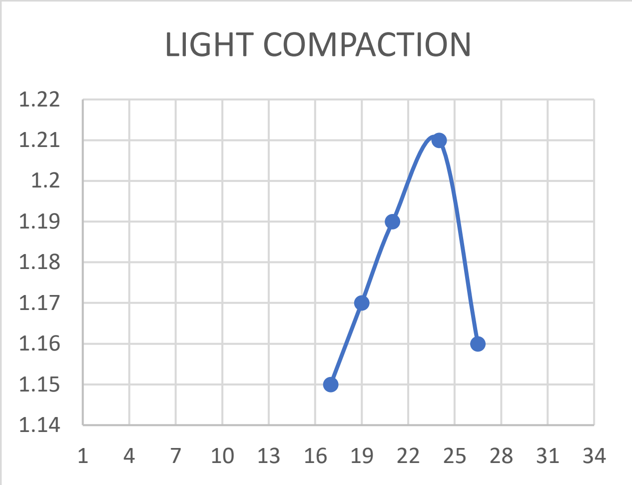
Direct shear test (IS 2720 PART-13)-

Normal load (Kg/cm^2)	Shear stress (Kg/cm^2)
0.5	0.845471522
1	1.100091199
1.5	1.464210324

- Standard proctor compaction test

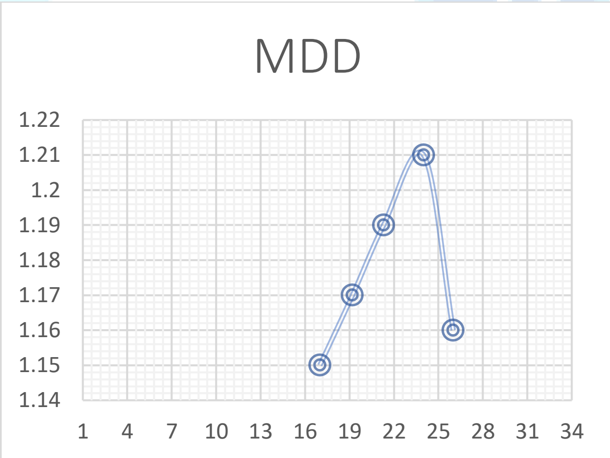
Compaction is the method employed to increase the soil density by minimizing air voids within it. The level of compaction for a specific soil is quantified through its dry density. The maximum dry density is achieved at the optimal water content. To establish the relationship between water content and dry density, a curve is plotted, allowing the determination of both the maximum dry density and the corresponding optimum water content

OMC (Optimum Moisture Content)	25.7
MDD (Maximum Dry Density)	1.17



- MODIFIED PROCTOR COMPACTION TEST-

OMC (OPTIMUM MOISTURE CONTENT)	23.2
MDD (MAXIMUM DRY DENSITY)	1.212



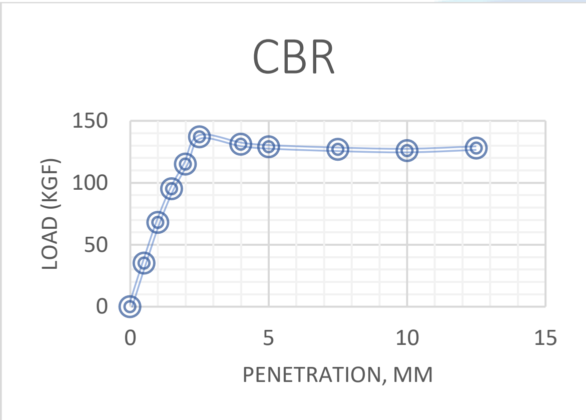
- CALIFORNIA BEARING RATIO TEST- (IS 2720 (Part XVI)-1987)

The California Bearing Ratio (CBR) test is a penetration test employed to assess the potential strength of subgrade, subbase, and base course materials, including recycled materials. The outcomes of this test are crucial for the design of roads and airfield pavements. Originally developed by the California State Highway Department, the test involves measuring the pressure needed to penetrate a sample of soil or ash using a plunger with a standardized area. The CBR value exhibits an increase with the rise in the surface hardness, indicating that a higher CBR value corresponds to a harder surface. This information is valuable in evaluating the load-bearing capacity and structural integrity of the tested materials, aiding in the design and construction of durable and resilient road and airfield pavements.

The average value of CBR for ash is 10.

PENETRATION, mm	LOAD (Kgf)
0	0
0.5	35
1	68
1.5	95

2	115
2.5	137
4	131
5	129
7.5	127
10	126
12.5	128



CBR@2.5 mm	10
CBR@5mm	6.28

Result
Average value of CBR at 2.5mm penetration is = 10
Average value of CBR at 5mm penetration is = 6.28.

5. Conclusion:

The findings of this research underscore the significance of soil stabilization as a fundamental component of construction projects. Soil, being a complex and dynamic material, requires careful consideration and management to ensure the long-term stability and performance of structures. The integration of Fly Ash, PVC, and GI Pipe has emerged as a promising strategy for enhancing soil stability by addressing key geotechnical properties. The study has highlighted the influence of the incorporation of PVC and GI pipes as reinforced elements, akin to steel reinforcement, in altering the California Bearing Ratio (CBR) values of the soil. These variations in CBR values indicate a substantial improvement in the load-bearing capacity of the soil, which is crucial for the construction of foundations, pavements, and other structures.

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