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Experimental Evaluation of Expansive Subgrades Stabilized Via Liquid Polyvinyl Acetate (PVA) Matrix Modifications

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ABSTRACT

Extensive subgrade foundations in the form of BC clay soils in central and peninsular India have been the cause of recurring geotechnical problems because of their cyclic swelling-shrinkage behavior. This study is a laboratory-based investigation involving the chemical treatment of expansive clays via a novel polymer treatment process that uses liquid Polyvinyl Acetate (PVA) emulsion. Untreated and treated clay layers have been evaluated based on the results of Atterberg index tests, light compaction tests, Unconfined Compressive Strength (UCS), and soaked California Bearing Ratio (CBR) profiles at varying additive concentrations (0.5%, 1.0%, 1.5%, and 2.0% in relation to the dry weight of soil). The chemical cross-linking process results in the formation of macromolecular envelope barriers that encapsulate the expansive montmorillonite layer structure, thereby limiting their water-holding capacity and interstitial pathways. Optimum polymer treatment at 1.5% has led to more than 115% increases in UCS values and improved subgrade bearing capacity.

1. INTRODUCTION

Pavement network and foundation strength and performance depend greatly on the shear and stability of the subgrade. The expansive soils known locally as Black Cotton soils in many Indian States pose challenges for construction projects due to the unusual volume changes resulting from wetting and drying cycles. During the rainy season, capillary action wetting of the soil causes considerable volume expansion with very high swelling pressures. On the other hand, during dry spells, drying of the soil results in extensive cracking caused by tensile contraction, thus destabilizing the overlying structures.

To deal with these structural problems, current geotechnical practice utilizes mechanical mixing of the soil matrix with traditional chemical binders such as OPC or quicklime. However, the processes involved have serious sustainability problems due to increased carbon emission during production. Furthermore, such methods are vulnerable to local degradation caused by the leaching process in contact with ground water. Therefore, this research investigates an alternative soil stabilization approach whereby the expansive clay soil matrix is stabilized using a synthetic polymer emulsion (**Polyvinyl Acetate - PVA**).

Key words - Physical Properties, Durability, Additives, Strength, Polyvinyl Acetate (PVA), Soil Stabilization, Black Cotton Soil, Synthetic Polymer, Swelling Pressure, Unconfined Compressive Strength (UCS), Direct Shear Test, Compaction Characteristics, Laboratory Study.

2. EXPERIMENTAL MATERIALS & TESTING CRITERIA

Intact expansive soil samples that were used for this test program were obtained from test pits dug out specifically for construction excavation purposes. The index properties of the virgin material were measured strictly in accordance with **IS 2720** guidelines of Bureau of Indian Standards, as follows:

SOIL EVALUATION CRITERI PARAMETER	INDIAN STANDAR REFERENCE CODE	MEASURED BASELINE DAT VALUE
Liquid Limit (LL)	IS 2720 (Part 5)	68.4 %
Plastic Limit (PL)	IS 2720 (Part 5)	29.1 %
Plasticity Index (PI)	Calculated Value (LL - PL)	39.3 % (Highly Plastic Clay - C Classification)
Maximum Dry Density (MDD)	IS 2720 (Part 7)	1.52 g/cm³
Optimum Moisture Content (OMC)	IS 2720 (Part 7)	19.8 %
Unconfined Compressive Strengt (UCS)	IS 2720 (Part 10)	112.5 kN/m²
California Bearing Ratio (CBR) Soaked	IS 2720 (Part 16)	1.8 %

3. STRESS FORMULATION & CONTINUUM MODELING

Evaluation of load transfer due to modified subgrades can be done using elastic boundary calculations. Vertical stress distribution ($\Delta\sigma z$) due to localized structural foundation footings at any depth (z) and radial distance (r) is calculated as per the Boussinesq formula as follows:

$$\Delta\sigma_z = [\, 3Q / (2\pi z^2) \,] \times [\, 1 / (1 + (r/z)^2) \,]^{5/2}$$

Long-term consolidation settlement adjustments (Sc) taking place inside the clay layer under loadings can be confirmed by means of conventional one-dimensional equations for settlements:

$$S_c = [\, C_c \cdot H_0 / (1 + e_0) \,] \times \log_{10} [\, (\sigma'_{v0} + \Delta\sigma_z) / \sigma'_{v0} \,]$$

4. RESULTS, ANALYSIS & ENGINEERING DISCUSSION

Adding the liquid polymeric stabilizer caused some significant improvement in the soil matrix's performance properties. The polymer serves as a lubricant during initial compaction that helps the clay particles to settle in a more dense configuration at reduced water content. It changes the conventional compaction curves, resulting in a gradual rise in the Maximum Dry Density while decreasing the Optimum Moisture Content. Optimal mechanical shear strength was achieved at an additive concentration of **1.5% PVA**. The value of Unconfined Compressive Strength significantly grew up to **245.8 kN/ m²** at an additive concentration of **1.5% PVA** from its initial value of **112.5 kN/m²**. It is a total improvement of more than **115%** in the structural strength limit. The growth in strength is due to the fact that the liquid polymer wraps each clay platelet and forms strong bonding between them.

5. CONCLUSIONS

1. Liquid PVA Matrices operate efficiently to serve as safe chemical stabilizers for highly expansive subgrade materials.
2. An optimal mixture of **1.5% PVA** based on dry mass provided the best values of performance indicators in all tests conducted in laboratories.
3. Polymer stabilization is an efficient means for the control of structural swelling and shrinkage.

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