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ENHANCING GEOTECHNICAL PROPERTIES OF EXPANSIVE SOILS USING FLY ASH AND PLASTIC FIBERS: A COMPREHENSIVE REVIEW

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ABSTRACT

Enhancing the characteristics of the soil by the application of chemical and mechanical methods is known as soil stabilization. Cement and lime are examples of binder materials that promote soil stability, enhancing their technical qualities and producing a better building material. A critical review research on the effectiveness of powdered fuel ash (PFA) as a stabilizing agent is presented in the current book chapter. The results of a thorough literature study are provided, taking into account the use of various PFA-binders and their impact on minerals, geotechnical soil problems, and hazardous metal leaching. Expansive soils, characterized by their significant volume changes due to moisture fluctuations, present considerable challenges in geotechnical engineering. Traditional stabilization methods have limitations, prompting the exploration of innovative materials such as fly ash and plastic fibers. This review comprehensively examines the efficacy of these materials in improving the geotechnical properties of expansive soils.

Fly ash, a by-product of coal combustion, has been widely studied for soil stabilization due to its pozzolanic properties. When mixed with expansive soils, fly ash reduces plasticity, shrink-swell potential, and increases strength and compaction characteristics [1] [2]. It also enhances the soil's bearing capacity and reduces the free swell index, making the soil less susceptible to volumetric changes [3].

Plastic fibers, derived from recycled materials, offer an environmentally friendly solution to soil stabilization. The inclusion of plastic fibers in soil enhances tensile strength and ductility, mitigating the propagation of cracks and improving the overall durability of the stabilized soil. The fibers' reinforcement effect distributes stress more evenly and improves the load-bearing capacity of the soil, making it more resilient under cyclic loading conditions [4].

Combining fly ash and plastic fibers in soil stabilization offers synergistic benefits. Fly ash improves the soil's chemical properties and reduces plasticity, while plastic fibers enhance mechanical properties by providing reinforcement. This dual approach addresses both the volumetric instability and mechanical weakness of expansive soils, leading to more durable and reliable soil stabilization solutions.

The integration of fly ash and plastic fibers presents a promising advancement in the stabilization of expansive soils. This comprehensive review highlights the potential of these materials to enhance geotechnical properties, offering sustainable and effective solutions for infrastructure development on expansive soils.

Keywords: Stabilization, Fly Ash, Atterberg's Limit, CBR and UCS.

INTRODUCTION

Soils that expand and contract in response to variations in moisture content are referred to as swell-shrink soils. This conduct has the potential to cause serious issues, frequently leading to harm to the buildings that are erected atop it. Heavy rainfall causes these soils to absorb water and swell, weakening their structure and decreasing their ability to support loads. On the other hand, during dry seasons, they get denser, shrink, and lose moisture. These untreated expansive soils may cause significant harm to infrastructure and are frequently found in dry and semi-arid environments.

In the semi-parched districts, just over the foremost recent few decades, harms due to the swelling-contracting activity of broad soils are watched unmistakably in kind of making and break-laugh uncontrollably of roadways, channel and store linings, asphalts, building establishments, water lines, water system frameworks, sewer lines, and section on-level individuals.

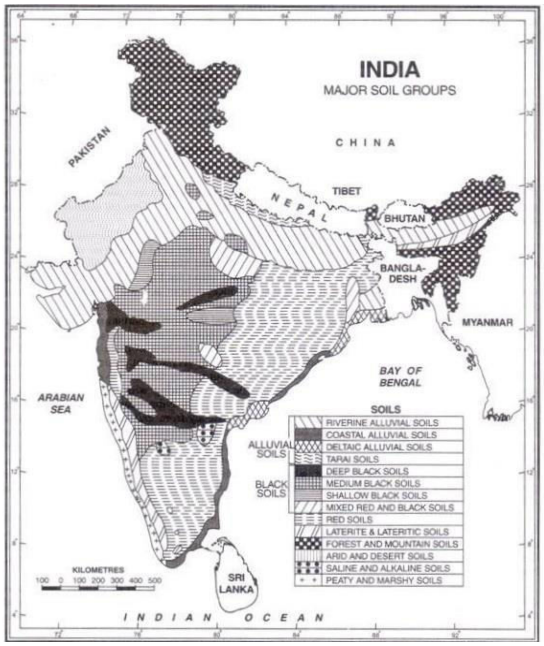

Figure 1 Major Soil Types in India

2. LITRATURE REVIEW

Phani Kumar and Sharma evaluated the addition of fly ash in expanding soils (2004). According to their research, there are negative relationships between plasticity and the free swell index and the rising amount of fly ash added to treated soils. Indiramma et al. (2020) conducted research on expansive soils and treated them with binders consisting of 10% fly ash and 4% lime and 10% fly ash and 8% lime. According to research findings, fly ash–lime binders may be used as stabilizing admixtures for expansive soil with good results (Indiramma et al., 2020).

Using fly ash and granulated blast furnace slag, Laxmikant Yadu and Dr. R.K. Tripathi (2013) conducted tests on soft soil that was taken from the rural Tatibandh-Atari route in Raipur, Chhattisgarh. In accordance with the I.S.Soil classification system, the soil was categorized as CI-MI. To stabilize the soil, varying proportions of GBS (3%, 6%, and 9%) and fly ash (3%, 6%, 9%, and 12%) were applied. The ideal ratio of GBS to fly ash was found by the authors to be 3% fly ash to 6% GBS, based on compaction and the C.B.R test.

Numerous laboratory UCS and CBR experiments were conducted by Prof. S. Ayyapan, Ms. K. Hemalatha, and Prof. M. Sundaram. Different lengths of polypropylene fibers (6 mm, 12 mm, and 24 mm) were utilized as soil reinforcement. Compaction of soil containing fly ash specimens was done at MDD using a modest percentage of reinforcement (between 0% and 1.5% by weight). They came to four preliminary findings from their experiment. The UCS of soil fly ash mixes was considerably raised by the addition of dispersed fibers. In any soil fly ash mixture, longer fibers contribute more to the strain energy absorption capacity while contributing less to the maximum compression strength. The optimal dosage rate of fibers was determined to be 1% of the mixture's dry weight for all soil and fly ash mixes.

Jeny Merin Paul, Jithin Thomas Joy, and Jasmin Varghese Kalliyath (2016) This experiment's primary goal is to ascertain whether plastic cover wastes have the capacity to stabilize soil. To ascertain the impact of plastic fibers in silt-clay, many experiments, including Standard Proctor and Unconfined Compression experiments, were conducted using a variety of samples. The main findings validated the idea that the soil was becoming more stable. The conclusions drawn from this experimental investigation are, Expanding soil loses its Optimum Moisture Content and gains more M.D.D. when 0.50% plastic fibers are added. It was discovered that the soil's UCS had improved by 0.5%. It was observed that the MDD and UCC were lower with a one percent substitution.

H. K. Mahiyar1, Amit Tiwari1, et al. (2014)The current studies' goals are to analyze various soil properties, such as Atterberg's Limits, the Compaction Curve (O.M.C. and M.D.D.), the Shrinkage Limit, the California Bearing Ratio, the Swelling Pressure, the Permeability, the direct shear test, the effects of fly ash, coconut fiber, and crushed glass at varying rates, and the Black Cotton Soil.In order to achieve this goal, a two-stage test analysis was conducted on 48 preliminary instances. The first stage involved the physical characteristics of the soil, such as its explicit gravity, hygroscopic wetness material, particle size dispersion, and Atterberg's breaking points. The esteems of the permeability test, MDD-OMC, swelling weight, CBR, and direct shear test are all resolved. Using varying rates of Fly Ash (FA) at 10%, several test examinations were conducted on dark cotton soil in the second stage.

S. Jyothirmayee2, L. Vimala3, K. Padmavathamma1, et al. (2017) The current tests aim to deconstruct soil properties, such as the farthest point of Atterberg, the compaction bend (O.M.C. and M.D.D.), the shrinkage limit, California The factors to consider are bearing proportion, swelling weight, porosity, direct shear test, the impact of fly cinder, the various rates of Cocunut coir fiber alongside Black cotton soil, blending on the above amounts of fixings, using waste materials instead of traditional materials like bond, lime, and so forth, and how to build a money-saving advantage ratio. Based on this analysis, it was concluded that the soil's engineering qualities are enhanced by the growth of fly slag and coconut coir fiber (CCF) in black cotton soil. The liquid furthest point decreases as the amount of fly fiery debris and coconut coir fiber increases.

Malik Mahevi Gavit Deepak Bhagwat2, Affan Masood Javeed1, et al. (2018) Although block cotton soil is abundant and great for gardening, it isn't as helpful for structural construction projects. A major source of intensity age in India is the heated power plants, which produce more than 150 million tons of fly cinder annually as a result of burning pulverized coal, which has real health and environmental risks in addition to transfer difficulties. This study led to the conclusion that the black cotton soil of Maharashtra, which is very compressible by nature, is combined with varying amounts of fly ash and coconut coir in the current study. The dark cotton soil was partially replaced with different amounts of fly slag and coconut coir. The exam results

3. MATERIAL USED

Expensive Soil

Since clay, or expansive soil, has the ability to expand and contract when wet, it is one of the most troublesome soil types and can harm a variety of civil engineering buildings. Because they have a propensity to expand and shrink, expansive soils act differently from other regular soils. Expansive soils' tendency to swell and contract can lead to the following issues with buildings or construction projects:

structural damage to thin buildings, such driveways and sidewalks

• Building settlement, basement damage, and building lifting

• Fissures in the roof and walls

• Damage to public services such as pipelines

• Pressure on vertical walls causes foundations and retaining walls to slide laterally.

• Remaining shear strength loss leading to slope instability, etc.

Table 1 Soil Parameter

Soil Parameters	Value
Specific Gravity, G_s	2.63
Liquid Limit, w_L (%)	69
Plastic Limit, w_p (%)	35
Plasticity Index, I_p (%)	34
Linear Shrinkage, L_s (%)	16.48
Maximum Dry Density,. γ_d (kN/m^3)	16.64
Optimum Moisture Content, w_{opt} (%)	25.10
Activity, A	0.76
pH	4.6

Fly Ash

Man-made volcanic material comprised of silicate or aluminosilicate compounds is referred to as fly ash. Although its capacity to self-cement is limited or nonexistent, it can react with Ca(OH)2 in moist settings to produce gel products. Fly ash is distinguished by its spherical particles, which include unburned carbon and irregularly shaped minerals, as well as solid spheres and cenospheres. It also has calcium oxide, metallic oxides, and trace elements.

Numerous studies have demonstrated that while greater doses of FA application cause metal(loid) toxicity and reduce microbial activity, lesser doses of FA application alter the physicochemical, biological, and nutritional quality of the soil system. Once specific soil quality and safety have been confirmed via repeated field testing, the FA dosages for each kind of soil may be determined. As a low-input method of lowering the toxicity of FA, organic waste amendments (such as press mud, farmyard manure, sewage sludge, agricultural waste, etc.) should be added. This chapter examines the ways in which the distinct physicochemical characteristics of FA may be intentionally utilized to address various soil degradation issues, including acidic and sodic soils, mine spoilage, and physical and fertility issues.

Figure 2 fly ash

Table 2 Properties of fly ash

CHARACTERISTICS	VALUES
Specific gravity	2.07
Fineness	290 m^2/kg
Bulk density	1100-1200 kg/m
Colour	Light grey

Table 3 Chemical Properties of fly ash

S.No	Parameter	Percent by mass
1	Silica as SiO_2	51.57
2	Alumina as Al_2O_3	22.57
3	Iron as Fe_2O_3	14.91
4	Calcium as CaO	4.82
5	Magnesium as MgO	1.74
6	Sulphur as SO_3	0.99
7	Loss in Ignition	3.56
8	$Na_2O + K_2O$	0.68

Plastic Fiber

Plastics that have been spun into filaments or fibers and used to create optical fibers, cables, ropes, and textiles are known as plastic fibers. Although there are many more types of plastic fibers, polyester, nylon, rayon, acrylic, and spandex are some of the most well-known. Polyethylene terephthalate, or PET, is referred to as polyester and is also used to produce beverage bottles.

Adhesives, elastomers, and coatings are made of different kinds of plastic. Fluoroelastomer, nitrile, polychloroprene, and ethylene-propylene-diene rubber are examples of artificial rubber types.

Plastic fibers will be gotten from waste plastic materials (milk and curd parcels). After cleaning and drying, the plastic materials will be shred into filaments every one of normal thickness. These plastic spreads are normally viewed as waste materials.

Figure 3 Plastic fiber

Table 4 Properties of plastic fiber

Basic properties	Values
Core material	PMMA
Cladding material	PMMA/Teflon
Diameter (mm)	0.5
Core refraction index	1.49
Cladding refraction index	1.42
Numerical aperture	0.44
Acceptance angle (°)	52.2
Storage temperature (°C)	-20 to +70
Specific gravity (g/cm³)	1.19
Wavelength (nm)	400–780
Limit of bending radius	8 × fibre diameter

4. METHODOLOGY ADOPTED

I. Broad Soil Using Fly Ash

In a series of studies, the fly ash content in the expansive soil was adjusted between 10% and 50% (multiples of 10) by weight of the total quantity obtained in order to assess the effect of fly ash as a stabilizing addition in expansive soils.

The following tests were carried out using the Indian Standard codes:

Proctor exam standard - IS: 2720 (Part 7) – 1980

II. Broad Soil Using Plastic Fiber

While incorporating the fiber into the soil, the following procedures are followed. According to the standard proctor compaction tests, each soil sample is compacted at its associated maximum dry density (MDD) and optimum moisture content (OMC).

Here, the following formula determines the soil's fiber content:

The proportion of fiber reinforcement in the current study was calculated using four distinct values: 0, 0.05, 0.15, and 0.25.

If fiber was not utilized during sample preparation, the air-dried soil was combined with a water content based on the soil's organic matter content.

If fiber reinforcement was utilized, the appropriate amount of fibers was manually mixed into the air-dried soil in small amounts, making sure to fully include all of the fibers to produce a reasonably uniform mixture, and then the necessary amount of water was added.

To assess the impact of fly ash and plastic waste fiber as a balancing out added substance in reaching soils, arrangement of tests, where the substance of fly powder in the sweeping soil was differed in estimations of 5% to 20% and 1% plastic fiber by weight of the all out amount taken. The Indian Standard codes were pursued during the conduction of the accompanying analyses:

- Standard proctor test – IS : 2720 (Part 7) - 1980
- Unconfined compressive strength (UCS) test – IS : 2720 (Part 10) - 1991
- California bearing ratio (CBR) test – IS : 2720 (Part 16) - 1987
- Liquid & Plastic limit test – IS 2720 (Part 5) - 1985

CONCLUSION

The polypropylene fiber's ability to increase in different types of soil contributes significantly to the soil's increased shear strength. All things considered, it can be stated that fiber reinforced soil made of polypropylene fiber can be taken into consideration for the improvement of deep foundation and soil properties, particularly in engineering projects on loose or weak soils. It can also be used as a cost- and energy-effective deep foundation substitute. When fly ash was added to the black cotton soil, the soil's Maximum Dry Density (MDD) value initially dropped.

The performance evaluation of plastic fiber and fly ash as soil stabilizing materials is the main goal of this study. According to the study, fly ash and plastic fiber may be combined and applied correctly to create a fantastic soil stabilizing method.The study's findings lead to the following conclusions.

1. For highly dynamic soils that often expand and contract, fly ash is a good soil stabilizing material.

2. The addition of fly ash strengthens the expansive soils and reduces their swelling.

3. The bearing capacity of expansive soil is improved by a drop in the plasticity index and an increase in dry density.

REFERENCES

[1]. Prof. S. Ayyappan, Ms. K. Hemalatha and Prof. M. Sundaram(2010), "Investigation of Engineering Behavior of Soil, Polypropylene Fibers and Fly Ash -Mixtures for Road Construction", International Journal of Environmental science and development (IJESD) IJESD 2010 Vol.1(2): 171-175 ISSN: 2010-0264
DOI: 10.7763/IJESD.2010.V1.31.

[2]. Jasmin Varghese Kalliyath, Jithin Thomas Joy, Jeny Merin Paul(2016), "Soil Stabilization using Plastic Fibers", IJSTE - International Journal of Science Technology & Engineering | Volume 2 | Issue 12 | June 2016 ISSN (online): 2349-784X.

[3]. Amit Tiwari[1], H. K. Mahiyar[2], et al.,(2014), "Experimental study on stabilization of black cotton soil by fly ash, coconut coir and crushed glass", International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 11, November 2014).

[4]. Mahevi Malik Affan Masood Javeed[1], Gavit Deepak Bhagwat[2], et al.,(2018), "Stabilization of Black Cotton Soil using Fly Ash and Coconut Coir", IJSRD - International Journal for Scientific Research & Development| Vol. 6, Issue 01, 2018 | ISSN (online): 2321-0613.

[5]. K.Padmavathamma[1], S.Jyothirmayee[2], L.Vimala[3], et al.,(2017), "Experimental Study on Stabilization of Black Cotton Soil by Using Fly Ash and Coconut Coir Fiber", International Journal of Innovative Research in Science, Engineering and Technology.

[6]. Laxmikant Yadu, Dr. R.K. Tripathi,(2013), "STABILIZATION OF SOFT SOIL WITH GRANULATED BLAST FURNACE SLAG AND FLY ASH", IJRET: International Journal of Research in Engineering and Technology ISSN: 2319-1163

[7]. Woldesenbet, T.T. Experimental Study on Stabilized Expansive Soil by Blending Parts of the Soil Kilned and Powdered Glass Wastes. Adv. Civ. Eng. 2022, 12, 96455589.

[8]. Zha, F.; Liu, S.; Du, Y.; Cui, K. Behavior of expansive soils stabilized with fly ash. Nat. Hazards 2008, 47, 509–523.

[9]. Jones, L.D.; Jefferson, J. ICE Manual of Geotechnical Engineering Volume 1: Geotechnical Engineering Principles, Problematic Soils and Site Investigation; The National Academies of Sciences, Engineering, and Medicine: Washington, DC, USA, 2012.

[10]. Kamei, T.; Ahmed, A.; Ugai, K. Durability of soft clay soil stabilized with recycled Bassanite and furnace cement mixtures. Soils Found. 2013, 53, 155–163

[11]. Higgins, D. Briefing: GGBS and sustainability. Const. Mater. 2007, 160, 99–101.

[12]. Shihab, A.M.; Abbas, J.M.; Ibrahim, A.M. Effects of temperature in different initial duration time for soft clay stabilized by fly ash based geopolymer. Civ. Eng. J. 2018, 4, 2082–2096.

[13]. Suhendro, B. Toward green concrete for better sustainable environment. Procedia Eng. 2014, 95, 305–320. [

[14]. Krivenko, P. Why alkaline activation—60 years of the theory and practice of alkali-activated materials. J. Ceram. Sci. Technol. 2017, 8, 323–333.

[15]. Davidovits, J. False values on CO2 emission for geopolymer cement/concrete published in Scientific Papers. Geopolym. Inst. Libr. Tech. Pap. 2015, 24, 1–9.

[16]. Palomo, A.; Krivenko, P.; Garcia-Lodeiro, I.; Kavalerova, E.; Maltseva, O.; Fernández-Jiménez, A. A review on alkaline activation: New analytical perspectives. Mater. Construcc. 2014, 64, 315.

[17]. Jia, Z.; Yang, Y.; Yang, L.; Zhang, Y.; Sun, Z. Hydration products, internal relative humidity and drying shrinkage of alkali activated slag mortar with expansion agents. Constr. Build. Mater. 2018, 158, 198–207.