Improvement in the Bearing Capacity of Black Cotton Soil: E-Waste Stabilizers

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Abstract:
Black cotton soil, known for its high clay content, low shear strength, and significant swell-shrink behavior, possesses serious challenges in civil engineering constructions such as pavements and foundations. To overcome these limitations, soil stabilization techniques are employed to improve strength and reduce volumetric changes. Conventional stabilizers like lime, cement, and fly ash, although effective, have environmental and economic drawbacks.
This study investigates the use of electronic waste (e-waste) as an alternative eco-friendly stabilizer to enhance the bearing capacity of black cotton soil. Crushed e-waste materials such as printed circuit boards, CDs, and wires were added to the soil in varying proportions (4%, 8%, and 12% by weight). Different laboratory tests including water content, specific gravity, Atterberg limits i.e. Liquid limit (LL), Plastic Limit (PL) and Plasticity Index (PI), compaction, Free swell Index (FSI) and soil classification were conducted without stabilization. California Bearing Ratio (CBR) were conducted with and without stabilization.
The results revealed that the inclusion of e-waste improved the CBR value and reduced the swelling and shrinkage potential of black cotton soil. The maximum improvement in bearing capacity was observed at 8% e-waste content. The findings demonstrate that using e-waste as a soil stabilizer is not only technically effective but also promotes sustainable waste management by recycling non-biodegradable materials.

Keyword: Black cotton soil, e-waste, soil stabilization, California Bearing Ratio, bearing capacity.

1. INTRODUCTION

Black cotton soil (also called expansive clay) is widespread in many parts of the world. It has high clay content, high plasticity, low shear strength, high compressibility and pronounced swell–shrink behaviour with moisture changes. These characteristics cause foundation distress, cracking of pavements and structures, and make construction on such soils challenging and costly.
Problem with black cotton soil: It has low bearing capacity and high plasticity, which makes it unsuitable for supporting heavy structures without modification. Sseasonal moisture variations cause significant volume changes, leading to structural damages. Enhancing the bearing capacity of black cotton soil is crucial to ensure the safety and durability of civil engineering structures.

Traditional methods like lime and cement stabilization are effective but may not always be environmentally sustainable or cost-effective. Components in e-waste (glass from screens, silica from ceramics, metal powders, polymeric fragments) can act as fillers, coarse aggregate substitutes, or pozzolanic material after thermal treatment. Thermal or chemical processing of certain e-waste fractions (e.g., pyrolysis/combustion of plastics/PCBs) can produce ash rich in metal oxides and siliceous residues that may have cementitious or pozzolanic properties or can be used in geopolymer binders. Use of e-waste diverts hazardous material from landfill, supports circular economy goals, and may reduce use of virgin stabilization materials.

1.1 Objectives of the Study

1. To find out different soil properties using lab tests without E-waste (i.e. water content, Specific Gravity, Sieve Analysis, Atterberg's Limits, Compaction test, California Bearing Ratio etc.)
2. To classify the soil by using IS classification chart.
3. To find out the ratio of E-waste for stabilize the soil.
4. To find out the engineering property with E-waste (i.e. California Bearing Ratio)
5. To perform comparison study of lab tests with and without E-waste.

2. Materials Used for Study

2.1 Black Cotton Soil

Materials used for the tests were black cotton soil and E-waste. Soil was obtained from Manevada in the Nagpur District. Material procurement was done manually, and lumps of larger masses were broken by rammers. Then the soil was dried in the oven for a period of 24 hours at an oven temperature of 105°C to 110°C.

Fig.1: Black Cotton soil

2.2 E-waste

Electronic waste may be described as the discarded electronic equipment's such as mobile phones, computers, household appliances which fail or are no more fit for its originally intended use. Everyday Advances in technology have resulted in a fast-growing surplus of electronic waste globally. Approximately

50 million tons of E-waste is generated annually around the globe. Developing countries like India are being
used to dump large masses of E-waste without its sorting or dismantling.

Fig.2: E-Waste Without Crushed

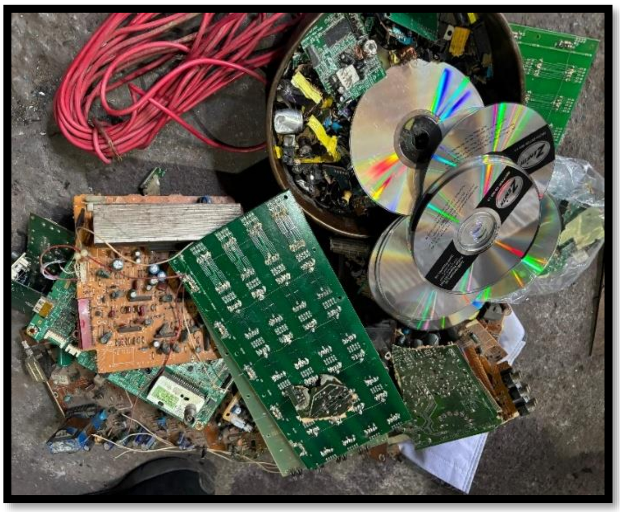

Fig.3: E-Waste with Crushed

3. Methodology

Methodology This chapter presents the methodology adopted for the experimental investigation into the improvement of bearing capacity and engineering properties of Black Cotton Soil with the addition of E-waste materials. It describes material collection, sample preparation, and laboratory testing, and how the findings were analysed to establish the efficiency of E-waste as a soil stabilizer.

3.1 Materials Used

3.1.1 Black Cotton Soil (BCS)

Source: The soil will be collected from Nagpur
Characteristics: Typically rich in montmorillonite clay, showing high swelling and shrinkage potential.
Purpose: Used as the base soil for testing stabilization performance.

3.1.2 E-Waste Material

Source: Collected from discarded electronic devices such as printed circuit boards, computer casings, and cables.

Processing: -

E-waste is crushed using a jaw crusher and pulverized into fine granular particles (<2 mm).

Ferrous and non-ferrous metals are separated magnetically to avoid contamination.

Purpose: Used as a stabilizing additive in varying proportions to the soil.

3.1.3 Water

Type: Potable water, free from organic impurities, will be used for sample preparation.

3.2 Experimental Procedure

3.2.1 Preliminary Tests on Black Cotton Soil

To establish the basic geotechnical properties, the following tests will be conducted on the natural soil:

- Grain size distribution (IS 2720 Part 4)
- Specific gravity (IS 2720 Part 3)
- Atterberg limits (IS 2720 Part 5)
- Standard Proctor test (IS 2720 Part 7)
- California Bearing Ratio (CBR) test (IS 2720 Part 16)
- Free shelling index (IS 2720 part 40)

3.3 Preparation of Soil-E-waste Mix

E-waste material will be blended with Black Cotton Soil in different percentages by weight of dry soil, for example:

- 0% (control sample)
- 4%
- 8%
- 12%

Each mixture will be thoroughly homogenized in a dry state before adding water at the Optimum Moisture Content (OMC) obtained from compaction tests.

4. Properties of Black Cotton Soil

Table 1- Properties of Black Cotton Soil

SR.NO	PROPERTY	VALUE
1	Specific Gravity	2.22
2	Free Swell Index	39%
3	Sieve Analysis	-
	a) D10	0.77
	b) D30	1.40
	c) D60	3.20
	d) Cc= D60/D10	0.80
	e) Cu=D30^2/D10*D60	4.16
4	Liquid Limit	33.5%
5	Plastic Limit	6.11

6	**OMC**	**13.05%**
7	**MDD**	**1.142**
8	**Water Content**	**38.78%**
9	**CBR without E-waste**	**-**
	a) At 2.5mm	**3.125**
	b) At 5mm	**4.375**

5. Results and Discussion

After the determination of basic properties of black cotton soil, soil stabilized with E-waste CBR (California bearing ratio) Following are the results obtained after performing tests.

5.1California Bearing Ratio (CBR)

The CBR value of the black cotton soil increased with the addition of E-waste. The objective of increasing the CBR value was achieved. The figure below shows the improvement of CBR value with respect to different addition of E-waste. From figure A the variation of CBR value with addition of E-waste can be observed.

	Use of E-waste stabilizer (%)			
	0	**4**	**8**	**12**
CBR	**1.14**	**1.43**	**1.63**	**1.52**

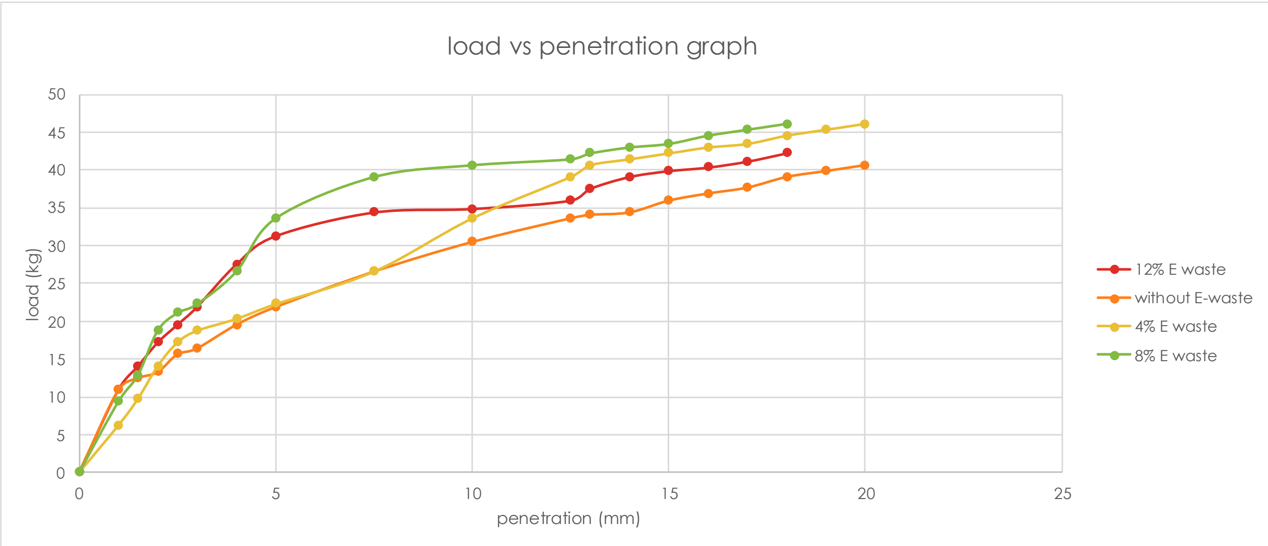

Fig No. A (Variation in CBR value with addition of E-waste.)

6. Conclusions

1. Black cotton soil, which is naturally present (0% E-waste) indicates high plasticity, low shear strength, high swelling, and shrinkage behavior, and therefore does not display suitable engineering properties for foundation or pavement applications without some stabilization.
2. The addition of solid E-waste (in granular form) starts to ameliorate the engineering properties of soil, depending on better interlocking of particles, reductions in voids, and increases in frictional resistance.
3. At 4% E-waste, there is some improvement in dry density, the CBR value (California Bearing Ratio),

and shear strength. There is a corresponding decreasing trend in the plasticity index while the tendency to swell decreased compared to natural soil.
4. The 8% E-waste proves optimal improvement, by: The maximum increase in dry density; The most significant improvement in CBR values; soaked and unsoked; The best shear strength; The most reduction in plasticity and swelling; 8% E-waste is the optimum dosage for the stabilization of the black cotton soil using E-waste for moisture.
5. At 12% E-waste, the strength parameters slightly improve due to excess E-waste and non-cohesive material, which results in reduced bonding of the soil (producing less coherent or stable conditions). Beyond the optimum percentage, the soil became too granular and loose, losing compaction efficiency.
6. The E-waste as a soil stabilizer is attractive economically, as it promotes the use of recycled materials, brings environmental benefit by reducing the burden on landfills while supporting environmentally-friendly construction applications with E-Waste engineering, soil stabilization.

The results of present study are:
1. The bearing capacity of black cotton soil improved significantly after adding e-waste.
2. CBR values increased at all percentages (4%, 8%, and 12%)
3. The maximum improvement of CBR value is found to be 1.63 at 8% addition of E-waste.
4. The use of e-waste reduces swelling and shrinkage, improving the durability of foundations and pavements.
5. This method is eco-friendly and cost-effective, supporting sustainable waste management.

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