CHAPTER THREE

MATERIAL AND EXPERIMNTAL TEST PROGRAM

3.1 Introduction

This chapter contains a description of materials which were considered for beneficial reuse in soil stabilization applications. These materials included cement kiln dust as chemical stabilizers, plastic waste and fiber glass waste as soil reinforcement. These materials were selected based on their engineering properties, availability in Sudan, and their potential for use in geotechnical applications.

For the current research the main application of these materials focused on soil blending. In other words, these materials were mixed with soils and tested in order to determine whether or not the addition of the materials enhanced the engineering properties of the soil itself. Each material was mixed with soil and tested for index properties, compaction behavior, and strength effects.

3.2 Materials Description:

The detailed description of the materials is presented in the following sub-sections:

3.2.1. Soil:

The soil that had been used in this research was collected from Alnneil Street, located in Khartoum State, Sudan (Fig 3.1). The soil passing through sieve No 4, was air-dried overnight in large pans, and then prepared for testing using quartering method (Fig 3.2, fig 3.3 and fig 3.4). The properties of the soil were determined by standard test procedures as per relevant IS codes and are tabulated as shown in Table (3.1)

Fig 3.1: Clay soil (collection site)

Fig 3.2: Clay soil preparation (air dried sieve no 4)

Fig 3.3: Quartering method

Fig 3.4: samples of clay soil

Table 3.1: Properties of Soil

Properties	Standards	Value	Unit
Clay	-	58	%
Silt	-	22	%
Sand	-	20	%
Liquid Limit	ASTM: D4318-00	36.9	%
Plastic Limit	ASTM: D4318-00	27.85	%
Plasticity Index	ASTM: D4318-00	9.41	%
Shrinkage Limit -	ASTM: D4318-00	10	%
Specific gravity, Gs	ASTM: D854-02	2.43	
Max. Dry Density	ASTM: D698	1.68	g/cm^3
Optimum Moisture Content	ASTM: D698	18	%
Compressive Strength , qu	ASTM: D7181	219.8	kg/cm^2
Cohesion, C	ASTM: D7181	165.4	kg/cm^2
Angle of Internal Friction (Φ)	ASTM: D7181	18	*Degree*
Soil Classification (USCS)	ASTM: D2487-00	CL-ML	-

3.1.4. Cement kiln dust

Cement kiln dust (CKD) was collected from Atbara Cement Company. The chemical composition and properties of the CKD are given in the Table (3.2) and Table (3.3) respectively.

Table (3.2): Chemical Composition of the cement kiln dust

S. No	Compound	Value %
1	SiO_2	17.84
2	Al_2O_3	4.57
3	Fe_2O_3	2.76
4	CaO	49.36
5	MgO	2.56
6	SO_3	9.65
7	K_2O	3.99
8	Na_2O	0.33
9	TiO_2	0.45
10	LOI	5.38

Table (3.3): Properties of the cement kiln dust

Test	Test method	Value	unit
Retained on No 0. 325 sieve		16.8	%
Specific surface area	ASTM: C 204	25000	cm^2/g
O.M.C	ASTM: D698	26	%
M.D.D	ASTM: D698	1.36	g/cm^3
Initial setting time	ASTM: C 403	15	hr
Specific gravity	ASTM: D 854	2.95	g/cm^3

3.1.3. Fiber glass waste:

The strips of fiber waste that had been used in this research was collected from tanks and septic tank industry in Khartoum state (Fig 3.5). The strips were cut into pieces of different length ($10mm - 20mm$) having average width $0.5mm$ (Fig 3.6)and were randomly mixed with soil in varying percentages (0.5, 1.5, 3, 6, 9, 12 and 15%)by dry weight of soil. The tensile strength of the strips was determined using tensile testing machine (ASTM D638), the density (ASTM D792) and the length and width are measured, and presented in Table 3.4.

Fig 3.5: Collection of fiber waste

Table 3.4 Properties of Fiber Waste:

Test	Test method	Value	Unit
Fiber type	Fiber glass	-	-
Average Width	Measurement	0.5	*mm*
Average Length	Measurement	10	*mm*
Average Tensile Strength	ASTM D638	350	*mPa*
Shape	-	Line	-
Color	-	Clear	-
Density	ASTM D792	2.58	g/cm^3

Fig 3.6: fiber waste used in the study

3.1.2. Plastic waste:

As outlined by Ismail (2010) [86] in Khartoum state there are (7) soft drinks factories and more than fifty water bottling factories. All of these factories are using PET plastic bottles for their packaging Most of these factories distributing their products to all state of Sudan. There are also (4) four formal small- scale grinding plastic recycling units and many informal recycling units in Khartoum state. Only one of the formal units is grinding collected PET bottles for export. This clearly shows that PET plastic bottles are available in vast quantities. Hence, their reuse for any beneficial way will be useful environmentally

For the present study, plastic waste (PET) was obtained from PET water bottles Fig (3.7). The strips were cut into pieces and crushed to different lengths (5*mm* - 15*mm*) having average width of 5*mm* (Fig (3.12)), and were randomly mixed with soil in varying percentages of (0.5, 1.5, 3, 6, 9, 12and 15%) by dry weight of soil.

In general the steps required for recycling PET are not quite different from the other plastic types especially in the preparation steps. For the purpose of this current work the preparation steps are:

1. *Collection of PET:*

The PET bottles used in current study were collected from plastic recycle industry in Khartoum state from domestic house holds and from Canteens disposables (Fig 3.8)

Fig 3.7: PET water bottles ***Fig 3.8: Collection of PET water bottles Wastes***

2. *Sorting:*

There are two generic types of sorting systems used as plastic recycling facilities. These are manual and automated sorting system Manual system rely on plant personnel who visually indentify and physically sort Plastic bottles traveling over a conveyor belt system (Fig 3.9)

Fig 3.9: Sorting of PET water bottles Wastes

3. *Crushing:*

The plastic materials were prepared for melting by cutting them into small pices. The plastic items were fed into a machine which has a set of blades that slice through the material and break the plastic into tiny bits (Fig 3.10)

Fig 3.10: crushing of PET water bottles

4. *Washing:*

The washing process for the separated PET bottles with some detergents to remove any suspended physical contamination is a necessary step to insure the top quality for the recycling process (Fig 3.11)

Fig 3.11: washing of PET bottles

The properties of plastic strips (PET) were determined and tabulated in the Table 3.5

Table 3.5 Properties of Plastic Waste (PET Bottle) Strips:

Test	Test method	value	Unit
Plastic type	PET Bottle	-	-
Average width	Measurement	5	*mm*
Average length	Measurement	5-15	*mm*
Average Tensile Strength	ASTM D638	55	*mPa*
Density	ASTM D792	1.38	g/cm^3

Fig 3.12 PET bottles used in the study

3.3 Test Program:

Various experiments had been conducted to find the stabilization of clay soil using the wastes materials, these based on the ASTM procedure, are:

- Liquid Limit (ASTM D 4318 – 05)
- Plastic Limit (ASTM D 4318 – 10)
- Sieve Analysis (ASTM D 6913)
- Specific Gravity (ASTM D 6473)
- Standard Proctor Compaction Test (ASTM D 1557)
- Triaxial Test (ASTM D 2166)

- California Bearing Ratio Test (CBR)(ASTM D 1883)
- X-ray diffraction (ASTM) for cement waste
- Tensile strength (ASTM D638)

3.4 Preparation of Soil Mixes:

Plastic, fiber, cement wastes and soils were prepared manually by hand mixing. Oven dried soil after passing through 4.75 *mm* sieve was taken and water added for clayey soil and mixed uniformly. For a particular percentage of fiber content, the one third (1/3) of total amount of plastic strips were distributed evenly and mixed thoroughly with wet soil. After mixing the (1/3^{r}) amount, another one third (1/3) amount was mixed in the same way. Finally the last amount was mixed with the wet soil. The wet plastic-mixed soils were then used for proctor tests, triaxial test and CBR test as shown in Fig (3.13).

Fig 3.13 Plain Soil mixed with fiber glass, PET Strips and cement waste

addition of equal or more than 9% of fiber glass to clay soil with the optimum moisture content (OMC =18%) resulted in difficultly in samples preparation as they became very stiff and began to segrate as shown in Fig (3.14).

Fig 3.14 segregation and cracks on fiber glass samples

Similarly problems resulted on addition of equal or more than 9% of PET waste and the samples became non homogenous and difficult to prepare.