CLAY SOIL STABILISATION USING RED GLASS POWDERED

ABSTRACT

The stabilizing effect of powder red glass on clay soil. Broken waste glass was collected and crush into powder form suitable for addition to the clay soil in varying proportions namely 5%, 10% and 15% along with 15% cement (base) by weight of the soil sample throughout. Consequently, the moisture content, specific gravity, particle size distribution and Atterberg limits tests were carried out to classify the soil using the ASSHTO classification system. Based on the results, the soil sample obtained corresponded to Group A76 soils identified as 'fair to poor' soil type interms of use as drainage and subgrade material. This justified stabilisation of the soil. Thereafter, compaction, California bearing ratio (CBR) and direct shear tests were carried out on the soil with and without the addition of the powdered glass. The results showed improvement in the maximum dry density values on addition of the powdered glass and with corresponding gradual increase up to 5% glass powder content after which it started to decrease at 10% and 15% powdered glass content. The highest CBR values of 13.90% and 110.91% were obtained at 5% glass powder content and 5mm penetration for both the unsoaked and soaked treated samples respectively. Themaximum cohesion and angle of internal friction values of 15.0 and 12.0 respectively were obtained at 10% glass powder content.

1. Introduction

Clay soils exhibit generally undesirable engineering properties. They tend to have low shear strength which reduces further upon wetting or other physical disturbances. They can be plastic and compressible; expand when wetted and shrink when dried. Some types expand and shrink greatly upon wetting and drying, thereby, exhibiting some very undesirable features. Cohesive soils can creep

Nomenclatures

G_s	Specific gravity
M_1	Mass of empty can, g
M_2	Mass of can and wet sample, g
M_3	Mass of can and dry sample, g
m_1	Mass of specific gravity bottle, g
m_2	Mass of specific gravity bottle with 50 g of soil sample, g
m_3	Mass of specific gravity bottle with water and soil sample, g
m_4	Mass of specific gravity bottle filled with water, g

Greek Symbols

γ	Density, kN/m^3

γ-max Maximum density, kN/m^3

Maximum shear at failure

Abbreviations

CBR	California bearing ratio
LL	Liquid limit
LS	Linear shrinkage
MC	Moisture content
MDD	Maximum dry density
OMC	Optimum moisture content
PI	Plasticity index
PL	Plastic limit

In recent years, applications of industrial wastes have been considered in road construction both in industrialised and developing countries. Utilization of such materials is based on technical, economic and ecological criteria which are crucial for a country like Nigeria which normally provides a good environment for both the manufacture and importation of glass materials. However, Nigerian cities and towns are currently facing serious environmental problems arising from poor solid waste management. The rate of solid waste generation in Nigeria has increased with rapid urbanization. Solid waste is generated at a rate which has grown beyond what the capacity of the city authorities can handle

2. Background Literature

Soil stabilisation is the alteration of soils to enhance their physical properties. It can increase the shear strength of a soil, control its shrink-swell properties and improve its load bearing capacity. Soil stabilisation can be utilized on roadways, parking areas, site development projects, airports and many other situations where sub-soils are not suitable for construction. It can also be used to treat a wide range of subgrade materials varying from expansive clays to granular soils as well as improve other physical properties of soils such as increasing their resistance to erosion, dust formation or frost heaving.

Historically, engineers have long been aware of the stabilizing effects of various materials in earth works. The first and by far, the most extensive and successful application of stabilisation was developed by the French engineer, Henry Vidal, in the late 1950's. Vidal’s system was known as 'Reinforced Earth', which consists of placing steel reinforcing strips at predetermined intervals within the fill mass for the purpose of providing tensile or cohesive strength in a relatively cohesionless material

Principles of soil stabilization

Stabilization is defined as the process of improving the soil aggregate properties by blending in materials that increase the load bearing capacity, firmness and resistance to weathering or displacement. It can be defined as the process of altering the soil properties by mechanical or chemical means thereby improving the desired engineering properties of such soils. There are three purposes for soil stabilization namely strength improvement, permeability control and enhancement of soil durability and resistance to weathering.

Chemical stabilization

This method deals with improving the engineering properties of soil by adding chemicals or other such materials and it is generally cost effective. These additives react with the soil usually clay minerals, with subsequent precipitation of new and insoluble minerals, which bind the soil together [3]. There are various categories of these chemical admixtures namely cementing agents, modifiers, water proofing agents, water retaining agents, water retarding agents and miscellaneous chemicals. In addition, their characteristics are vastly different from the others and each has its particular use as well as limitations.

Considering the cementing agents first, the materials often used are Portland cement, lime, mixture of lime and fly ash, and sodium silicate. Portland cement has been used extensively to improve existing gravel roads as well as stabilize the natural subgrade soils. Other admixtures that have come into extensive use in recent years are lime and fly ash admixtures. Fly ash is a by-product of blast furnaces and is generally high in silica and alumina. However, the quantity of fly ash required for adequate stabilization is relatively high, making its use restricted to areas with availability of large quantities of fly ash at relatively low cost.

Engineering properties of fiber reinforced soil

The addition of fiber reinforcement in the sand and clay specimens was reported to cause a substantial increase in the peak friction angle and cohesion values. The shear strength envelope for the clay specimens is described by a combination of curvilinear and linear sections. The friction angle at low confining pressures was found to be slightly larger than that at higher confining pressure. The phenomenon was explained as an effect of dilatancy which increases the interface shear strength between fiber and soil. This effect is more pronounced at low confining stresses than at high confining stresses.

Previous research on the equivalent shear strength of fiber-reinforced soil has focused on quantifying the effect of fiber content and aspect ratio. Several predictive models have been proposed. These include a load transfer model that requires parameters obtained with non-conventional testing of soil-fiber composites, a strain energy approach that uses energy concepts and a statistical model based on the regression analyses of previous test results. A recently proposed discrete design methodology used concepts derived from limit equilibrium, and requires independent characterization of soils and fibers [9]. However, additional experimental results are needed to validate the proposed design models. The accuracy of the prediction of these models also relies on a proper understanding of the mechanism of interface and interactions between the fibers and soils.

Powdered glass stabilization

This involves the addition of broken glass powder to soil so as to improve its engineering performance. Glass is totally inert and therefore non-biodegradable. It degrades in a manner similar to natural rock. As an inert construction material, it can increase the strength of various road building elements. Glass has been experimented on as a substitute aggregate in asphalt concrete. Crushed glass has also been used as an aggregate for sub-base.

Glass is an amorphous non crystalline material, which is typically brittle and optically transparent. The familiar type of waste glass materials are drinking vessels and windows, however, most of the readily available waste glass material is soda-lime glass composed of about 75% silica ($Si0_2$), Na_2O, CaO and several additives.

3. Methodology and Materials

The materials used in carrying out this project are powdered glass, cement, clay soil and water. Glass is an amorphous non crystalline material which is typically brittle and optically transparent. The familiar type of waste glass materials found around are drinking vessel and windows, most of the readily available waste glass materials are soda-lime glass, composed of about 75% silica (SiO_2) plus Na_2O, CaO, and several additives. This material is added to clay soil in its powdered form for soil stabilisation.

Cement can be described as a material with adhesive and cohesive properties, which make it capable of holding material fragment into a compacted aggregate. It is manufactured from limestone and is added to an expansive soil to improve its engineering properties. It may be formed in place as residual deposits in soil while larger deposits usually are formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation. Lastly, water is a universal solvent. The water used is obtained from bore holes and is free from suspended particles like organic matter and silt which might affect the hydration process of cement.

Laboratory tests and analysis

Various tests and analysis were carried out to examine the effects of the glass powder on the clay soil namely particle size distribution analysis, specific gravity test, Atterberg limits test, compaction test, California Bearing Ratio test and Direct Shear test were carried to the investigate the effect of glass. Based on these tests, the required quantity of glass for effective stabilization of the clay soil was determined.

Table 1. Mix Proportions Used for Tests.

S/N	Clay soil (%)	Cement (%) by Mass of Soil	Glass Powder (%) by Mass of Soil
1	100	15	0
2	100	15	1
3	100	15	2
4	100	15	5
5	100	15	10
6	100	15	15

Table 2. Moisture Content Test Results.

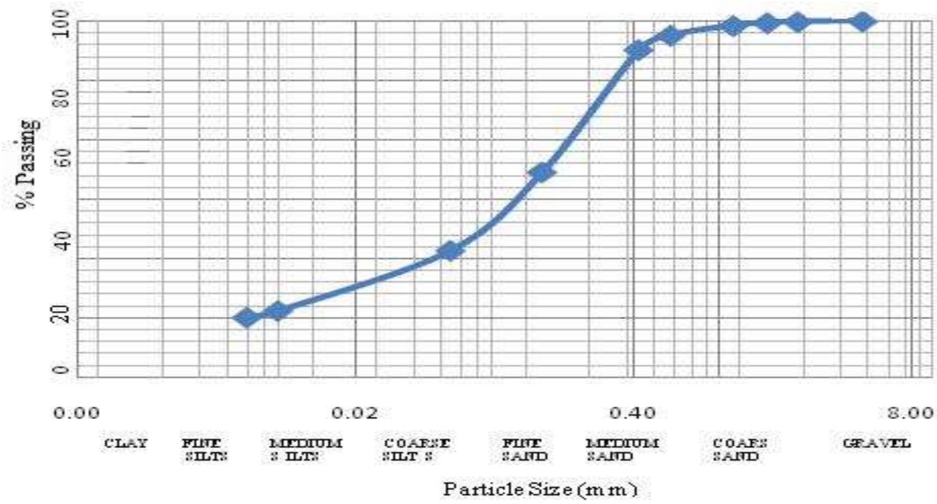
Test Sample	Mass of Empty Can (g) (M_1)	Mass of Can + Wet (g) (M_2)	Mass of Can + Dry (g) (M_3)	Moisture (g)	MC (%)
1	46.30	92.90	84.60	7.30	20.67
2	48.50	103.40	90.80	8.60	20.19
3	49	110.40	95.30	10.10	20.24
Average MC (%)					20.70

Table 3. Specific Gravity Test Results.

Masses (g)	Test 1	Test 2	Test 3
Mass of density bottle + Water (Full) = m_4	600.5	570	582.21
Mass of density bottle + Soil + Water = m_3	625.6	600	621.3
Mass of density bottle + Soil = m_2	350.9	302.5	312.2
Mass of density bottle = m_1	305.9	251	256.6
Specific gravity	2.25	2.15	2.12
Average specific gravity (G_s)		1.86	

Table 4. Particle Size Distribution Analysis.

Sieve Diameter (mm)	Mass Retained (g)	% Retained	% Passing
4.75	0	0	100
2.36	0.2	0.23	98.23
1.700	0.3	0.30	97.10
1.18	1.1	0.98	96.2
0.600	4.1	3.24	94.4
0.500	5.5	4.90	90
0.425	0.25	0.83	88.23
0.212	51.7	40.47	47.063
0.150	32.3	26.45	21
0.075	26	20.35	2.26
pan	2.8	2.26	0.00



Particle Size Distribution Chart.

Summary of Unsoaked CBR

Values for the Clay Soil Samples (Treated and Untreated).

Penetration (mm)	**Control (15% cement)**		**1% glass + 15% cement**		**2% glass + 15% cement**	
	Top (%)	Bottom (%)	Top (%)	Bottom (%)	Top (%)	Bottom (%)
5.0	8.18	8.17	8.54	9.12	11.27	13.33

Penetration (mm)	**5% glass + 15% cement**		**10% glass + 15% cement**		**15% glass + 15% cement**	
	Top (%)	Bottom (%)	Top (%)	Bottom (%)	Top (%)	Bottom (%)
5.0	13.90	10.11	13.04	13.90	10.32	13.04

Summary of Soaked CBR Values

for the Clay Soil Sample (Treated and Untreated).

Penetration (mm)	**Control (15% cement)**	**1% glass + 15% cement**	**2% glass + 15% cement**

	Top (%)	Bottom (%)	Top (%)	Top (%)	Bottom (%)	Top (%)
5.0	89.98	88.26	94.00	89.98	88.26	94.00

Penetration (mm)	**5% glass + 15% cement**		**10% glass + 15% cement**		**15% glass + 15% cement**	
	Top (%)	Bottom (%)	Top (%)	Top (%)	Bottom (%)	Top (%)
5.0	109.01	111.11	63.70	109.01	111.11	63.70

Summary of Cohesion Values and Angle of Internal Friction of the Treated Soil Sample.

	Control (15% cement)	**1% glass + 15% cement**	**2% glass + 15% cement**	**5% glass + 15% cement**	**10% glass + 15% cement**	**15% glass + 15% cement**
Cohesion value	10.6	13.6	12.0	13.60	15.05	13.5
Angle of internal friction	8.5	10.0	11.0	13.0	16.03	14.0

Conclusion

This study has shown that the improvements in the properties of the clay soil obtained herein are more significant with the addition of the powdered glass. It seems that the percentage quantity of the powdered glass required achieving the best results in terms of the clay soil properties lies between 5% and 10% by mass of the soil. This is because the corresponding maximum values from both the compaction and CBR tests were obtained at 5% glass powder content while the maximum values from the shear strength test were obtained at 10% glass powder content.

Furthermore, it can be concluded based on the results obtained that powdered glass can be effectively used as a soil stabilizer since it was able to produce considerable improvements in the properties. Such improvements included an increase in the MDD value from 23.37 kN/m^3 for the control sample up to 23.90 kN/m^3 for the sample containing 5% powdered glass by mass of the soil, achievement of the highest CBR values of 13.90% and 111.11% obtained at 5% powdered glass content for both the unsoaked and soaked treated samples respectively as well as achievement of the maximum values of cohesion and angle of internal friction of 15.5 and 16.03 respectively obtained at 10% powdered glass content.

Recommendation(s)

It is recommended that further research should be carried out to determine the optimum amount of this additive for effective clay soil stabilization, which apparently seems to have a value between 5% and 10% of powdered glass content. The effect of the powdered glass on other kinds of soils such as literates should also be investigated to determine whether similar results will be obtained which will help to establish it as an all-round or general soil stabilizer.

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