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Strength improvement of clay using waste soda lime glass powder and sodium alginate.

Mejora de la resistencia de la arcilla utilizando polvo de vidrio sodocálcico y alginato de sodio.

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ABSTRACT

Clayey soil is generally weak in nature. When constructions are carried out on clayey soil, especially highways, railways, buildings and embankment face many difficulties. Therefore, the improvement of such type of soil is crucial. Soil stabilization can be done by different methods, which includes stabilization using lime, cement and waste materials from various industries etc. Soda lime glass powder is a waste material from glass industries. Clay is a type of soil that can be categorized as problematic due to its weak properties like volumetric expansion, low strength etc. In this soil, the shear strength of the soil is less due to its very high initial moisture content and plasticity. Construction is difficult in such type of weak clay. The main aim is to identify the properties of clay and to study the effect of waste soda lime glass powder (WSLGP) and sodium alginate (SA) on clay. Standard proctor compaction test and Unconfined strength test is carried out using varying (3%, 6%, 9%, 12%, 15%) percentages of WSLGP and optimum WSLGP content is determined. The sodium alginate in varying (0.25%, 0.5%, 0.75%, 1%, 1.25%) percentages is added to clay with optimum soda lime glass powder. Standard proctor compaction test and Unconfined compressive strength test were carried out. The maximum strength is obtained at optimum 12% WSLGP and 1% SA content.

Keywords: Soil strength improvement, Soda lime glass powder, Sodium alginate, Pallipad clay, Standard proctor compaction test, Unconfined compression test.

RESUMEN

El suelo arcilloso es generalmente de naturaleza débil. Cuando se construyen en suelos arcillosos, especialmente las carreteras, los ferrocarriles, los edificios y los terraplenes se enfrentan a muchas dificultades. Por tanto, la mejora de este tipo de suelo es crucial. La estabilización del suelo se puede realizar mediante diferentes métodos, que incluyen la estabilización con cal, cemento y materiales de desecho de diversas industrias, etc. El polvo de vidrio de cal sodada es un material de desecho de las industrias del vidrio. La arcilla es un tipo de

suelo que puede clasificarse como problemático debido a sus propiedades débiles como expansión volumétrica, baja resistencia, etc. En este suelo, la resistencia al corte del suelo es menor debido a su muy alto contenido de humedad inicial y plasticidad. La construcción es difícil en este tipo de arcilla débil. El objetivo principal es identificar las propiedades de la arcilla y estudiar el efecto del polvo de vidrio sodocálcico (WSLGP) y el alginato de sodio (SA) sobre la arcilla. La prueba de compactación Proctor estándar y la prueba de resistencia no confinada se llevan a cabo utilizando porcentajes variables (3%, 6%, 9%, 12%, 15%) de WSLGP y se determina el contenido óptimo de WSLGP. El alginato de sodio en porcentajes variables (0,25%, 0,5%, 0,75%, 1%, 1,25%) se agrega a la arcilla con polvo de vidrio de cal sodada óptimo. Se llevaron a cabo la prueba de compactación Proctor estándar y la prueba de resistencia a la compresión no confinada. La resistencia máxima se obtiene con un contenido óptimo de 12% de WSLGP y 1% de SA.

Palabras clave: mejora de la resistencia del suelo, polvo de vidrio de cal sodada, alginato de sodio, arcilla Pallipad, prueba de compactación Proctor estándar, prueba de compresión no confinada.

INTRODUCTION

Clayey soil stabilization is the process of permanent physical and chemical alteration of soils for enhancing their physical properties. Soil stabilization can be done with base soils or without admixtures, to increase their load carrying capacity and resistance to physical and chemical stress of the environments over the service life of the engineered structure [2]. Stabilization can increase the strength of soil or can control the shrink swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Stabilization can be achieved with a variety of chemical additives including lime, fly ash and Portland cement etc[7]. There are several industries which face issues in disposing their waste products. The waste from these industries having serious environmental impact if it is not disposed properly. Glass manufacturing industry is one among them. Therefore, the timely action regarding the safe disposal of waste soda lime glass powder is necessary. Keeping in the view of environmental problems associated with it, one of the common feasible ways to utilize these waste products is to explore their uses in construction of roads, highways, embankments and fill material. The waste soda lime glass in the form of powder is effective in protecting the environment and conserving natural resources [10]. Sodium alginate was investigated as an environment friendly soil-surface stabilizer to enhance compressive strength on clay. The detailed study is undertaken to study the effect of soda lime glass powder and sodium alginate as a material in clayey soil.

MATERIALS AND METHODS

A.Materials

The materials used in the experimental work are Clay and Waste soda lime glass powder (WSLGP). Clay was collected from paddy field in Pallipad, Alappuzha district, Kerala, India during June, 2022. Clay is brown coloured. Clay in its natural state is found to have very low shear strength and very high in compressibility. Table 1

shows the properties of clay. Soda lime glass powder was collected from Globe glass industries in Thrissur district, Kerala. Glasses are brittle and optically transparent [16]. Soda lime glass also called soda lime silica glass. It is a type of glass used for window panes and glass containers like bottles and jars for beverages, food and some commodity items [10].Some glass bakeware is made of soda lime glass, as opposed to more common borosilicate glass. Soda lime glass accounts for about 90% of manufactured glass. Soda lime glass has several properties that make it useful as a glass for general and more specific applications. It is cheap, chemically stable, hard, workable, electrical insulator and also it transmits visible light. Table 2 shows the chemical properties of soda lime glass powder.Sodium alginate is a natural polysaccharide extracted from brown algae. Brown algae comprising the class phaeophyceae, are large group of multicellular algae including many seaweeds located in colder waters within the Northern Hemisphere.Alginates are polymers known for their gelling and thickening properties. Applications of sodium alginate in the food industry are as follows. Alginate is used as a thickening agent, gelling agent, emulsifier, stabilizer, texture improver. Nowadays, alginate is added to numerous kinds of food such as ice cream, jelly acid milk drinks, dressings, instant noodles, beer etc.

B. Physical properties of materials

Table 1 Initial properties of clay

PROPERTIES OF CLAY	Natural moisture content (%)	Specific gravity	Liquid Limit(%)	Plastic Limit (%)	Plasticity index (%)
VALUE	108	2.803	113	30	82
PROPERTIES OF CLAY	Toughness index	Free swell index (%)	Maximum Dry Density (g/cm^3)	Optimum Moisture Content (%)	Unconfined compressive strength (KN/m^2)
VALUE	0.364	35	1.331	31	2.20
PROPERTIES OF CLAY	Cohesion (KN/m^2)	Clay(%)	Silt(%)	Sand (%)	Soil classification
VALUE	1.1	55	26	19	CH

Table 2 Chemical properties of soda lime glass powder

CHEMICAL CONSTITUTENTS	Silica (SiO_2)(%)	Alumina (Al_2O_3)	Sodium Oxide	Lime (CaO) (%)

		(%)	(Na_2O)(%)	
PERCENTAGE COMPOSITION	75	1.5	14	10.8

(Source: From manufacturer)

Table 3 Chemical properties of sodium alginate

CHEMICAL CONSTITUTENTS	Fe_2O_3	P_2O_5	Na_2O	K_2O	TiO_2	MnO	CaO	LOI
PERCENTAGE COMPOSITION	0.46	0.06	12	0.03	0.016	0.014	0.75	87.5

(Source: From manufacturer)

C. Tests on clay

The experimental tests likeStandard proctor compaction, Unconfined compressive strengthtests conductedare discussed below.

Standard proctor test (light compaction): Compaction is the process of densification of a soil mass by reducing air voids in the soil by applying compaction energy. An amount of 3kg soil sample is used. The object of that compaction test is to determine the optimum moisture content (OMC) and the maximum dry density (MDD).The standard proctor test was conducted as per IS: 2720 (part 8)-1983. From table 1, the optimum moisture content is obtained as 31% for clay. The value of maximum dry density obtained is 1.331g/cm³ for clay.

Fig. 1 Proctor's cylindrical mould and base plate Fig. 2 UCS Apparatus

Unconfined compressive strength test (UCS): It is used to determine the unconfined compressive strength of the given soil sample. It is not always possible to conduct the bearing capacity test in the field. Sometimes, it is

cheaper to take the undisturbed soil sample and test its strength in the laboratory.An amount of 150g soil sample is taken for conducting the test. Water content used for mixing soil sample is as per optimum moisture content obtained from compaction curve. In this test, a cylindrical soil specimen usually 3.8cm in diameter is subject to an axial compression without any lateral confining pressure. The unconfined compressive strength, qu is defined as the compressive load per unit area at the time of failure of the soil sample.The unconfined compression test was conducted as per IS: 2720 (part 10)-1991. The results obtained are shown in (table 1) The unconfined compressive strength of clay is 2.20kN/m².

RESULTS AND DISCUSSION

Effect of Soda lime glass powder on Standard proctor light compaction test

The compaction test is carried out for different percentages (3%, 6%, 9%, 12% and 15%) of Waste soda lime glass powder on clay.

Table 4Variation of OMC and MDD with percentage of WSLGP

PERCENTAGES OF WSLGP (%)	0	3	6	9	12	15
OMC	31	27.5	24.13	23.33	17.85	22.7
MDD	1.331	1.525	1.580	1.633	1.674	1.622

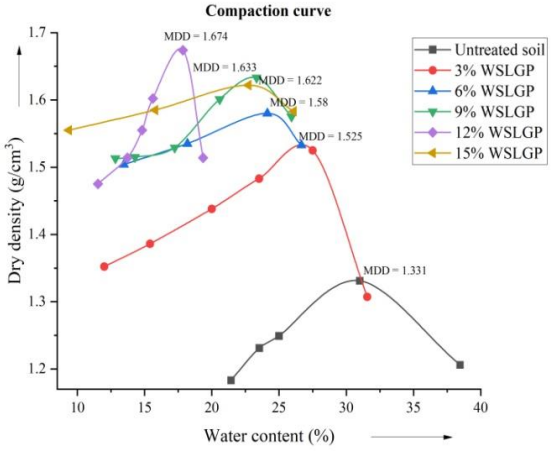

Fig. 3 Variation of MDD with percentages of WSLGP

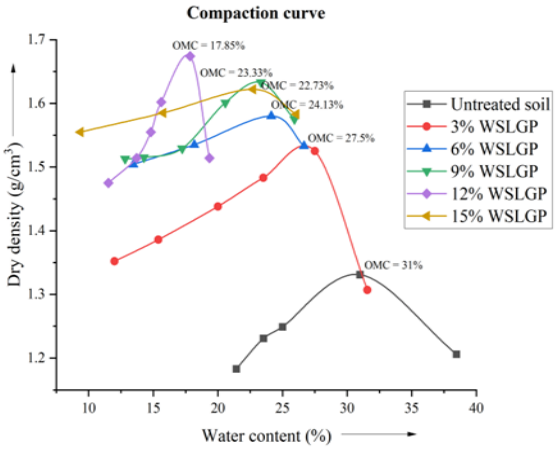

Fig. 4 Variation of OMC with percentages of WSLGP

From (fig. 3), it is observed that the inclusion of Waste soda lime glass powder increases maximum dry density up to 12%. This is due to cohesionless behaviour of soda lime glass powder.From (fig. 4)shows that OMC decreases with increases in percentage of WSLGP up to 12% and thereafter it increases. This is due to water absorption capacity of soda lime glass powder.

Effect of Soda lime glass powder on Unconfined compressive strength test

Table 5 Variation of UCS with percentage of WSLGP

PERCENTAGES OF WSLGP (%)	0	3	6	9	12	15
UCS (kN/m^2)	22.0	22.7	23.4	24.2	25.8	23.2

From (table 5), shows variation in UCS on clay with and without addition of WSLGP. It is observed that the addition WSLGP up to 12% in the clay causes an increase in Unconfined compressive strength.

Effect of Sodium alginate on Standard proctor light compaction test

The compaction test is carried out for different percentages of sodium alginate (0.25%, 0.5%, 0.75%, 1.00% and 1.25%) with optimum percentage of Waste soda lime glass powder on clay

Table 6 Variation of OMC and MDD with percentages of SA

OPTIMUM PERCENTAGE OF WSLGP + PERCENTAGES OF SA (%)	0.25	0.50	0.75	1.00	1.25
OMC	25	22.22	20.68	15.62	19.23
MDD	1.394	1.475	1.574	1.729	1.597

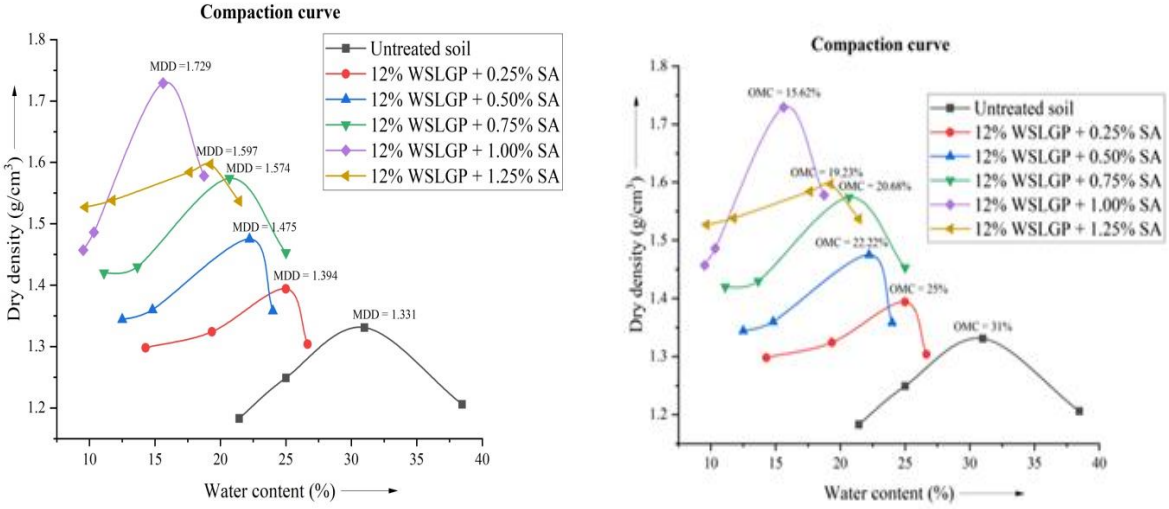

Fig. 6 Variation of MDD with percentages of SAFig. 7 Variation of OMC with percentages of SA

From (fig. 6), it is observed that the inclusion of Sodium alginate dust increases maximum dry density up to 1.00%. This is due to the bonding of clay particles with the Sodium alginate dust.From (fig.7), shows that OMC decreases with increases in percentage of SA up to 1.00% and thereafter it increases. When sodium alginate dust comes in contact with water the alginate forms a flocculated structure by adhering and adjoining the clay particles hence forms a viscous gum due to its aqueous solubility. Hence, it can absorb water at levels of more than its weight.Effect of Sodium alginate on Unconfined compressive strength test

Table 7 Variation of UCS with percentages of SA

OPTIMUM PERCENTAGE OF WSLGP + PERCENTAGES OF SA	0.25	0.50	0.75	1.00	1.25
UCS (kN/m^2)	23.6	24.4	25.7	27.1	26.3

From (table 7), shows variation in UCS on clay with and without addition of SA. It is observed that the addition SA up to 1.00% in the clay causes an increase in Unconfined compressive strength. Sodium alginate improve the soil structure by filling the pore space and enhancing the interparticle bonding strength. Therefore, the strength improvement. The decrease in value after the 1.00% SA is due to the lost mechanical properties by increasing the percentage concentration of SA.

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