Sustainability,Agri,FoodandEnvironmentalResearch,(ISSN:0719-3726),12(X),2024:
http://dx.doi.org/10.7770/safer.v12i1.2878

Stabilization of Kuttanad clay using marble dust and sisal fiber.

Estabilización de arcilla Kuttanad utilizando polvo de mármol y fibra de sisal.

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ABSTRACT

Construction of engineering structures on clayey soil poses a significant risk due to the soil's susceptibility to differential settlements, low shear strength, and high compressibility. So, it needs proper stabilization. Kuttanad clay are soft deposits of fine-grained soil found in the Kuttanad region of Alappuzha district, Kerala. Here construction is very difficult as the soil is poor in drainage and strength properties. The main aim of this work is to identify the various properties of lower Kuttanad clay and stabilizing the soil using marble dust (MD) and Sisal fiber (SF). Marble dust is a waste product collected from Marble industry. The major constituent of marble dust is Calcium Carbonate and its powder has high percentage of lime content so it can be used as an effective material for the stabilization of clayey soil. Varying percentages (3,6,9,12%) of marble dust are added to soil. Optimum moisture content, Maximum dry density, Unconfined compressive strength (UCS) value were determined by laboratory testing and Optimum marble dust content for stabilizing the soil is determined. The optimum improvement in the strength behavior of soil is observed with a marble dust content of 9%. A varying percentage of sisal fiber with length 10 mm (0.25%,0.5%,0.75%,1%) is added to clay with optimum marble dust content. Compaction test andUnconfined compressive strength test were carried out. UCS value increased with increment in fiber from 0.25 to 0.75%. The maximum strength is obtained at optimum 9% MD and 0.75% SF content.

Keywords: Clayey soil, Kuttanad clay, Standard proctor compaction test, Atterberg's limit test, Unconfined compressive strength test California bearing ratio test, Marble dust powder.

RESUMEN

La construcción de estructuras de ingeniería en suelos arcillosos plantea un riesgo significativo debido a la susceptibilidad del suelo a asentamientos diferenciales, baja resistencia al corte y alta compresibilidad. Por tanto, necesita una estabilización adecuada. La arcilla de Kuttanad son depósitos blandos de suelo de grano fino que se encuentran en la región de Kuttanad del distrito de Alappuzha, Kerala. Aquí la construcción es muy difícil porque el suelo tiene malas propiedades de drenaje y resistencia. El objetivo principal de este trabajo es identificar las diversas propiedades de la arcilla inferior de Kuttanad y estabilizar el suelo utilizando polvo de mármol (MD) y fibra

de sisal (SF). El polvo de mármol es un producto de desecho que se recoge en la industria del mármol. El componente principal del polvo de mármol es el carbonato de calcio y su polvo tiene un alto porcentaje de contenido de cal, por lo que puede usarse como un material eficaz para la estabilización de suelos arcillosos. Se añaden al suelo porcentajes variables (3,6,9,12%) de polvo de mármol. El contenido de humedad óptimo, la densidad seca máxima, el valor de resistencia a la compresión libre (UCS) se determinaron mediante pruebas de laboratorio y se determina el contenido de polvo de mármol óptimo para estabilizar el suelo. La mejora óptima en el comportamiento resistente del suelo se observa con un contenido de polvo de mármol del 9%. Se añade un porcentaje variable de fibra de sisal con una longitud de 10 mm (0,25%, 0,5%, 0,75%, 1%) a la arcilla con un contenido óptimo de polvo de mármol. Se llevaron a cabo pruebas de compactación y pruebas de resistencia a la compresión ilimitada. El valor de UCS aumentó con el incremento de fibra de 0,25 a 0,75%. La resistencia máxima se obtiene con un contenido óptimo de 9% MD y 0,75% SF.
Palabras clave: suelo arcilloso, arcilla Kuttanad, prueba de compactación Proctor estándar, prueba límite de Atterberg, prueba de resistencia a la compresión no confinada, prueba de relación de soporte de California, polvo de polvo de mármol.

INTRODUCTION

Design and construction of civil engineering structures on and with expansive soils and improving the engineering properties of soil by numerous creative and cost effective methods has always been a challenging task for geotechnical engineers. The solution for this is the stabilization with an appropriate stabilizing agent[4]. The most cost-effective and efficient method of stabilizing weak soils is to use admixtures that exhibit volume change. Due to the rising cost of materials required for various geotechnical projects, engineers are attempting to improve the physical properties of local soils using various low cost methods and techniques [6]. One of them is proper and efficient waste disposal. In general, industrial waste causes numerous serious environmental issues. As a result, utilizing industrial waste in the construction industry is the best way to dispose of it. Using industrial waste in the construction industry is beneficial in many ways, including waste disposal, preserving bio diversity, increasing soil properties such as strength and permeability, preserving natural soil, and creating cost-effective structures [5]. Lime, cement, and bitumen are common additives used to stabilize expansive soils. Various additive materials, such as fly ash, rice husk ash, silica fume, furnace slag, and geo fibres, have recently been used to improve some geotechnical properties of poor soils. Furthermore, for soil remediation purposes, industrial wastes such as olive oil waste and basalt fibers are utilized as additives. In this study it is attempt to study the effect of marble dust and sisal fiber on Kuttanad clayey soil.It is one of the expansive soils where any type of construction is difficult as the soil is poor in drainage and weak in shear strength. Therefore, it requires an efficient stabilization method to improve its properties. It is well known for failure of pavement and foundation structures constructed over it in the past. This is due to the weak soil characteristics which the soil possesses such as high settlements and low strength. So it is necessary to improve the soil characteristics for construction purposes

MATERIALSANDMETHODS

A. Materials

The materials used in the experimental work are Kuttanad clay, Marble dust. and sisal fiber. Kuttanad clay is a soft deposit of silt or clay discovered in the Ramankery, Kuttanad region of Kerala's Alappuzha district. Kuttanad clays are black colored, medium sensitive, alluvial deposit, spread over the kuttanad region in the state of Kerala in India. The soil was air dried before the commencement of the experiments. It was collected at a depth of 1.5- 2 metres. The waste materials generated from various industries causes huge disposal problems to the environment. Marble dust is one such waste product and it can be used as an effective material for the stabilization of soil. Marble dust is formed from cutting and polishing of the marble stone. Calcium carbonate is the primary component found in marble dust, and its powder possesses a high concentration of lime content. Marble dust contains high amount of calcium, silica and alumina which aids in the stabilization of the soil [1]. In this study marble dust is collected from Shila Marbles, Ernakulam. Sisal fiber is a natural fiber obtained from the leaves of the sisal plant. It is commonly used in the construction industry to reinforce materials such as concrete and soil. When sisal fiber is mixed with soil, it can improve the soil's strength, durability, and resistance to erosion. Sisal is a natural fiber having greater tensile strength and can be used as an effective reinforcing material in soil stabilization [11]. It is collected from Fiber region Chennai. NaOH (sodium hydroxide) is a strong alkali that is commonly used in sisal fiber treatment for soil stabilization. The treatment process involves immersing the sisal fiber in a solution of NaOH and water, which helps to remove impurities and increase the fiber's strength and durability.

Properties of materials

Table1Initial properties ofclay

Properties Ofclay	Natural Moisture Content(%)	Specific Gravity	Liquid Limit(%)	Plastic Limit(%)	Plasticity Index(%)
Value	133.4	2.61	68	30.5	37.5
Properties Of Clay	Toughness index	Free Swell index(%)	Maximum Dry Density (G/Cm³)	Optimum moisture content (%)	Unconfined compressive strength (Kn/M^2)
Value	0.310	53	1.739	30	22.79
Properties of clay	Cohesion (Kn/M^2)	Clay(%)	Silt(%)	Sand(%)	Soilclassification
Value	11.39	64	30	6	Ch

Table2 Chemical properties of Marble dust

Chemical Constituents	Sio_2(%)	Al_2o_3(%)	Mgo(%)	Fe_2o_3	$Caco_3$cao (%)
Percentage composition	1.28	0.39	20.10	9.6	4010.8

(Source:From Manufacturer)

Table3chemical Properties Of Sisal Fiber

Chemical constituents	Cellulose(%)	Hemicellulose (%)	Lignin (%)	Waxes(%)
Percentage Composition	70	18	10	2

(Source:From manufacturer)

- *Tests on clay*

Compaction is the process of densifying a soil mass by reducing air voids in the soil through the application of compactive energy. That compaction test's goal is to determine the optimum moisture content (OMC) and maximum dry density (MDD).. Thestandard proctor test was conducted as per IS: 2720 (part 8)-1983. The results obtained is shown in table 4 &6. The unconfined compressive strength, denoted as qu, represents the compressive load exerted on a soil sample per unit area at the point of failure. The unconfined compression test wasconducted as per IS: 2720 (part 10)-1991. The results obtained is shown in table 5 & 7.

Fig.1. Proctor cylindrical mould, base plate and hammer Fig.2 UCS Apparatus

RESULTS AND DISCUSSION

The compaction test is carried out for different percentages (3%, 6%, 9%, 12%) of Marble dust on clay.

Table 4 Variation of OM Cand MDD with percentage of MD

PERCENTAGES OF MD(%)	0	3	6	9	12
OMC (%)	30	28.5	27.2	22.72	26
MDD(g/cm^3)	1.73	1.82	1.84	1.93	1.89

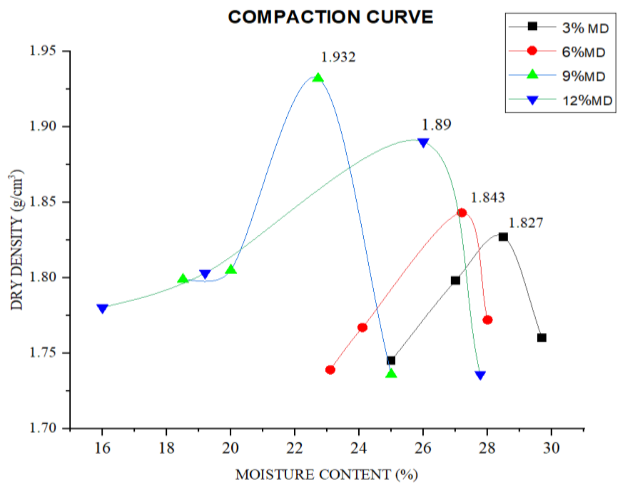

Fig. 3 Variation of MDD and OMC with percentages of MD

From the Fig.3, it is observed that the addition of marble dust to the soil sample increases the maximum dry density (MDD) up to 9%. After 9% MDD decreased. Marble dust helps to improve the MDD of soil because it is a fine-grained material that can fill the pore spaces between soil particles and create a more tightly packed soil structure. Thus, decrease in the void ratio of the mixture cause increase in MDD. After 9% inclusion of Marble dust the MDD decreased, this is attributed to the flocculation of particles as a result of reaction between the marble dust and clay. The flocculated particles occupy larger spaces, increasing the volume of the voids and consequently reducing the weight volume ratio. The inclusion of MD Decreases the Optimum moisture content (OMC) up to 9%. And after it get increases. Decrease in the water holding capacity due to the decrease in the porosity of the soil marble dust matrix leads to decrease in the OMC. The drop in OMC is due to the substitution of clay with marble dust, which has a lower attraction for water particles.

Effect of marble dust on unconfined compressive strength test

Table5.Variation of UCS with percentage of MD

PERCENTAGES OF MD (%)	0	3	6	9	12
UCS(kN/m^2)	22.79	27.35	31.67	33.94	24.89

Table 5. shows the variation in UCS on clay with and without addition of MD. It is observed that the addition of MD up to 9% increases the Unconfined compressive strength. A further increase in the marble dust content leads to lower strength of the soil.

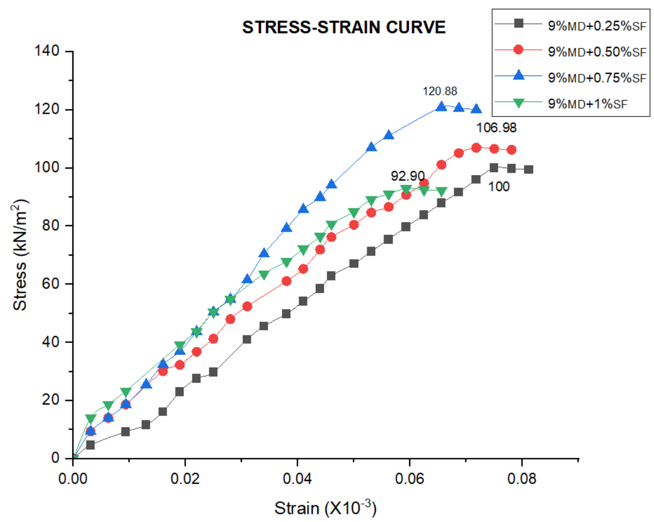

Fig.4 Variation in UCS with the addition of MD

Marble powder is considered as ultrafine aggregates that fill spaces. The increase in the strength of the soil with up to 9 % MD can be attributed to the increase in the compactness of the soil matrix due to the decrease in porosity and the enhancement in the inter-particle bonding between the soil marble dust mixes. The mechanism by which strength is gained in the soil –marble dust mixture is similar to that which occur in soil-lime mixture. Improvement in the strength can also be attributed to the pozzolanic reaction in soil- marble dust mixes. When marble dust mixed with soil, calcium carbonate in the marble dust reacts with water and pozzolanic material in soil such as alumina and silica to form CSH (Calcium Silica Hydrate) and CAH (Calcium Alumina Hydrate) binder. The CSH and CAH that is formed acts as a binding agent, bonding the soil particles together and improve the soil's overall strength. These substances facilitate additional consolidation and agglomeration of the particles, resulting in the formation of a compact and consistent structure with high strength properties. After 9% inclusion of MD the strength of soil is reduced. This is because, when MD content is increased beyond the optimum value, the soil particles get coated with the dust, reducing their ability to bind with each other and result in increased porosity with in the soil matrix. Thus 9% can be considered as optimum MD content.

Effect of sisal fiber and optimum marble dust on standard proctor light compaction test

The compaction test is carried out for different percentages of sisal fiber (0.25%, 0.5%, 0.75%, 1.%) with optimum percentage of marble dust on clay.

Table 6 Variation of OMC and MDD with percentages of SF

9% MD+ PERCENTAGES OF SF(%)	0.25	0.50	0.75	1
OMC (%)	26.9	24	20	23
MDD(g/cm^3)	1.87	1.91	1.97	1.90

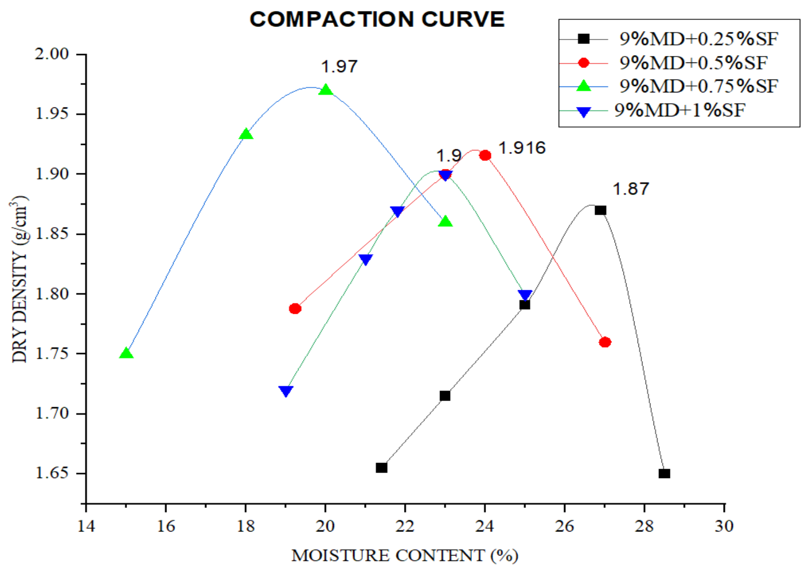

Fig. 5 Variation in OMC and MDD on addition of 9% MD and percentages of SF

In the case of sisal fiber reinforced soil, it is observed that, as fiber content increases, maximum dry density increases to its maximum value at 0.75% replacement of sisal fiber. It can be seen that for 0.75% sisal fiber with optimum marble dust content the maximum dry density is 1.97g/cm^3. It is due to the presence of sisal fiber and marble dust filling the voids within the soil. With further addition of Sisal fiber, the maximum dry density is decreased, because the SF occupied more spaces than soil was naturally supposed to thereby creating some voids in the mixture. It is clear that an increase in SF content combined with an optimum MD resulted in a drop in OMC values from 26.9 to 20%. This means that the decrease in OMC with increasing percentage of fiber is due to water absorption nature of organic natural fiber and the effect of optimum marble dust content. The trend of reduction in OMC after initial increase is principally associated with water absorption property of sisal fiber [11]. The drop in OMC is also due to the presence of optimum marble dust content which has a lower attraction for water particles.

Effect of Sisal fiber and optimum Marble dust onUnconfined compressive strengthtest

The UCS test is carried out for different percentages of sisal fiber (0.25%, 0.5%, 0.75%, 1.%) with optimum percentage of marble dust on clay.

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Table 7 Variation of UCS with percentages of SF

9% MD+PERCENTAGESOF SF(%)	0.25	0.50	0.75	1
UCS(kN/m^2)	100	106.98	120.88	92.90

Table 7 shows variation in UCS on clay with the addition of SF with 9% MD. It is observed that the addition SFup to 0.75% in the clay causes an increase in Unconfined compressive strength

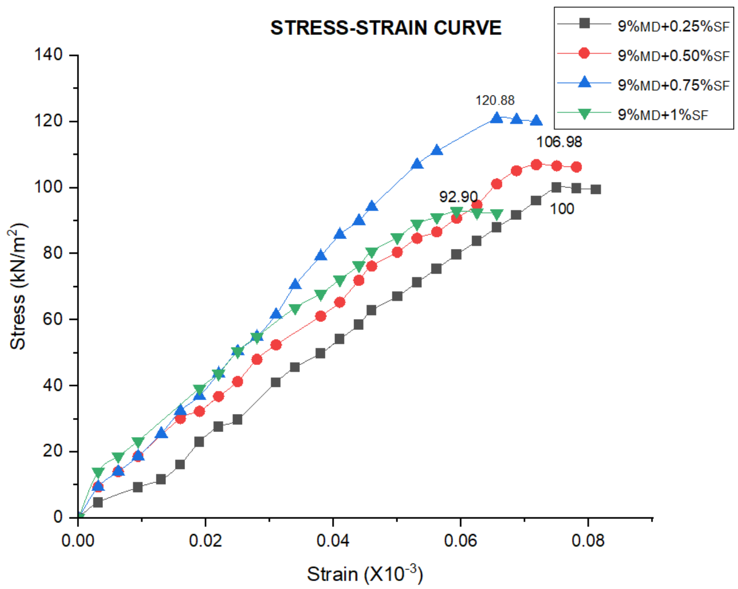

Fig.6 Variation in UCS with the addition of optimum MD and percentages of SF

From results, it is evident that the increase in percentage inclusion of sisal fiber with optimum marble dust increased the UCS value up to 0.75% inclusion, after which the UCS start decreasing. Increase in fiber content consequently increases the friction between the discrete fiber and soil particles, which contribute to the increased resistance to force applied. But with further increase in the percentage of sisal fiber beyond the required, the strength of reinforced soil is reduced. Because the addition of excess fiber leads to the domination of fiber-to-fiber interaction rather than soil to fiber interaction. This phenomenon was observed when fiber content exceeds ,0.75% and UCS value decreased. 0.75% inclusion of SF is established as the optimum percentage inclusion. Addition of 0.75% of 10mm length sisal fiber with optimum marble dust gave the maximum strength of 120.88 kN/m^2.

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Received: 24th March 2023; Accepted: 03th August, 2023; First distribution: 31th October 2023.