PAPER • **OPEN ACCESS**

Study of low plasticity clay for optimum dosage of the soil-cement

To cite this article: J P Rojas-Suárez *et al* 2019 *J. Phys.: Conf. Ser.* **1386** 012078

Study of low plasticity clay for optimum dosage of the soil-cement

J P Rojas-Suárez[1], **M S Orjuela-Abril**[1] **and G Prada-Botía**[1]
[1] Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia

E-mail: sofiaorjuela@ufps.edu.co, gaudycarolinapb@ufps.edu.co

Abstract. The need to improve people's living conditions starts from the reality of the durability of rural road constructions, which have a short useful life and have a negative impact on the inhabitants of these regions. This project aims to improve access to rural areas, rural economic development and thus improve the quality of life of people in the sector; taking into account that at the moment of building a rural road, has a better resistance and durability in time, this was done by analyzing the properties of the clay mixture of low plasticity in the dosage of soil-cement that were tested by tests to determine the liquid limit of soils, determination of the plastic limit, plasticity index, moisture test, classification of soil by sieving, granulometric analysis, unit weight-humidity relations in soils, soil support relationship in the laboratory; in order to find the best dosage that provides greater strength, long-term durability and risk reduction. The results indicate that this type of clay requires an improvement with cement, due to its bearing capacity of 2% and 4%, which gives it a very poor quality to be used in the construction of rural roads.

1. Introduction

The need to expand has forced professionals to build infrastructures that are not very solid, with cracks, segregation, partial detachment, resistance, smoothness and other defects that occur on roads [1]; in the search for a potential solution, techniques have been carried out to stabilize soft clay, one of these being the addition of a cement additive, improving the inherent properties of the soil for better resistance to deformation [2].

The main raw materials used for cement production are limestone, clay and marl, mixing in proportion to their respective chemical composition. The clay minerals are derived from the analysis carried out on the basis of the silicate-alumina ratio [3]. Clay-cement suspensions are used in the construction and maintenance of hydrotechnical constructions such as embankments, dikes and dams, where the main factor in their suitability is high water tightness. This material, in addition to its very good waterproofing properties, must be characterized by its low cost, easy manufacture and application [4].

One of the most important characteristics of clay when used in soil cement, is its plasticity, which is defined as "the characteristic of a material that accesses a repeated deformation without breaking when it acts by a sufficient force to cause deformation, allowing it to retain its shape after the force applied has been eliminated" [5]. For this reason, the plasticity capacity of the clay is investigated, due to the fact that, if it has a low plasticity of shear support, the construction will be at risk of suffering damage, compliance with the technical requirements must be guaranteed [6].

The calculations for the dosage must be made by proposing a system of equations corresponding to the balances of raw material and required composition, always considering the order in which the various components of the raw materials react [7]; this technology provides the improvement of physical and toxicological characteristics of the residue and/or soil, in addition, the cost of the process is considered low in relation to other treatment techniques [8], for this reason it was selected as a process to improve the conditions of resistance and stability of the soil-cement.

Laboratory tests were carried out on three samples of clay with low plasticity to be used in the dosage of soil cement, determining whether it improves the conditions of resistance, hardness and rigidity in order to obtain the optimum mixture in rural roads, due to the fact that rural or tertiary roads present significant differences in economic development and quality of life with respect to urban roads; This project provides improvements to rural roads throughout the country, thus giving greater connectivity of families with consumption, facilitating the flow of workers to urban centers, increases migratory flows, enables a greater presence of the state and improves the productivity of rural enterprises as a result of access to investment channels and credit [9].

2. Methodology

Three laboratory tests of low plasticity clays were carried out to establish the behavior of the clays when using the ideal dosage, according to the procedures of the Invias Standard [10] that were commented in each test: Determination of the soil liquid limit, determination of the plastic limit, plasticity index, moisture test, classification of the soil by sieving, granulometric analysis, unit weight-humidity ratios in soils, soil support ratio in the laboratory [11], designing a mixture with the optimum dosage of low plasticity soil cement. Oriented in analyzing and determining the characteristics that it possesses, to determine if it fulfills the Standard of Invias [10] in the ideal dosage of the soil-cement in the rural ways, being an alternative to improve the resistance of them and to increase the economic benefits of the sector.

3. Result and discussion

3.1. Determination of soil liquid limit

In Table 1, the clay was combined with 15-20 ml of distilled water and is added from 1-3 ml in an evaporation vessel, agitating it until a homogeneous mixture, after this, it is placed in a bronze pot to compress it and extend it to a depth of 10 mm at its maximum thickness. The mixture is started to review with a groove along the diameter and center line of the mixture, the ideal is to make the minimum number of passes, otherwise, the maximum number of passes will be 6, to avoid tearing the sides of the groove and crumbling of the soil mixture in the bronze pot [10].

Table 1. Determination of the liquid limit of soils.

Sample No.	1	2	3
No. of strokes	15	24	35
Container weight + wet floor (g)	24.50	21.30	25.420
Container weight + dry soil (g)	19.79	17.99	21.92
Container weight (g)	5.87	6.12	6.52
Dry soil weight (g)	13.92	11.87	15.40
Weight of water	4.71	3.31	3.50
Moisture content (w-%)	33.83	27.88	21.29
Liquid Limit (LL-%)		27	

3.2. Determination of plastic limit and plasticity index

In Table 2, the plasticity index indicates the range of moisture through which cohesive soils have properties of a plastic material [12]. From 1.5-2.0 g an ellipsoidal mass is made, forming rolls of 3 mm of soil diameter, by 80 to 90 rotations per minute, always returning to the initial position [10].

3.3. Moisture test

The mass is deposited in a container to determine the weight of the container and the sample, then the mass is introduced into the oven to remove moisture and create a constant mass, ideally a temperature of 110±5°C, while the temperature is depending on the type of material, sample size, oven class and capacity [10]; the results of this test are illustrated in Table 3.

Table 2. Plastic limit and plasticity index.

Sample No.	1	2	3
Container weight + wet floor (g)	11.92	12.04	12.76
Container weight + dry soil (g)	11.25	11.23	11.87
Container weight (g)	6.92	6.45	6.12
Dry soil weight (g)	4.33	4.78	5.75
Weight of water	0.67	0.81	0.89
Moisture content (w-%)	15.47	16.95	15.48
Plastic Limit (LP-%)		15.97	
Plasticity Index (IP-%)		11.03	

Table 3. Moisture test.

Token N°	1	2	3
Container weight + wet floor (g)	119.7	112.37	106.92
Container weight + dry soil (g)	116.87	109.82	104.98
Container weight (g)	69.03	69.55	72.05
Dry soil weight (g)	47.84	40.27	32.93
Weight of water	2.83	2.55	1.94
Moisture content (w-%)	5.92	6.33	5.89
Average humidity (w-%)		6.05	

3.4. Particle size analysis and soil classification by sieving

The granulometric analysis is based on separating the components by the size of their grains [13]. After drying the mixture with 0.1% of the original dry mass of the sample, a group of sieves is decided in decreasing order by their opening size, in this way the sample is placed on top of the upper sieve and shaken by hand or a mechanical sieve [10]. The results of these tests can be found in Table 4 and Table 5.

Table 4. Granulometric analysis.

Sieve	Diameter. (mm)	W Retained	% Retained	%passing
3"	76.12	0.00	0.00	100.00
2"	50.80	0.00	0.00	100.00
1-1/2"	38.10	0.00	0.00	100.00
1"	25.40	0.00	0.00	100.00
3/4"	19.05	0.00	0.00	100.00
3/8"	9.52	0.00	0.00	100.00
N° 4	4.76	0.00	0.00	100.00
N° 10	2.00	5.50	1.83	98.17
N° 20	0.84	6.12	2.04	96.13
N° 40	0.42	17.12	5.71	90.42
N° 60	0.25	8.32	2.77	87.65
N° 100	0.11	12.14	4.05	83.60
N° 200	0.07	10.23	3.41	80.19
Bottom	-	240.00	80.00	0.19
Total		299.43	99.81	

3.5. Soil unit weight-humidity ratios

The mixture is moistened up to 4% below the optimum moisture content in a 101.6 mm mould in five equal layers and with a total height of 125 mm, each layer being compacted by 25 strokes. When finished, the extension collar is removed, trimming the surplus to weigh the mold with the soil moistened. Consequently, the mass of the mixture and of the mould is multiplied (the mass of the mould is removed) in kg/m^3 of the compact floor; the sample is cut vertically to be weighed and dried in the oven for a minimum of 12 hours [10]; the results are illustrated in Table 6.

Table 5. Classification of sieved soil.

Classification	
AASHTO	A-6
I.G	7
U.S.C	CL
GRAVA	0
SAND	20
FINES	80

Table 6. Soil unit weight-humidity ratios

Proof/mold #	1	2	3
Quantity of water	90.00	210.00	330.00
Mould weight + wet soil (g)	5,570.00	5,720.00	5,730.00
Weight of mould (g)	3,730.00	3,730.00	3,730.00
Weight of wet soil (g)	1840.00	1990.00	2000.00
Dampness	8.37	12.37	16.35
Dry weight (g)	1,697.89	1,770.86	1,718.86
Volume cm^3	944.00	944.00	944.00
Dry density (g/cm^3)	1.79	1.88	1.82

3.6. Floor support ratio in the laboratory

The extension collar is used with the mold to the base plate and weighed, in addition, a spacer disc must be inserted inside the mold and a thick filter paper is placed on top of the disc. Water is added to the mixtures and we compacted in three equal layers, obtaining a total compacted depth of 125 mm and compacted density of 95% of the maximum density. The collar and making up the mixture must be removed and, consequently, the mixture must be disassembled and inverted without the spaced disc, but introducing the filter paper between the mould and the base; in this way we determine the mass of the mold with the compacted specimen [10], in Table 7, the results obtained by reference are show.

Table 7. Soil support ratio in the laboratory.

Compact in the laboratory									
Reference	2	10	13	49	4	5	15	9	3
w mold + soil (g)	13.10	13.45	11.82	12.12	12.87	13.62	12.98	12.82	13.52
w mold (g)	8.58	8.54	6.85	7.78	8.25	8.95	9.02	8.53	9.20
Number of strokes	55.00	55.00	55.00	26.00	26.00	26.00	12.00	12.00	12.00
Quantity of water	174.00	348.00	580.00	174.00	348.00	580.00	174.00	348.00	580.00
Weight of wet soil (g)	4,525.00	4,910.00	4,970.00	4,340.00	4,620.00	4,670.00	3,960.00	4,290.00	4,320.00
Dampness	8.13	12.45	16.39	8.37	12.44	16.45	8.63	12.26	16.50
Dry weight (g)	4,184.53	4,366.22	4,269.97	4,004.81	4,108.86	4,010.29	3,645.37	3,821.25	3,708.13
Weight of dry soil lb	9.22	9.62	9.41	8.82	9.05	8.84	8.03	8.42	8.17
Mold volume (ft^3)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Dry density (lb/ft^3)	112.50	117.38	114.80	107.67	110.47	107.82	98.00	102.73	99.69
Dryness (g/cm^3)	1.800	1.87	1.83	1.72	1.76	1.72	1.56	1.64	1.59

3.7. California bearing ratio results for different densities

California bearing ratio (CBR) for a humidity of 12,45% and a density of 117,38lb/ft^3 → 2.41%. CBR for a humidity of 11,43% and a density of 110,47lb/ft^3→ 1.45%. CBR for a humidity of 12,26% and a density of 102,73lb/ft^3→ 1.00%.

4. Conclusions

The clay of low plasticity has an average of determination, the liquid limit depends on the number of blows, for 15 it will be of 33.38%, 24 blows of 27.88% and 35 blows of 21.29%, obtaining an average of 27% liquid limit. On the other hand, the plastic limit is at 16%, giving a plasticity index of 11.03%, thus characterizing the clay in low plasticity.

The moisture content is analyzed depending on the weight of the container, wet soil and dry soil, obtaining an average moisture of 6.05% in the three samples performed, which have: I.G of 7, U.S.C of CL, sand of 20 and fine of 80, after making the granulometric analysis. For such percentage of humidity and classification, the dry density of the samples is deduced: 1.799 g/cm^3, 1.876 g/cm^3 and 1.821 g/cm^3; giving it a CBR of 2.41%, 1.45% and 1% respectively.

Laboratory tests showed that for low plasticity clay it is recommended that, for its use as a subgrade, an improvement with cement is required, due to its bearing capacity of 2% and 4%, giving it a very poor quality.

References

[1] Yu M, Chang X and Chen S 2018 Analysis of factors affecting the vompressive strength of cement stabilized Gravel *IOP Conf. Ser.: Mater. Sci. Ing* **381** 012030
[2] Mansour M A, Samieh A M and Matter H E 2015 Engineering properties of cement/lime-stabilized Egyptian soft clay *IOP Conference Series: Earth and Environmental Science* **26** 012041
[3] Bilgin O 2017 Study of Usage Areas of Clay Samples of Asphaltite Quarries in Sirnak, Turkey *IOP Conference Series: Earth and Environmental Science* **95** 042066
[4] Kane S N, Mishra A and Dutta A K 2014 Preface: International Conference on Recent Trends in Physics ICRTP *Journal of Physics: Conference Series* **755** 011001
[5] Andrade F A, Al-Qureshi H A and Hotza D 2011 Measuring the plasticity of clays: A review *Applied Clay Science* **51** 1–7
[6] Hastuty I P, Roesyanto R and Napitupulu S M A 2018 Clay Stabilization Using the Ash of Mount Sinabung in Terms of the Value of California Bearing Ratio (CBR) *IOP Conf. Ser.: Mater. Sci. Ing.* **306** 012060 pp 1-7
[7] Caselles M, Gómez M, Molero M and Sardá J 2015 *Química Aplicada a la Ingeniería* (España: Universidad Nacional de Educación a Distancia)
[8] Jiménez J, Consoli N and Salvagni K 2008 Durabilidad de un suelo contaminado y tratado con cemento portland *Revista Ingeniería de Construcción* **23** 163-170
[9] Hincapie G, Montoya I and Jaime J 2017 Sistema vial terciario y educación rural en Antioquia (Colombia): Un modelo probit ordenado y multivariado *Ecos de Economía* **21** 72-85
[10] Institución Nacional de Vías (INVIAS) 2007 *Determinación en laboratorio del contenido de agua (Humedad) del suelo, roca y mezclas de suelo-agregado INV E-122* (Colombia: Instituto Nacional de Vías)
[11] Redondo R and Clavijo M 2014 *Análisis y comparación de las investigaciones para la obtención de la dosificación óptima del suele cemento en los diferentes tipos de arcilla* (Colombia: Universidad Francisco de Paula Santander)
[12] Crespo V 2004 *Mecánica de suelos y cimentaciones* (México: Limus) p 69
[13] Güeto J 2005 *Tecnología de los materiales cerámicos* (España: Díaz de Santos) p 104