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Determination of the adequate dosage of the soil-cement, using clay of high plasticity

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Determination of the adequate dosage of the soil-cement, using clay of high plasticity

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Abstract. The clay is used in the area of constructions, ceramics and industrial applications: insecticides, pharmaceutical industry, cosmetics and painting, for its physical and chemical properties that are suitable for different civil projects (roads, public services network, constructions); the dosage is a technique to modify and improve the conditions of the soil-cement in reference to the resistance, conditions of insolubility, impermeability, durability and appearance. In this study, high plasticity clay was evaluated through different laboratory tests (humidity test, soil liquid limit, plasticity index, granulometric analysis, California Bearing Ratio) for three samples and specifying the methodology used in each step, with the objective of knowing its structure and functioning in rural roads in combination with soil-cement, looking for a more profitable and lasting option in this sector, in order to benefit the people surrounding these sectors, improving the income of the sector and seeking to mitigate the environmental impact.

1. Introduction

The properties of clay are important in determining the type, stability and also its use as a basic material in construction, ceramics or the pharmaceutical industry [1]. Soil stabilization is the mixing of soils with certain materials, improving the technical properties of the soil, meeting the technical requirements [2]; through industrial by-products, the treatment of problematic soils has had a great demand to obtain more sustainable constructions and lower the cost [3]. Plasticity is a property of clays, which allows to form a plastic body, submitting itself to the action of a force, it can be deformed and conserved the same after eliminating the applied force [4]. It is important to identify the plasticity index, which indicates the range of moisture through which cohesive soils have properties of a plastic material [5].

There are different indicators that must be verified before being used in rural roads; one of the main technical requirements is that they comply with moisture indicators, because in humid conditions, these soils tend to swell and become weak as they gain water, while in dry seasons the opposite occurs, they tend to shrink and harden [6]. Similarly, a granulometric analysis should be performed to separate complementary and heterogeneous materials by the size of the particles [7]. The california bearing ratio (CBR) identifies when materials that are in poor condition (CBR < 2%), subsequent to this it is necessary to make soil improvements. There are several ways to increase the value of CBR in the subgrade layer, one of which is soil stabilization [2].

In this study the properties of high plasticity clay are identified by different laboratory tests (humidity test, soil liquid limit, plasticity index, granulometric analysis, CBR) by means of three samples to optimize the dosage of this type of clay in the soil-cement and to be used in rural roads; as for the technological scope for Colombia, it influences positively, since it facilitates the transport of technologies that contribute to the development of the type of economic activities that are developed in this zone, emphasizing the importance of the clay of high plasticity, with the purpose of improving the conditions of use of the rural ways, finding the suitable dosage to be able to be used in any part of the world.

The contracting of public works has been captured by those who finance the campaigns of politicians, but even so, the backwardness of tertiary roads, crucial for the peasant economy [8], is notorious, even though the majority of tertiary roads in the country have low volumes of traffic, there are special cases where the pavement is subject to significant loads [9] but according to the national planning department (NPD) and the Ministry of Transport it was estimated and explained that the budget required to maintain the tertiary road network for approximately 15 to 20 years is 48 billion pesos [10].

2. Methodology

The research project focuses on rural roads that are able to use the optimal dosage of high plasticity clays complying with the Invías E-122-07 [11] standard, by means of three samples that were subjected to different laboratory tests with due procedure: moisture test, determination of the liquid limit of soils, determination of the plastic limit and plasticity index, granulometric analysis and classification of the soil by sieving, unit weight-moisture ratio in soils, soil support ratio in the laboratory (laboratory CBR), comparison of densities; testing their properties to be used in the mixture in the soil-cement, improving quality standards [12].

3. Result and discussion

3.1. Moisture test

Start by determining and recording the mass of a clean, dry container, then place the wet sample in the container; place the lid firmly in position, proceed to determine the weight of the container with the sample of material. If the lid has been used, remove it and place the container with the wet material in the oven to dry it until a constant mass is obtained (the drying oven is kept at a temperature of 110±5 ºC). The time required to obtain a constant mass may vary depending on the type of material, specimen size, furnace type and capacity, and other factors. The influence of these factors can generally be established using good judgment and with the experience gained with the materials being tested and the equipment being used [11], these results are shown in Table 1.

Table 1. Determination of moisture content.

Sample No.	1	2	3
Container weight + wet floor (g)	119.94	95.01	127.89
Container weight + dry soil (g)	117.97	93.80	125.06
Container weight (g)	80.73	70.37	71.26
Dry soil weight (g)	37.24	23.43	53.80
Weight of water	1.97	1.21	2.83
Moisture content (w-%)	5.29	5.16	5.26
Average humidity (w-%)		5.24	

3.2. Determination of soil liquid limit

The soil sample is introduced into the evaporation vessel and mixed with 15 ml-20 ml of distilled water, shaking it, kneading it and chopping it with a spatula alternately and repeatedly, making further water additions in 1 ml-3 ml increments. Each increase of water is completely mixed with the soil as previously described, before any new addition.

When sufficient water has been mixed perfectly with the soil to form a uniform paste of hard consistency, an adequate amount of this mixture is placed in the pan above the point where it rests on the base and is compressed and extended with the spatula to level it and at the same time, it is advisable to leave it 10 mm deep at the point of its maximum thickness. Use as few passes as possible with the spatula, avoiding trapping air bubbles in the soil mass. Excess soil should be returned to the mixing container and covered so that the moisture in the sample is retained.

Start by dividing the soil in the bronze casserole with a firm grooving pass along the diameter and through the centerline of the soil mass so that a clean groove of appropriate dimensions is formed. To avoid tearing the sides of the slot and crumbling of the ground paste in the bronze casserole, it is permitted to make up to 6 passes, front to back or back to front, counting each run as one pass; with each pass the router must penetrate a little deeper, until the last pass from back to front cleans the bottom of the casserole. The slot should be made with as few passes as possible [11], Table 2 shows the determination of the liquid limit, according to the procedure performed.

Table 2. Determination of the liquid limit.

Sample No.	1	2	3
No. of strokes	11	23	40
Container weight + wet floor (g)	23.80	19.35	26.60
Container weight + dry soil (g)	16.66	14.57	19.56
Container weight (g)	5.12	6.28	6.33
Dry soil weight (g)	11.54	8.29	13.23
Weight of water	7.14	4.78	7.04
Moisture content (w-%)	61.87	57.66	52.61
Liquid Limit (LL-%)		57.20	

3.3. Determination of plastic limit and plasticity index

A portion of 1.5 g-2.0 g of the soil mass taken is sectioned. With the selected portion, an ellipsoidal mass is formed. Use one of the following methods to form the rolls of 3 mm diameter soil mass at a rate of 80-90 rotations per minute, counting as rotation a complete movement of the hand back and forth, thus returning to the initial position [11], thus determining the plastic limit, which are shown in Table 3.

Tabla 3. Determination of the plastic limit.

Sample No.	1	2	3
Container weight + wet floor (g)	10.90	11.53	12.76
Container weight + dry soil (g)	10.20	10.55	11.45
Container weight (g)	7.12	6.16	5.95
Dry soil weight (g)	3.08	4.39	5.50
Weight of water	0.70	0.98	1.31
Moisture content (w-%)	22.73	22.32	23.82
Plastic Limit (LP-%)		22.96	
Plasticity Index (IP-%)		34.24	

3.4. Granulometric analysis and classification of the soil by sieving

The sample is dried at a temperature of 110±5°C (230±9°F) until a constant mass is obtained, approximating 0.1% of the original dry mass of the sample. Samples may also be dried at higher temperatures associated with the use of heating plates, without affecting the results, provided the steam escapes without generating sufficient pressure to fracture the particles and the temperatures are not so high as to cause chemical breakage of the aggregate.

Tables 4 and Table 5 show the results of the selection of a group of sieves of suitable sizes to provide the information required by the specifications of the material to be tested. The use of additional sieves is advisable if other information is desired, such as the fineness modulus, or to regulate the amount of material on a given sieve. The sieves are fitted in decreasing order, by opening size and the sample (or portion of sample if the material is to be sieved by portions) is placed over the top sieve. The sieves are shaken by hand or by means of a mechanical sieve for an appropriate period [11].

Table 4. Granulometric analysis.

Sieve	Diameter (mm)	W Retained	%Retained	%passing
3"	0.00	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	9.82	2.46	97.55
N° 20	0.84	8.12	2.03	95.52
N° 40	0.42	5.00	1.25	94.27
N° 60	0.25	1.00	0.25	94.02
N° 100	0.11	3.00	0.75	93.27
N° 200	0.07	3.06	0.77	92.5
Bottom	-	370	92.5	0.00
Total		400.00	100.00	

Table 5. Classification.

Classification	
AASHTO	A-7-6
U.S.C	CH
GRAVA	0
SAND	7.5
FINES	92.5

3.5. Unit weight-humidity ratios in modified proctor soils

The chosen representative sample is perfectly mixed with sufficient water to moisten it to approximately 4% below the optimum moisture content. A specimen is prepared by compacting the soil moistened in the 101.6 mm (4") diameter mold (with the collar tightened) into five approximately equal layers giving a total compacted height of about 125 mm (5"). Each layer is compacted by 25 evenly distributed strokes with the hammer with a free fall of 305 mm (12") above the approximate height of the compacted soil when using a manually operated hammer or from 305 mm (12") above the approximate elevation of the compacted soil when using the mechanically operated hammer. During compaction, the mould must remain firm on a dense, uniform, rigid and stable support. After compaction, the extension collar is removed, the compacted soil protruding from the top of the mold is carefully trimmed using the metal ruler. Weigh the mold with wet soil, in kilograms, to about 5 g (in pounds to about 0.01 lb).

Table 6. Modified Proctor.

Proof	1	2	3
Mold #	1	1	1
Quantity of water	120.00	180	270
Mould weight + wet soil (g)	5,080.00	5,275	5,210
Weight of mould (g)	3,245.00	3,245	3,245
Weight of wet soil (g)	1,835.00	2,030	1,965
Dampness	8.46	100,302.42	13.38
Dry weight (g)	16.87	18.45	17.33
Volume (cm^3)	944.00	944.00	944.00
Dry density (g/cm^3)	17.92	19.54	18.35

For moulds complying and whose weights have been recorded in kg, multiply the mass of the compacted soil and of the mould, minus the mass of the mould, by 1060.44 (1/0.000943 m^3), and record the result as the wet unit mass, d h1, in kg/m^3, of the compacted soil. When using moulds that do not meet the tolerance of less than 50%, the calculation should be made taking into account the calibrated volume of the mould. The compacted sample is taken from the mould and cut vertically through its center. A representative sample according to INV E-122-07 [11] is taken from the material on one side of the cut; it is immediately weighed and dried in an oven at 110±5°C (230±9°F) for a minimum of 12 hours, or to constant mass, to determine the water content. The sample for moisture should not have a mass of less than 300 g. Table 6 presents the results obtained.

Determining the optimum humidity to obtain the maximum density of the modified proctor where it could be found from such humidity of 10.03% with a maximum density of 1.95 g/cm.

3.6. Soil support ratio in the CBR laboratory

Attach the mold to the base plate, attach the extension collar, and weigh to about 5 g (0.01 lb). The spacer disk is then inserted into the mold and a thick filter paper is placed on top of the disk. Each of the three 6.8 kg portions is mixed. (15 lb) with enough water to obtain the optimum moisture content determined, the first of the three portions of the soil mixture is compacted, water in the mold, using three equal layers and the appropriate hammer if the maximum density was determined by INV E-141-07 [13] or five equal layers if the maximum density was determined by INV E-142-07 [14] to obtain a total compacted depth of plus or minus 125 mm, by compacting each layer with the least number of strokes selected to obtain a compacted density of 95% or less of the maximum density, the results are shown in Table 7.

The moisture content of the material being compacted is determined at the beginning and end of this procedure (two samples). Each moisture sample shall have a mass of at least 100 g for fine-grained soils and 500 g for coarse-grained soils. Determination of moisture content should be made according to INV E-122-07 [11]. After compaction, the collar is removed and the specimen is made up to the mark with a grease nipple or knife with a strong, straight blade. Any surface void produced by removing coarse particles during the trimming is filled with excess material without thickness by compressing it with a spatula. The mould is disassembled and reassembled upside down, without a spacer disc, by placing a filter paper between the mould and the base. The mass of the mold is determined with the compacted specimen, approximating 5 g (0.01 lb).

All compaction must be done on CBR molds. Each specimen used to develop the compaction curves for 12, 26 and 55 strokes per layer will be penetrated. In cases where the specified dry unit mass is at or near 100% of the maximum, it will be necessary to include a compaction effort greater than 55 strokes per layer [11].

Table 7. Compaction in the laboratory.

Reference	6	4	49	12	1	11	9	13	52
W mould + soil (g)	12.49	13.25	12.62	13.23	12.42	13.82	12.45	11.21	13.37
W mold (g)	7.97	8.22	7.79	8.92	7.76	9.20	8.36	6.87	9.05
Number of strokes	55	55	55	26	26	26	12	12	12
Quantity of water	174	290	464	174	290	464	174	290	464
Weight of wet soil (g)	4,515	5,025	4,830	4,310	4,660	4,619	4,090	4,340	4,320
Dampness	8.22	10.33	13.05	8.22	10.31	13.47	8.16	10.16	13.34
Dry weight (g)	4,172.03	4,554.46	4,272.54	3,982.61	4,224.62	4,070.80	3,781.47	3,939.47	3,811.25
Weight of dry soil (lb)	9.19	10.04	9.42	8.78	9.31	8.97	8.34	8.68	8.40
Mould volume (foot^3)	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Dry density (lb/ft^3)	112.17	122.45	114.87	107.07	113.58	109.45	101.67	105.92	102.47

3.7. CBR results for different densities

CBR for a humidity of 10.33% and a density of 122.45 lb/ft^3 → 6.10%
CBR for a humidity of 10.30% and a density of 113.58 lb/ft^3 → 3.81%
CBR for a humidity of 10.16% and a density of 105.9 1lb/ft^3 → 2.23%

3.8. Social, environmental and economic impact

The increase in agricultural and livestock activities has caused rural roads to increase considerably, due to the need for transport and communication of both urban and rural industrialized sectors, having a positive impact on the social and economic environment of the people involved in these sectors and activities [15]. In another aspect, this project will focus on rural roads that have already been built earlier, so as not to generate indirect damage, since it is only proposed to improve the roads with soil-cement and not expand the roads, an issue that causes deforestation.

4. Conclusions

The average moisture of the samples was 5.24%, the highest being 5.29%, demonstrating that they have a good resistance and less probability of deformability of the mixture; while the average liquid limit was 57.2% according to the number of blows, moisture content and weights analyzed in the samples; adding the plasticity index of 34.24%, determining that the treated clay was one of CH (high plasticity clays). The optimum compaction density is 1.95 g/cm^3 with an optimum humidity of 10.03% of the modified shield and thus find the different CBRS for the different sample densities ranging from 105.91 lb/ft^3 to 122.45 lb/ft^3.

The clay of high plasticity has helped in the seismology of many industrialized countries by its high resistance to these events, achieving to be the main focus of the engineers. The correct dosage of the clay for the soil-cement depending on its humidity, plasticity index, granulometric analysis and CBR would be able to balance the industrial by-products with the natural ones, increasing its technical properties. Developing the laboratory tests to the clay of high plasticity in natural state, it was analyzed that this type of clay of high plasticity is not necessary to realize an improvement with cement for its use as subgrade, but, if its use is like rasante for tertiary routes a 1.2% of cement guarantees its behavior since it can reach CBR from 28% to 30%.

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