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CHEMICAL STABILIZATION AND GEOSYNTHETIC APPLICATION FOR ROAD PURPOSES

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ABSTRACT

The chemical stabilization of the clay soil from the Puraquequara branch located between Manaus and Rio Preto da Eva was evaluated, with the participation of the chemical additives ECOLOPAVI®, EMC²® and TERRAZYME®, as well as the geogrid MacGrid® NET. The natural material and the compositions were characterized according to physical, chemical, mineralogical and mechanical tests, for the curing times of 3 and 28 days. The results showed the natural material as clay soil classified as A-4 and CL. Mineralogical characterization through X-ray Fluorescence identified natural soil with high aluminum oxide content (36.5%) and silicon dioxide (57.2%) of quartz. In accordance with the results of tensile strength (RT), the composition, having the presence of ECOLOPAVI®, indicated the best values related to the soil "in natura" and the other formulations. According to data from Resistance to Simple Compression (RCS), compositions with the participation of additives ECOLOPAVI® and TERRAZYME® obtained the best results. Regarding the RCS assay, using the MacGrid® NET geogrid and the ECOLOPAVI® product, a considerable increase of this parameter was observed for the cure time of 3 (three) days.

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INTRODUCTION

Superficial clay soils are predominantly found in the State of Amazonas, and, as a rule, they do not have compatible technical characteristics for their use in pavement bases and subbases. In this case, the total or partial removal is necessary, preferably replacing it with a granular material, thus providing the required design strength. However, it is observed that the stone materials, due to their high demand and low supply, or even the transport distance of the deposit, make their use unfeasible. Likewise, knowledge of the potentialities and limitations of materials in a region, allows the choice of economically viable solutions for the implementation of subfloors of a floor. Thus, Civil Engineering uses, among other methods, the mixing of soil from the work site with additives (lime, cement, etc.), the so-called chemical stabilization, of paramount importance to the reality of urban paving in cities and towns.

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Such procedures aimed at improving the geotechnical properties of soils for use in engineering works are widespread. In spite of several works that are part of the literature (Cristelo, 2001; France, 2003; Silva, 2007; Picanço, 2012; Silva et al, 2015), research continues to be developed with this theme. It is also observed that such process proves to be a solution to the preservation of natural resources in road construction. In another aspect there are geosynthetics, industrialized products, with at least one of its components made of synthetic or natural polymer. They are in the form of a blanket, strip, or three-dimensional structure, andare used in contact with soil or other materials in civil engineering applications (IGS, 2018). They may have several functions, such as separation, filtration,drainage, reinforcement, fluid / gas containment, or erosion control. Among the main types, there are the geogrids, whose main application is the reinforcement of soils. They are formed by tensile resistant elements and integrally connected in order to bring resistance to the ground GeofocoBrasil(2018). The Brazilian Army, through its military teaching and research organizations, such as the Construction Engineering units in the Amazon,

Table 1. Physical and Chemical

Properties	ECOLOPAVI®	EMC²®	TERRAZYME®
Aspect	Liquid	Liquid	Liquid
Color	Brown	Brown	Dark brown
Odor	Characteristic	Characteristic	Characteristic
Solubility	Total	Total	Total
Free Alkalinity w / (NaOH)	0.7% to 1.5%	0.9% to 1.3%	0.7% to 1.5%
Density 20 ° C +/- 4 ° C	1.050 g / ml to 1.070 g / ml	1.020 g / ml to 1.050 g / ml	1.060 g / ml to 1.080 g / ml
Insoluble in ethyl alcohol	1% maximum	---	1% maximum
Total solids at 105 ° C (3 hours)	40.0% to 42.0%	---	40.0% to 42.0%
concentrated pH	12.00 to 14.00	8,5	4.3 to 5.3
Toxicity	Non toxic, non flammable, non corrosive	Non toxic, non flammable, non corrosive	Non toxic, non flammable, non corrosive
0 ° to 5 ° cooling	Does not precipitate, does not cloud, does not solidify		-----

represented by the 2nd Engineering Group (2nd GPT E), is committed to studies and the application of new technologies in paving works in the Northern Region. Thus, several products have been made available to military engineers in order to implement technically and economically viable solutions to the problems of regional road paving. In this context, compositions of the clayey soil with chemical additives were evaluated and, according to the best mechanical response of these formulations, the influence of the participation of a geosynthetic was investigated, aiming to contribute with alternatives to paving in the Manaus region.

MATERIALS E METHODS

Materials

The clay soil participating in this work was obtained from Ramal do Puraquequara, Highway AM-449. A military restricted side road for the purpose of linking the Jungle War Instruction Center (CIGS) Bases of Instruction (BI) to km 53 of State Highway AM-010. In the chemical stabilization of this natural material the products ECOLOPAVI®, EMC²® and TERRAZYME® were used, which, in accordance with the IDESA of the Amazon (2018), BASEFORTE (2017) and Nature Plus Inc (2018), respectively, have the physical characteristics. It is noteworthy that, given the particle size of the particulate soil of the present study, such as the sandy loam type, it was necessary to add hydrated lime reagent at 2% by weight to the mixture with ECOLOPAVI® stabilizer. The geogrid type MacGrid® NET was also participating, donated by the company Maccaferri® Latin America in the form of a blanket with a length of 50 meters, net and gross weight of 21.00 kg and 22.4 kg, respectively (Table 1). Natural material and compositions were analyzed by the following activities, as provided for in ABNT technical standards: a) sample preparation (NBR 6457: 2016); b) physical tests (grain size, liquidity limit, plasticity limit, specific grain mass and compaction); and c) mechanical tests, which determined the Tensile Strength of Diametral Compression and the Resistance to Simple Compression, using a Universal Testing Machine, from the Geotechnical Research Group of the Federal University of Amazonas (GEOTEC / UFAM). In calculating the tensile strength (RT) of the cylindrical samples, compression loads with a constant velocity of 0.8 mm / s were applied, which produced a uniform transverse stress (tensile) along the vertical diameter. The test was conducted by the NBR 7222 standard (ABNT, 2010), accompanied by the UTS002 3.12 Stress Strain Test software. Regarding the Simple Compression Resistance (RCS), the test, with or without geogrid participation, followed the procedures of NBR 12770 (ABNT, 1992), and in line with the UTS002 3.12 Stress Strain Test software. These experiments were carried out at the Soil Laboratories of the 6th Construction Engineering Battalion (6th BEC), the Air Force (ALA / 8) and the Geotechnical Group (GEOTEC) of the Federal University of Amazonas. In the mineralogical analysis of the natural soil and compositions by the X-ray fluorescence spectrometry (FRX) technique, the PANalyticalSpectrometer, model EPSILON 3 XL, belonging to theAmazonian Materials and Composites Laboratory (LAMAC-UFAM) was used. The experiment was carried out according to the following characteristics: maximum voltage of 50 kV, maximum current of 3 mA, and the presence of helium gas at pressure 10 atm./10 kgf / cm.

Dosing and molding

The samples were obtained according to the expressed dosages in the methodologies established by the manufacturers of additives ECOLOPAVI®, EMC²® and TERRAZYME. Subsequently, specimens were molded according to the energy compression parameters of the modified proctor. Worked with outdoor healing at times 3 and 28 days.

RESULTS

Physical and mineralogical characterization

The natural material from the Puraquequara branch line, located on the border between Manaus and Rio Preto da Eva, in Amazonas, was obtained through the sieving and sedimentation granulometry test, and observing the NBR 7181 (ABNT, 2016), as follows: fractions: 2.3% boulder, 47.4% sand, 8.9% silt and 41.4% clay. Soon a sandy clay. The specific grain mass was 2.54 g / cm³. Regarding the consistency limits, they showed a liquidity limit and a plasticity limit of 33.2% and 12.1%, respectively. Therefore, a plasticity index of 21.10%, which typifies the material as high plasticity (DAS, 2016). By the compaction test, in the energy of the intermediate Proctor, the optimum humidity (ωot) equal to 12.1% and the maximum dry bulk density ($\rho dmax$) of 1.944 g / cm³ were obtained. Gathering the Atterberg granulometry and boundary data, the soil was classified as A-4 and CL according to the AASHTO and Unified Soil Classification (SUCS) systems, respectively. Allusive to natural soil compositions with additives, the consistency limits showed values very close to LL and LP, therefore, not changing the PI, regardless of product and cure time (Table 2).Regarding the natural soil, considering the curing times of 3 and 28 days, the results of the formulations respectively registered a decrease of 42.42% and 27.27% for values in the range of 19 to 24% of

Table 2. Atterberg Limits.

Sample	Cure	Liquidity Limit (%)	Plasticity Limit (%)	Plasticity (%)
NATURAL SOIL	-	33	12	21
SOIL-ECOLOPAVI	3 days	21	15	6
	28 days	23	16	7
SOLO-EMC²	3 days	19	14	5
	28 days	21	16	5
SOIL-TERRAZYME	3 days	24	14	10
	28 days	19	14	5

Table 3. FRX data from natural soil

Elements	Al	Si	P	K	Ca	Ti	V	Cr	Mn	Fe	Zn	Ga	As
Presence (%)	32,100	55,271	1,111	0,107	0,475	3,181	0,055	0,032	0,015	6,322	0,006	0,019	0,002
Oxides	Al_2O_3	SiO_2	P_2O_2	K_2O	CaO	Ti	V	Cr	Mn	Fe_2O_2	Zn	Ga	As
Presence (%)	36,528	57,167	1,039	0,051	0,260	1,216	0,055	0,012	0,005	3,260	0,006	0,019	0,002

Table 4. FRX identified structures (ICF) in natural soil

Fase	CIF	Group esp.	Structure	a	b	c	α	β	γ	Reference
SiO_2 - (Silicon oxide - alpha)	39830	P1 (1)	Triclinica	4.916	4.916	5.407	90	90	120	On the structure of alpha - SiO_2 crystals doped with F_e^{3+}, ZhurnalNeorganicheskoiKhimii (1993) 38, p44-50.
$Al_2(Si_2O_5(OH)4)$ - Kaolinite 1A	63192	C1 (1)	Triclinica	5,15	8,94	7,4	91,7	104,8	89,8	Rietveld refinement of non-hydrogen atomic positions in kaolinite, Clays and Clay Minerals (1989) 37, p289-296 DOI:10.1346/CCMN.1989.0370401

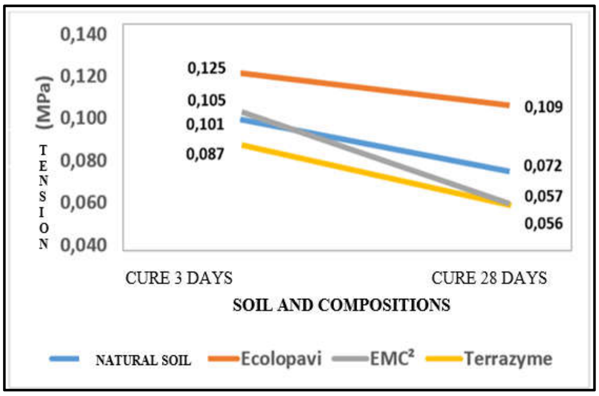

Figure 1. Tensile Strength x cure times

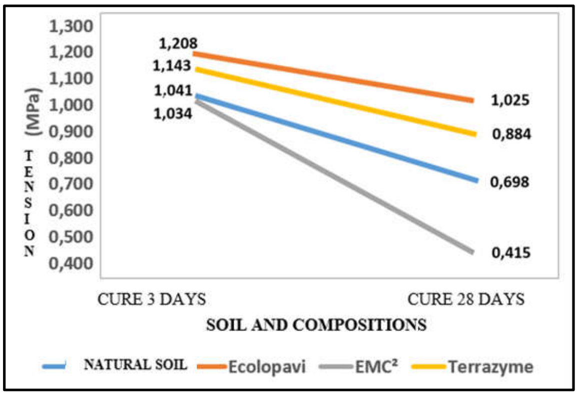

Figure 2. Simple Compressive Strength x cure times

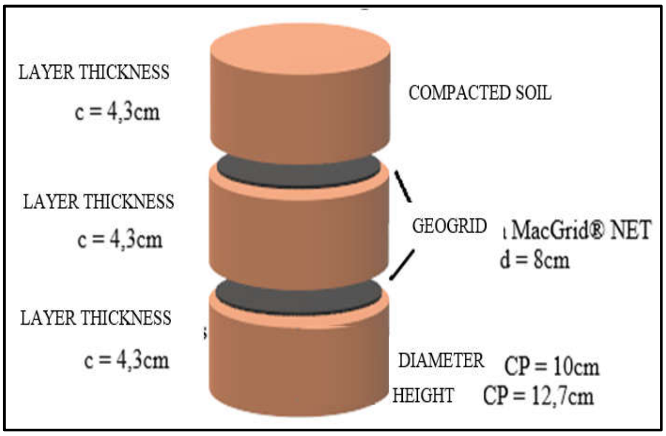

Figure 3. Model of the geogrid specimens for the RCS test

Liquidity, and respective increase of 16.66% and 33.33% for values in the range of 14 to 16% of the Plasticity Limit. As a result, a reduction in IP from 21% to 5 to 10%. X-ray fluorescence analysis determined the stoichiometry of each element present in the natural soil sample. Results (Table 3) show elemental forms and oxides. Such data helped in the identification of the crystalline phases by comparing with the crystallographic standards (CIF-Crystallographic Information

File) existing in the Inorganic Crystal Structure Database (ICSD). Relevant to the mentioned table, two crystallographic phases were distinguished. One of them showing the presence of kaolinite argilomineral (Al (Si2O5 (OH) 4), by means of the CIF - 63192 - ICSD standard, and the other, corresponding to the presence of SiO2Quartz, observed according to the reference CIF - 39830 - ICSD. Information on the structures recognized in the "in natura" material are shown in Table 4. The identified high alumina (32.1%) and silica (55.27%) were present in the two found structures. corresponding to the phases of kaolinite and quartz. The presence of the elements Ti (3.18%), Fe (6.32%), P (1.11%), as well as the others, were not associated with any pattern. Therefore, it was concluded that such elements are in non-crystalline form and can possibly be considered as contaminants in the material, and influence the coloration.Quartz, observed according to the reference CIF - 39830 - ICSD. Information on the structures recognized in the "in natura" material are shown in Table 4. The identified high alumina (32.1%) and silica (55.27%) were present in the two found structures. corresponding to the phases of kaolinite and quartz. The presence of the elements Ti (3.18%), Fe (6.32%), P (1.11%), as well as the others, were not associated with any pattern. Therefore, it was concluded that such elements are in non-crystalline form and can possibly be considered as contaminants in the material, and influence the coloration.

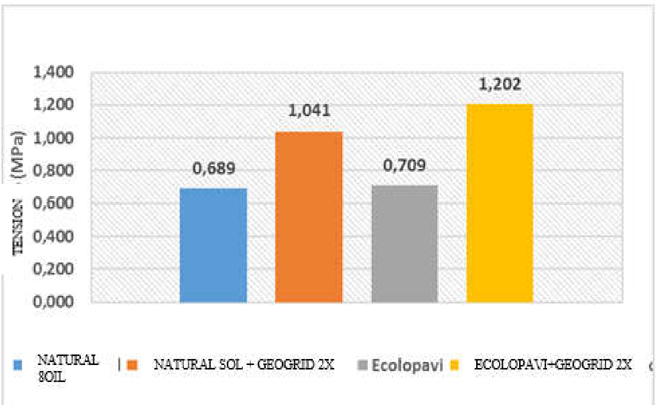

Figure 4. Resistance to Simple Compressionwith the presence of the geogrid

Mechanical behaviour

Three (3) specimens were molded for each condition, that is, natural soil and formulations with the participation of each additive, making 24 (twenty four) samples, according to the cure times of 3 and 28 days.

Tensile Strength (RT) by Diametral Compression

Regarding the set of results (Figure 1), there was a standard behavior, that is, a decrease in RT as the cure time increased. In isolation, compacted soil samples showed a reduction in RT of 28.7% from 3 to 28 days of cure. Concerning only the presence of ECOLOPAVI® mixtures, the tensile strength values showed a decrease of 12.8%, from 3 days to 28 days. In the comparison of these specimens regarding: a) the natural soil increased by 19.2% and 33.9% for 3 and 28 days, respectively; b) EMC²® formulations showed a reduction of 16.0% after 3 days and 47.7% after 28 days of cure; and c) TERRAZYME® product compositions resulted in an increase of 30.4% over 3 days and a reduction of 48.6% at 28 days. Regarding the mixtures with EMC²® additives, there was a reduction over the 3-day period, equal to 45.7% for 28 days of cure. Comparing these values it was observed: a) a small increase in the specimens with natural soil, concerning 3 days of cure with a value equal to 3.8% and at 28 days a reduction of 20.8%; b) in the mixtures with TERRA-ZYME®, results showed a value of 17.1% at 3 days of cure and practically no change at 28 days of cure. Concerning the formulations with TERRAZYME® there was a reduction of 35.6% of RT, from 3 days to 28 days. In the comparison of these samples, regarding: a) the natural soil, the results show for the 3 days of cure a reduction of 13.9% and for the 28 days a decrease of 22.2%; b) for the other products (ECOLOPAVI® and EMC²®) the results were discussed in the previous sub-items.

Simple Compression Resistance (RCS)

Depending on the total results (Figure 2), a standard behavior, similar to the experimental data of RT, was found, that is, a decrease in simple compressive strength with cure time. Occasionally, in the case of natural soil samples, they showed a reduction of 32.9% in RCS from 3 to 28 days. Concerning the formulations with Ecolopavi®, the values showed a decrease of 15.5% in RCS from 3 to 28 days. In the comparison of these specimens, regarding: a) to the natural soil there were increases of 13.8% and 31.9% relative to 3 and 28 days, respectively; b) the formulations with EMC²® decreased 14.4% after 3 days and 59.5% after 28 days of cure; and c) TERRAZYME® product compositions decreased by 5.4% for 3 days of cure and increased by 13.8% after 28 days. In the mixtures added with EMC²® there was a reduction of 59.8%, corresponding to the period from 3 days to 28 days of cure. Comparing these values, it was observed, as: a) to the natural soil, that different responses occurred by additions of this stabilizer. Concerning 3 days of cure practically did not change, that is, around 0.7%, and a reduction equal to 40.5% at 28 days; and b) formulations including TERRAZYME®, 9.5% after 3 days of cure and virtually unchanged for 28 days. Regarding TERRAZYME®, there was a reduction of 22.7% in Compression Resistance, from 3 days to 28 days. In the comparison of these samples it was indicated: a) to the natural soil, increase of the values with increase of the cure times in 8,9% for the 3 days and increase of 21,0% in the 28 days; and b) the additive compositions with the other products (ECOLOPAVI® and EMC²®), results already discussed in the previous sub-items. According to the Resistance to Simple Compression, the participation of the geogrid for the composition with the best response resulting from chemical stabilization was evaluated, in the case of mixing with Ecolopavi and, in particular, for the cure time of 3 days, aiming at portray more pressing field conditions. Allusive to such specimens with the insertion of the geogrid in 02 (two) meshes and the formulations compacted in 03 (three) layers with about 4.3cm each, we have in Figure 3 the model of the specimen. 08 (eight) specimens were made, 02 (two) for each condition: natural soil, natural soil with geogrid, soil formulation with Ecolopavi and the soil composition with Ecolopavi and the presence of the geogrid. The values of the Simple Compression Resistance (Figure 4), having the geosynthetic integrating the specimen, showed, for the period of 3 days: a) increases of 51.1% of the samples of natural soil with geogrid related to the formulation with only the natural material; b) 2.9% increase in natural soil samples with ECOLOPAVI® in relation to "in natura" soil; and c) a considerable increase of 75.5% of the ECOLOPAVI® additive soil compositions and the MacGrid® NET geogrid.

DISCUSSION

The particle size analysis showed the natural soil, derived from the Puraquequara branch, with clay predominance and classified as A-4 and CL according to the AASHTO and Unified Soil Classification (SUCS) systems, respectively. The Atterberg limits of the compositions, regardless of the cure time, presented values very close to LL and LP and, in relation to the natural soil, reduction of the first and addition of the second, respectively. In the case of mineralogical characterization, obtained by X-ray fluorescence assays, a high content of aluminum oxide (36.5%) and silicon dioxide (57.2%) were found in the natural soil, as well as contaminants such as iron oxide (3.26%), phosphorus oxide (1.04%), and traces of other elements. Particularly, structural patterns were distinguished from the "in natura" material, showing the presence of kaolinite and quartz. Regarding the results of the Tensile Compression, Tensile Strength of the natural samples and stabilized by the 03 (three) products individually, there was a standard behavior with the cure time, that is, a decrease of this parameter with the cure time. It is emphasized that the presence of ECOLOPAVI® resulted in the best values of RT regarding "in natura" soil and the other formulations. According to the values of the Simple Compression Resistance tests, it was found that the samples added by the 03 (three) products individually and the specimen with the natural soil, also showed results according to a standard behavior, ie reduction with increased healing time. It is noteworthy that ECOLOPAVI® stabilized mixtures also expressed the best results. Specific to the RCS tests with the MacGrid® NET geogrid and the soil added with the ECOLOPAVI® product, considerable increases in the values of this parameter were observed for the cure time of 3 (three) days.

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