A STUDY OF CHEMICAL-MINERALOGICAL PROPERTIES OF MODIFIED SOILS WITH POLYMERS ADDITION

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***Abstract*: On highways, the soil is considered a supported material and compound pavements layers. For this, they must have such characteristics that confer stability and mechanical resistance to traffic internal forces during the pavement life. When soils do not have required characteristics by the project can be used stabilization techniques that make the natural soil adequately to roads requirement. Based on this assumption, this study aimed to evaluate the efficacy of polymer association in soil stabilization for use in roads pavements. Were evaluated chemical and mineralogical properties on two different soils with sample of pure soil and with the addition of the polymer association Based on the obtained results, polymer association changes was observed on X-ray fluorescent spectrometry (XRF); X-ray diffraction (XRD); scanning electron microscopy (SEM) and Methylene blue. In general, the polymeric association studied in this research was effective in chemical and mineralogical analyzes for use on stabilized soils, making this technique efficient for use in layers of road pavements.**

***Keywords*: polymers, stabilization, pavements.**

INTRODUCTION

The Brazilian road sector is particularly important because it is the main modal used in loads transportation. During the decades of 1990 and 2000, road transport accounted for over 60% of the total transported in the country. This reflects a process that spanned several decades in which predominated the fast growth of road segment on all the other modalities (IPEA, 2010). On highways, the soil is considered a supported material and compound pavements layers. For this, they must have such characteristics that confer stability and mechanical resistance to traffic internal forces during the pavement life. When soils do not have required characteristics by the project two procedures can be used. Firstly, withdrawal of the original material followed by the replacement with desired geotechnical characteristics. This procedure can become impractical in the case of roads that require a large volume of replacement or large transport distances. The second procedure is to use stabilization techniques that make the natural soil adequately to roads requirement. Chemical treatment of pavement base, sub base, and sub grade materials is undertaken to improve workability during compaction, to create a firm working surface for paving equipment, to increase the strength and stiffness of a foundation layer, to reduce potential shrink and swell due to moisture changes or frost action, or both, or to control dust on unpaved roads (Rauch et al, 2002). Tingle et al (2007) aims to understanding the chemical and physical bonding mechanisms associated with selected nontraditional stabilizers. It was observed that polymer stabilizers coat soil particles and form strong physical bonds. Polar components present in the polymer may adsorb strongly onto soil particle surfaces, promoting adhesion. Based on this assumption, this study proposes to study chemical-mineralogical properties of modified soils with polymers addition seeing that, this technique improve best mechanical behavior of the soil and reduces deterioration of roads layers.

MATERIALS

For the present study was used the association of followed three polymers: Polymer A, Polymer B and Polymer C. The functions of those polymers are:

- Polymer A is water based heavy duty formulation of acrylic polymer specifically for road building or creating a hardened surface suitable for all types of traffic. When mixed into soil and compacted yields an extremely strong three dimensional substrate that can easily withstand traffic loads;
- Polymer B is a combination of two complementary components developed specifically to fill the capillary network with a silicone resin thus rendering the soil water repellent. So this is product is a water-proofing agent employed to reduce the water sensitivity of soil particles, especially in soils containing significant levels of clays or silts. It functions to hydrophobize the soil surface and resist water intrusion;
- Polymer C was formerly thought to function as a catalyst to enhance the drying process and impart early strength development.

According to the supplier of the products, a good formulation of polymer association was 6% of Polymer A, 2% of Polymer B and 5% of Polymers C (percent by weigh based on soil).
This research evaluated lower content but following the same percentages between the three products.

Table 1 describes contents of polymer association utilized in this research.

Table 1. Contents of polymer association.

Polymer A (%)	Polymer B (%)	Polymer C (%)	Total contents of polymer association (%)
3	0.9	2.6	6.5

It was studied two (2) different soils with the followed TRB classification: Soil 1 (A-2-6) and Soil 2 (A-2-4).
Table 2 presents a summary of the geotechnical properties of these soils.

Table 2. Physical properties of research soils.

Properties	Soil 1	Soil 2	Standard Method
Passing 4,8 mm Sieve (%)	96,34	99,98	ABNT- NBR 7181/1984
Passing 0, 42 mm sieve (%)	37,29	74,79	
Passing 0,074 mm sieve (%)	11,12	12,98	
Liquid limit (%)	34,22	NL	ABNT- NBR 6459/1984
Plastic limit (%)	NP	NP	ABNT- NBR 7180/1984
Specific Gravity	2,655	2,703	ABNT- NBR 6508/1984

3 Testing Program The study of physical-chemical-mineralogical properties of polymers addition on soil stabilization was analyzed by the results of,

(i) X-ray fluorescent spectrometry (XRF);
(ii) X-ray diffraction (XRD);
(iii) Scanning electron microscopy (SEM) and
(iv) Methylene blue.

X-RAY FLUORESCENT SPECTROMETRY

For determination of chemical composition of studied soils, it was used X-ray fluorescent spectrometry. This technique is based on the principle that the absorption of X-rays by the material causes internal ionization of atoms, generating a radiation characteristic, known as "fluorescence". This analysis allowed observes the presence of oxides such as SiO2, Al2O3, Fe2O3, CaO, MgO, K2O, Ti2O, among others. For X-ray fluorescent spectrometry tests was used the content of 6,4% of polymer association on stabilizers samples.

X-RAY DIFFRACTION

For mineralogical characterization of studied soils, it was used X-Ray diffraction. It was utilized Cukα radiation, 40kV voltage, 30 mA current and scan of $2^o < 2\theta < 30^o$ and $\lambda = 1{,}54$Å. For X-Ray diffraction was used the content of 6,4% of polymer association on stabilizers samples.

SCANNING ELECTRON MICROSCOPY

Electron Microscopy method is the generation of data that allows the observation and characterization of organic materials and inorganic heterogeneous on a micrometer scale. The SEM provides a magnified image of the surface of the material that is very similar to that expected if one could actually "look" this surface. Not only is the material topography of information produced as well as, information on their composition. For scanning electron microscopy was used the content of 6,4% of polymer association on stabilizers samples.

METHYLENE BLUE

The methylene blue adsorption test is an alternative very efficient, fast and inexpensive to determine the expanding activity plastic soils. The mechanism of adsorption of methylene blue by the particles is the ion exchange between the cations existing on the surface of these particles, such as calcium, sodium, magnesium and potassium cations, and cations resulting from the dissociation of methylene blue molecule aqueous solution. As a result of this cation exchange is formed around the particle a monomolecular methylene blue layer. For methylene blue adsorption test was used the content of 6,4% of polymer association on stabilizers samples.

RESULTS

X-ray fluorescent spectrometry

Table 3 shows the chemical composition of studied soil without stabilizers and with the addition of polymer association.

Table 3. X-ray fluorescent spectrometry

Properties	Soil 1		Soil 2	
	Pure	Polymer Add	Pure	Polymer Add
FL*	12,25	16,4	6,82	19,5
SiO2	49,04	39,60	57,70	35,03
Al2O3	31,67	32,55	26,56	32,54
Fe2O3	1,28	8,0	5,71	4,50
TiO2	-	0,96	1,23	1,20
TiO2	4,59	-	-	-
MgO	0,89	-		-
CaO	-	1,91	-	4,70
Others	0,28	0,58	1,98	2,53

***FL = Fire lost**

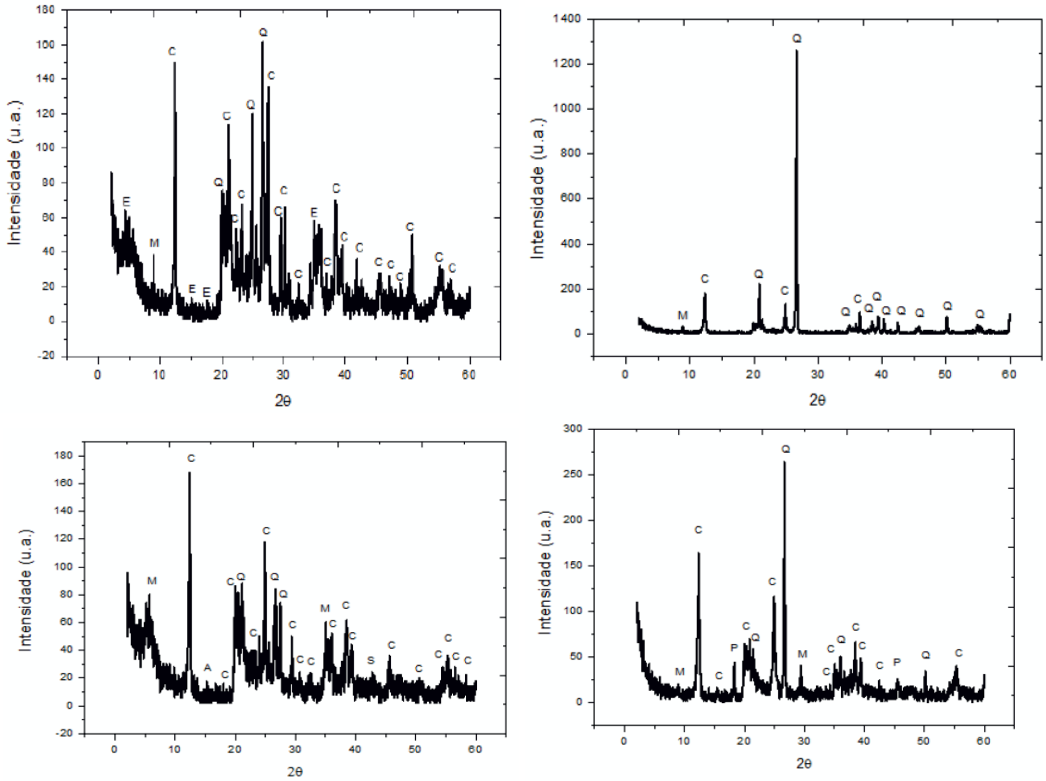
According with the results, Soil 1 chemical composition was basically formed by SiO2 (49%), Al2O3 (32%) and K2O (5%). Soil 2 was basically formed by SiO2 (58%), Al2O3 (27%) and Fe2O3 (6%).

The results indicate that the addition of the polymeric association caused an elevation of the fire lost, possibly because it is an organic material. Could be verified the presence of CaO in all soil samples with polymer addition, justified by the presence of inorganic calcium in the chemical composition of Polymer C.

X-RAY DIFFRACTION

Figure 1 shows the diffractogram of studied soil without stabilizers (Soil 1-Figure 1.a and Soil 2 – Figure 1.b) and with the addition of polymer association (Soil 1- Figure 1.c and Soil 2 – Figure 1.d).

(A) (B)



(c) (D)

Figure 1. Diffractogram for studied soils.

Legend: A = anorthite/ C = kaolinite/ E= smectite/ M= mica/ Q= quartz/ S= sanidine/P= portlandite.

According to the diffractogram, Soil 1 showed the mineralogical phases: Anorthite, kaolinite, quartz, mica and sanidine. Soil 2 showed the mineralogical phases:mica, portlandite, quartz and kaolinite.

SCANNING ELECTRON MICROSCOPY

Figure 2 shows the SEM of studied soil without stabilizers (Soil 1- Figure 2.a and Soil 2 – Figure 2.b) and with the addition of polymer association (Soil 1- Figure 2.c and Soil 2 – Figure 2.d).

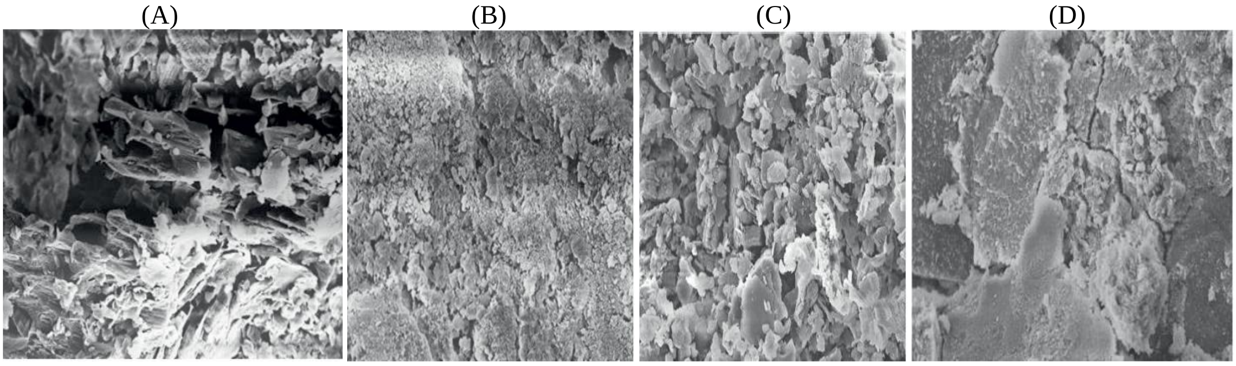


Figure 2. Scanning electron microscopy of studied soils.

According to Figure 2.a, Soil 1 shows a rough morphological structure and heterogeneous with the presence of pores, and dispersed particles, indicating that there was not a good interaction between the particles constituent material. Soil 2 shows a rough morphological structure with the densified regions and the presence of pores, characteristics of soils with lower average particle diameter

According to Figure 2.c, it was observed that the Soil 1 shows heterogeneous morphologic structure with the presence of a few pores, hexagonal crystals and needleshaped. Soil 2 (Figure 2.d) shows very densified structure with few pores and some particles dispersed in the matrix, which could be quartz.

METHYLENE BLUE

Table 4 shows the methelyne blue adsorption of studied soil without stabilizers and with the addition of polymer association.

Table 4. Methelyne blue absorption os studied soil.

Methelyne blue absorption (meq/100 g dryclay)	Pure	Polymer Add
Soil 1	28	20
Soil 2	28	20

The analysis of the results reveals that studied soils showed low cation exchange index. These values are justified by the presence of iron and aluminum oxides which have low capacity of cation change (20-50 meq/ 100g dry clay), and the presence of kaolinite which contributes significantly to the reduction of this index.

It was observed that after addition of the polymer association occurred reducing the adsorption of methylene blue at Soil 1, indicating that under these conditions these soils have a smaller cation exchange. This occurrence is explained by the crystallization process of the grains of clay minerals present in the soil. Particles soils were involved by polymers generating a barrier that prevents the exchange cations. This reduction may indicate a significant decrease in the activity of clay minerals causing a decrease in the plasticity of soils.

CONCLUSION

On the basis of the study presented above, the following conclusions are drawn: The results indicate that the addition of the polymeric association caused an elevation of the fire lost, possibly because it is an organic material. Could be verified the presence of CaO in all soil samples with polymer addition, justified by the presence of inorganic calcium in the chemical composition of Polymer C. Evaluating scanning electron microscopy results, can be observed that the presence of polymeric association form physical bound, causing union between the particles

of soil. Besides, it was observed the addition of polymeric association filled the capillary network with a silicone resin. It was observed that after addition of the polymer association occurred reducing the adsorption of methylene blue indicating that under these conditions these soils have a smaller cation exchange.

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