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Analysis of Concrete Residues as Clay Stabilizer for use in Embankment

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Abstract: In the stabilization of the material for embankment use, Lime and cement have been used, avoiding cutting, removing and supplying more material.The use of these stabilizers generates a cost for both their acquisition and their storage and surveillance, which makes decline their use in most cases.In addition, cut, remove and supply material generating Greenhouse Gases (GHG) emitted by the dump trucks used in these maneuvers.The use of waste material from a concrete dosing plant as a stabilizing agent in materials for embankment use according to norm N-CMT-1-01/16 of the Ministry of Communications and Transportation, would contribute to the reduction of GHG.

Keywords— Clay, fresh concrete Residue, stabilization, material for embankment.

I. INTRODUCTION

The stabilization of clay with residual material from the concrete dosing plant of Culiacán, Sinaloa, so that it can be used on embankments given in the earthworks, seeks the stabilization of clays with an alternative material, such as lime and cement.Stabilized clay is desirable to meet the characteristics of material for embankment according to N-CMT-1-01/16 [S.C.T.2016] of the Ministry of Communications and Transportation SCT, where the material must have a maximum liquid limit of 50%, a minimum california support value of 5%, a maximum expansion of 5% and a compaction degree of 90 ± 2%

At present, real estate development projects and/or urbanizations, to name an example, the presence of a cohesive material on the land to work is so frequent that it can cause the following:

1.-Not being able to place the cut material in the embankment areas, for not complying with the quality characteristics for embankment [S.C.T. 2016], bank material has to be supplied, having to open new extraction and material disposal banks.
2.- The emissions of carbon dioxide to the environment by the heavy machinery used in these banks, and that of the dump trucks used in the transport of withdrawal and supply of material [B.Muresan 2015, V. Kecojevic and D. Komljenovic 2011].
3.- The use of lime and/or cement to stabilize the material.

In the construction sector, especially earthworks, for example, in real estate developments, it occurs frequently that in the properties acquired to build, it is found a cohesive material which, having a change in humidity, presents volumetric variations,being unstable and hard to work.

At present, stabilizations are carried out with lime or cement, or a combination of both, limiting their use, since the price of these inputs is rising, especially cement by 12%, being the second increase for 2017 arrivingat 27% [S. Cantera 2017, CANADEVI 2017],coupled with a 13% increase this year [E.Herrera 2018], implying a cost for its acquisition, its storage and surveillance.

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In addition to the lack of studies, divulgation of and about alternative materials that can stabilize soils in our region;it makes the decision to remove the cut material and supply material until project levels are reached.

There are two main axes in the problematic: on one hand, the waste of fresh concrete, ranging from the production of cement up to the final product, in this case the waste of plant of ready-mix concrete;and on the other hand, it is the non-use of a cohesive material in the earthworks. The construction sector was directly and indirectly responsible for 18% of global Greenhouse Gas emissionsGHG in 2010 [M. Yu 2017].Another important fact is that the cement industry is one of the most important sources of GHG Greenhouse Gases, in particular with CO_2 carbon dioxide emissions, with approximately 7% of the total anthropogenic CO_2 emissions inall the world [T.Gao 2015, M. Uwasu 2014, M. Fry 2013 and L. Barcelo 2014].A large amount of energy is necessary for the production of cement, which leads to excessive pollution in emissions of sulfur dioxide SO_2 and carbon dioxide CO_2 [9].However, despite pollution data in its production, according to the projections of the cement industry, the global demand for this product will increase from 43 to 72% by 2050 [[T. Gao 2015 and Fry 2013]. Kazaz and Ulubeyli (2016) present several methods for the use of fresh concrete waste returned to concrete dosing plants.This document discloses an option for the use of waste material, which is the method of discharge in the sedimentation basin, where it mentions that this method is applied to concrete dosing plants of small to medium size, where, unloading the fresh concrete into the said container by washing the truck revolving pots,in the sedimentation basin, allowing the progressive settlement of the aggregates, thus being able to recycle some of them and obtaining the final product that is the residue of cement solids [A. Kazaz 2016].Another highlight is the Greenhouse Gas EmissionsGHG produced by dump trucks [B. Muresan 2015] used in the earthworks to carry the non-competent material for its use in the embankments of the site, in this sense by not having the material to compensate the cuts against the embankments, it must be supplied with a material that meets the characteristics of the CMT materials of the Ministry of Communications and Transportation SCT for roads [SCT 2016],depending on the type of material to be used and its year of publication depending on the specifications and executive project; thus having a fuel consumption and carbon dioxide emissions from these activities [A.L. Sharrard 2007].As well as the environmental impact of opening new material exploitation banks, the operations of the machinery for its extraction; also generating the need to have landfills for waste material, which, as in material extraction banks, has an impact on energy consumption for machinery operations and at the same time in the generation of GHG Greenhouse Gases [B. Muresan 2015 and A.L. Sharrard 2007].

Generally in earthworks, it is found that with a material that is not suitable for subsequent placement as an embankment material, this in its natural state, being forced to have to dispose of the cut material and provide a good quality material.Therefore, as mentioned in the document Admixture Soil Improvement [N.P.G. 2015] stabilization has been used for the construction of economic roads, conservation of materials and modernization of roads, where soils that are not suitable for use in their natural state can be made suitable for later use by means of treatment such as mixtures or stabilization.

The improvement of the mixed soil refers to any application where some material is added and mixed with the existing soil to improve the mechanical properties of the soil such as its strength, load capacity, volumetric stability, permeability and compressibility [N.P.G. 2015].In order to better understand the final behavior of the material, it is vital to optimize the design of the mixture and its method of mixing, to carry out an investigation and to carry out laboratory tests [O. Caraşca 2011].

Due to the aforementioned, the use of fresh concrete waste is proposed for the stabilization of clay in the earthworks.

The consequences of not implementing the proposal can be:

1.- Waste the residue from fresh concrete that currently has no cost.

2.- By not having an alternative to stabilize the clay and the price of cement on the rise, the same procedure continues: cutting, removing the material and supplying material for the embankment in the earthworks, impacting on:

- Need for banks for extraction and disposal of material.
- GHG generation by the machinery used in these banks [B. Muresan 2015].
- GHG emissions from dump trucks in material haulage, both for removal as for supply [B. Muresan 2015].

One of the key objectives of the global environmental agenda is the reduction of pollutant emissions, such as Greenhouse Gases to protect the global climate pattern [T. Gao 2015],in addition, this study is related to the problem currently presented in the country, due to the increase in the price of fuels [K. Garcia 2018], affecting all productive sectors, and the case of construction is no exception;as well as to mitigate the exploitation of extraction banks and material dumps, GHG emissions produced by the activities carried out in earthworks by haulage and machinery used in the banks of extraction and dumping of material,and above all to take advantage of a waste such as the fresh concrete residue of concrete dosing plants.

By implementing this research, the following benefits are obtained:
1. It is friendly to the environment:
a) The use of a waste material.
b) Transport and deposit of the waste in an authorized landfill will be eliminated.

c) Reduce the emission of GHG to the environment, both for the transport of waste material and for the supply of material in the earthworks, as well as the machinery used in the banks to extract the material and equipment for spreading the pouring banks.
d) Mitigate the need to open new extraction and material disposal banks.

1. Minimize social inconvenience by:
a) Do not excessively damage existing pavements, due to heavy machinery traffic.
b) Reduction of noise and dust pollution by trucks.
c) Mitigate the inconvenience caused by truck traffic.

2. Impact on the tender budget of both public and private works:
a) The fresh concrete waste material has no cost.
b) The expense for the removal of inappropriate material for use is eliminated.
c) Minimizes the cost of supplying material for the embankment.
d) Reduce the risk of having to outsource alliances for the transport of material, this due to the availability of dump trucks, the execution times of the work or wanting to move forward according to its program.
e) Reduce the insecurity in the quality of the material extraction banks, by focusing on a lower quantity of qualities to be used and/or in only one.
f) Discard the delays caused by the weather, by stabilizing the soil and continuing the work positively impacting in the work schedule to meet and even advance the execution times.

Therefore, it is of the utmost importance to promote awareness and good practices in all those involved in construction, especially in earth movements, such as:engineers, contractors, designers, quality control; on the new advances and investigations that are available in this regard, in this case, the use of the residue of fresh concrete as a stabilizing agent for clay, since at the moment, in the state of Sinaloa there is no proposal for the use of this residue;and at the same time we contribute to the environment by reducing the GHG emissions emitted by heavy machinery, both in the transport of material and the one used in the extraction banks and disposal of material,as well as the preservation of the ecosystem by mitigating the exploitation of material extraction banks and landfills for construction waste, and also landfills for fresh concrete waste.

II. MATERIALS AND METHODS

The activities were divided into: field, laboratory and cabinet work; In the field work the authorization was managed before the person in charge of the ready-mix concrete plant to take samples of the waste material

The laboratory work was carried out with various laboratory tests, both to the clay as to the residue to know its physical and mechanical characteristics, different mixtures of clay with waste were dosed and its physical and mechanical characteristics were obtained; finally, the cabinet work compiled the results obtained from the laboratory tests, and was compared with the quality requirements of the norm N-CMT-1-01/16 [S.C.T. 2016], which are the characteristics to be fulfilled so that it is approved as material for embankment, the data obtained and photographs were collected, and the conclusions of the study and recommendations for future research are presented.

Characterization of materials: residue, clay and mixtures

The tests performed on the samples of: cohesive material, residue and clay mixtures with residue; to know their characteristics, using the SCT manual were

- ✓ Drying, Disintegrating and Sample Quartet, M-MMP-1-03 / 03 [S.C.T. 2013]
- ✓ Water Content, M-MMP-1-04 / 03 [S.C.T. 2003]
- ✓ Granulometry, M-MMP-1-06 / 03 [S.C.T. 2003]
- ✓ Consistency Limits, M-MMP-1-07 / 07 [S.C.T. 2007]
- ✓ Density of solids, M-MMP-1-05 / 03 [S.C.T. 2003]
- ✓ Natural volumetric weight γm and dry volumetric weight γd in the laboratory [S. Sanchez 2008]
- ✓ pH test
- ✓ AASHTO compaction test, M-MMP-1-09 / 06 [S.C.T. 2006]
- ✓ California CBR Support and Expansion Value Test, M-MMP-1-11 / 16 [S.C.T. 2016]

Mix design

The proportions of clay mixtures with residue, where the percentage of residue was with respect to the weight of the clay, are shown in Table 1.

Tabla 1. Percentages of waste for mixtures.

Clay	7.5 kg	7.5 kg	7.5 kg	7.5 kg
Residue %, (gr)	10% (750)	15% (1125)	30% (2250)	50% (3750)

III. RESULTS AND DISCUSSION

Waste characterization

For the waste material it was determined a water content of 29.61%, the granulometry is shown in Figure 1, the limits could not be determined due to the consistency of the residue itself, the density of solids was 2.50, pH of12 similar to the pH in Portland cement [R. Corral 2016]

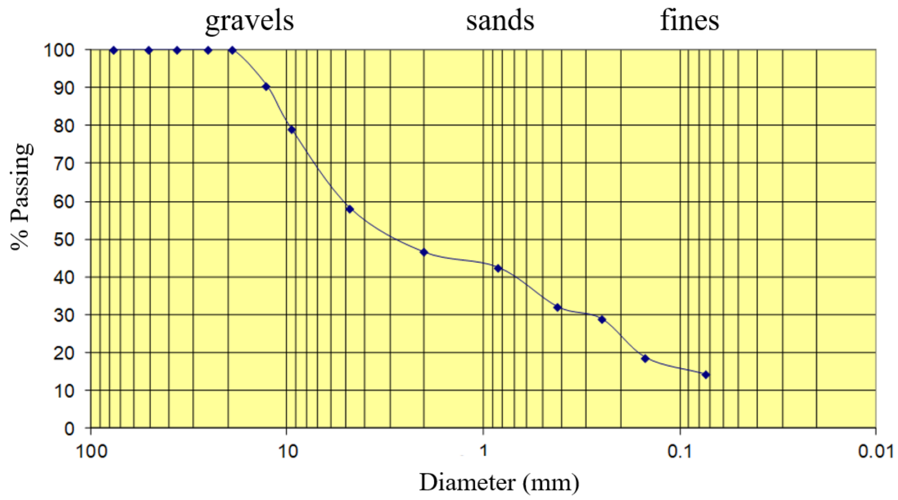

Figure 1Residue granulometry

Clay characterization

It was determined for the clay a water content of 23.41%, the granulometry is shown in Figure 2, the liquid and plastic limits were 91% and 30.95% respectively, the density of solids was 2.65, pH of 6, dry volumetric weight of 1.84 g / cm3, CBR of 1.48% for a degree of compaction of 90%as specified in standard N-CMT-1-01 / 16 [S.C.T. 2016] of that obtained in the standard AASHTO compaction test of 1,335 kg / m3 and an average expansion of 9.52%. Classifying as a *clay of high plasticity and high compressibility.*

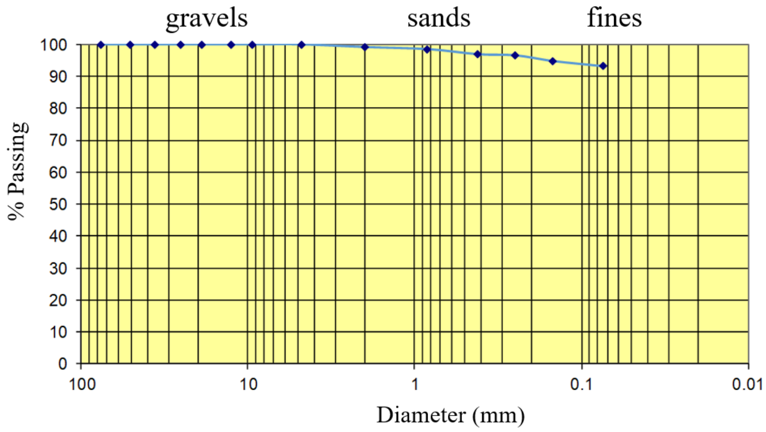

Figure 2Clay granulometry

Characterization of the mixtures

Table 2 shows a summary of the results obtained in the various tested mixtures mentioned in Table 1,

Table 2. Properties of mixtures.

Mix Waste Amount (%)	10%	15%	30%	50%
Percentage of fines (%)	90.61	90.55	84.55	-
Sand percentage (%)	9.39	9.45	15.45	-
Liquid limit (%)	87	85	73.50	66
Solidity Density	2.56	2.60	2.63	-
pH for Liquid limit	9	9	9	-
pH for granulometry	8	8	8	-
Maximum dry mass (kg/m^3)	1,339	1,353	1,395	-
Optimum water content (%)	-	30	30	-
C.B.R. (%)	1.68	1.90	2.65	-
Expansion (%)	7.16	2.97	4.82	-

The pH obtained in the mixtures to perform the Liquid Limits were constant up to the proportion of 30% increasing to 11 in the 50% mixture, almost equal to the pH that resulted for the residue being of12, approaching the average value of 12- 13 of the concrete [R. Corral 2016]. For granulometric tests it presents a value of 8 constants until the last test performed, may be due to the presence of aggregates in the mixture.

This meaning that the clay is reacting with the residue by increasing its pH, by reacting the silicate and calcium hydroxide of the residue with the silica and alumina of the clay, forming calcium hydrates of silica and alumina.

The Liquid Clay Limit was reduced by almost 20% for the 30% of mixture residue, and a 27.47% with the mixture of the 50% of residue. Producing a volumetric stability of the material in front of moisture changes, since it absorbs less water.

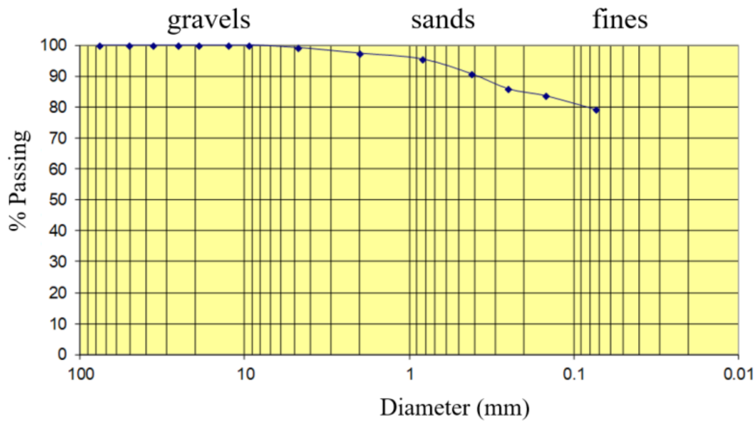

Figure 3Mix granulometry with residue of 10%

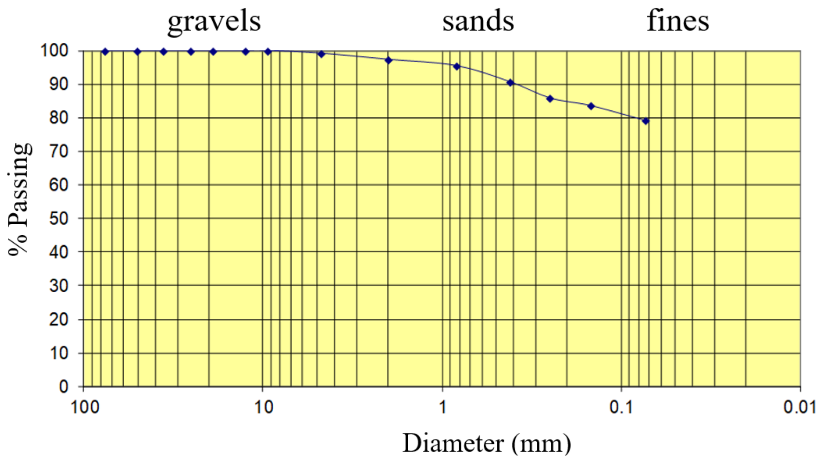

Figure 4Mix granulometry with residue of 15%

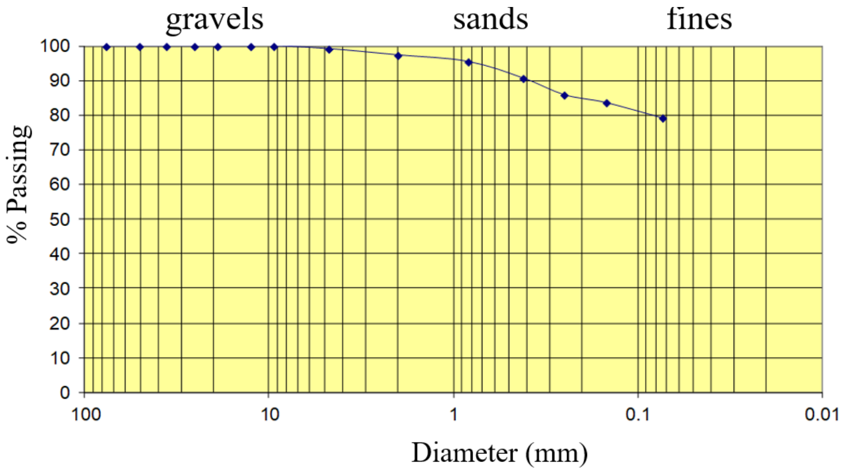

Figure 5Mix granulometry with residue of 30%

As the amount of waste increases, the percentage of sands increases since the greater amount of the residue is the size of sand, and as the material is flocculating producing a cementing structure, in other words, the union of the clay particles with the fine part of the residue, improving the granulometry of the material;taking into account that a material with the largest number of particle sizes is better suited and intertwined, increasing its mechanical properties.

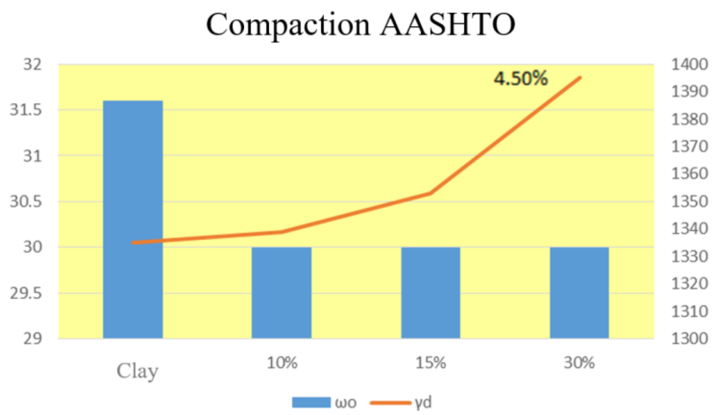

Figure 6.AASHTO compaction for clay and mixtures.

The optimum water content $\omega_o$remains constant at 30% for all compaction tests of the different mixtures, and has an increase of 4.50% the dry volumetric mass γd compared to that of clay.

Figure 7.California CBR Value Support and Expansion for clay and mixtures.

The California CBR Support value increased up to 79%, and the expansion decreased to a 50% for the mix of 30% of residue.

Table 3 shows the quality requirements for embankment material, with which the results of the mix tests were compared.

Table3.- Quality requirements for embankment materials

Characteristics	Value
Liquid limit; %, maximum	50
California Support Value (CBR)[1]; %, minimum	5
Expansion; %, maximum	5
Degree of compaction [2]; %	90 ± 2

[1] In specimens dynamically compacted to the compaction percentage indicated in this table, with a water content equal to the optimum compaction.
[2] Regarding the maximum dry volumetric mass obtained by means of the AASHTO testStandard, of the material compacted with the optimum water content of the test.

The material that was mixed with the residue had many improvements in its physical and mechanical characteristics, in this sense comparing them with the characteristics of an embankment material of the norm N-CMT-1-01 / 16 [S.C.T. 2016].

IV. CONCLUSIONS

Based on the results obtained and the analysis of the present study, some improvements are presented in the properties of the clay, taking as a comparison the mixture data of 30%, the following being:

- Its granulometry was improved.
- Liquid Limit reduced it to almost 20%.
- The maximum dry volumetric mass increased 4.5%
- CBR increased a 79%.
- Expansion decreased to 50%.

Coming to the conclusion that for a soil with a Liquid Limit of less than 70%, it would be cumplying with the maximum liquid limit specified in the norm N-CMT-1-01 / 16 [S.C.T. 2016], although the tests for the California Support Value would have to be performed to find the optimal proportion, in terms of the amount of waste as of water added to the mixture.

V. RECOMMENDATIONS

As recommendations, which arose during the execution of the laboratory work, as well as the drafting of this document to continue with laboratory studies and tests, are listed below:

- It would be convenient to analyze the issue of maximum clay particle size that could be stabilized in the laboratory and compare them with the ones you can get in the field with the machinery available in our region.
- Carry out the tests by passing the fresh concrete residue through 3”meshes to No 4 mesh to remove the gravel aggregates it presents.
- Perform tests on other material that does not meet the characteristics for use on embankment, which may be a CL, MH or ML.
- Analyze the mixture of the waste to a subgrade of pavements, since a subgrade of higher quality will allow savings in the thicknesses of the above-mentioned pavement, without prejudice to the joint structural function, since it will be able to absorb relatively high levels of effort from the surface and transmit them sufficiently diminished to the dirt roads [A. Rico 2016].
- Analyze the addition of waste to a sub base of a rigid pavement, to replace or be used as the fine part of the material, by eliminating the possibility that these fines are plastic, and thus avoiding the phenomena of pumping and volumetric changes, [TO. Rico 2016].
- The waste could be used to improve the quality of a subgrade used as a platform for foundation slabs in house construction.

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