Variation in the plasticity of fine grained soils according to its content of organic matter

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Abstract

According to the phenomena in fine grained soils, also named clayed soils, we can understand the term plasticity as the mechanical behavior characterized by the volumetric instability with moisture changes, which implies drastic changes in the shearing resistance of these type of soils; we will see that this behavior undergoes alterations in the content of organic matter which alter the consistency ranges and increase the compressibility of the structure.

These alterations are present according to one of the three most representative types of clay: kaolinites, illites and montmorillonites (A.Casagrande, 1931), and this research focuses on the illite type, the most common in the environment. The type of clay we study has this characteristic and we gradually added the organic matter in peat (turf). With this, changes in the behavior were recorded so as to determine the trends of a soil, subjected to an increasing organic contamination. A control was performed through the following indexes: plastic index, toughness and flow; the results are presented in relation to the content of organic matter as an informative basis in order to deduce the mechanical properties of the soil, such as compressibility, permeability and shearing resistance, which are the basis for analysis and calculations for the best geotechnical use of the soil in a wide array of civil works.

Keywords: clay, peat, consistency, plasticity, organic, compressibility limits, Atterberg, resistance.

1. INTRODUCTION

An illite clay behaves mechanically through its physical-chemical properties with volumetric instability, which means, it has volume variations with moisture changes, variations in its shearing resistance and a very low permeability, which can be translated into several characteristics such as cohesion, adhesiveness, water-holding capacity, hardness when dry, shearing resistance, which can vary according to the degrees of saturation of the soil, and all of these properties are modified according to the content of organic matter in the soil. The presence of organic matter in any type of soil is a major concern itself, due to the decomposition of organic tissue that alters, within time, the mechanical parameters used in the calculation of the load bearing capacity and the compressibility.

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However, a lot of times a little content of organic matter is enough for the soil to present alarming characteristics through its dark color and odor, without it being an obstacle for the proper usage of the soil as a subgrade soil. *(D.W.Taylor,1948).*

Clays have a structure comprised of microscopic sediments arranged by surface forces or electrostatic forces. These forces are the result of the molecular composition of the type of clay, in this case, illites, where their composition is formed by oxygen and silica grids, and by oxygen, hydrogen and aluminum, linked with potassium atoms. *(R. E. Grim,1953*). Statistically, each clay sediment is formed by slightly more than 100 grids, and around those sediments there is a double water film with characteristics of a solid, close to the mineral particle and of viscous consistence, a little further. And even further, gravitational water that once in stress, it applies confinement efforts to the soil mass.

The decomposition of organic matter, if abundant in clay type soils, modifies the mechanical response of clays to even changing their nature, and thus becoming another type of soil classified as OH, according to the Unified Soil Classification System (USCS), due to the fact that it lowers its plasticity and it becomes an organic clayed slit. Therefore, it is interesting to research how much organic matter a clay can take without significantly modifying its plastic properties, without rejecting contaminated fine grained soils only for their appearance and that mechanically are proper, but for them to be analyzed certainly knowing that their properties and behavior are provable and practically constant throughout time.

A control of the plastic nature of the soil was performed, with the different contents of organic matter through several test specimens and the results were related to the following mechanical behavior parameters according to the criteria launched by Karl Terzaghi: shearing resistance, compressibility and permeability. *(A. Casagrande, 1935).*

These three concepts are the basis in mechanical behavior of soil structures, and are related to certain qualitative- quantitative characteristics, denominated soil index properties, that indicate the trend of the mechanical behavior of the soil itself. Therefore, those laboratory tests constituted this laboratory experimentation research.

The index tests were performed, firstly to determine the initial gravimetric and volumetric conditions of an organic matter-free soil, and from there, follow-up the corresponding changes with the different degrees of contamination. This was controlled with the tests that determine humidity or water content, specific weight and solid relative weight. After that, the tests necessary to calculate the consistency or Atterberg limits, toughness, shaking reaction and dry-state resistance (*T.W. Lambe, 1958)* were performed, as well as an special test to determine the solubility of the structure in contact with gravitational water, a behavior directly related with the cohesive effect of clay, C parameter, and its permeability coefficient, K parameter (*K.Terzaghi y R. B. Peck, 1957)* due to the fact that the lower the cohesion in the structure, the higher the permeability and the lower the stability in between sediments, which increases its mobility potential and with it, the production of piping, cavities and undercuts that weaken the contaminated soil mass *(H.R. Cedergren, 1966).*

The object of this research is to obtain evidence on how the amount of organic matter in an illite-type clay begins to be a distorting factor in the mechanical behavior of soils, and thus guiding the beginner technicians and amateur engineers with little experience in Soil Mechanics onto acting judgmentally in face of certain properties that can inform us of contaminant material, thus rejecting the soil a priori or classify the soil as almost impossible to use. It is obvious that the ideal state of any fine grained soil would be free of organic contamination, but in practice, we need to optimize natural resources of the Works, benefiting its cost without jeopardizing safety. Such goal can be accomplished by the knowledge revealed in researches like this.

2. THEORETICAL APPROACH, INSTRUMENTS AND PROCEDURES

2.1. Theoretical approach

The geological history of a clay *(Dimitri P. Krynine y William R. Judd, 1961)* in a research like this one, demands a great amount of sampling in different locations, as well as exhaustive classifications in order to reduce the number of variables in the studied phenomenon, to its maximum. This can be avoided if controlled mineral composition soils are artificially fabricated, accepting the original limitation as a consequence of not studying natural soils, and understanding that the results obtained show trends and interesting knowledge on the behavior of soils. These results can be generally adjusted and related to the design parameters, given the lack of direct evidence which is difficult to obtain or simply not cost-effective. This research was based on the results obtained from A. Casagrande and R.B. Peck, demanded by K. Terzaghi who gave them the task of creating a procedure that allow to restore the criteria used by Atterberg and that was lost due to the lack of transmission: The Plasticity Chart.

This chart has been, for many years, a priceless instrument for the classification of the properties of fine grained soils, and thus, to define the trends of its mechanical behavior at the beginning of soil modeling.

Casagrande and Pecks's proposal can be summed up in the following expression:

$(PI)_A$ = 0.733 (LL%-20) ....equation of line A of the Plasticity Chart.

$(PI)_A$ = plastic index of soil.

LL% = humidity of the soil in the liquid limit.

In addition to the scale of consistency degrees of soils in relation to their water content, the range of their plastic behavior can be narrowed down through $(PI)_s$ =LL%-PL%, and through the comparison of these two indexes and the value of LL% a soil can be classified, according to its properties, as: ML, MH, CL, CH, OL y OH. It is precisely soils type OL and OH that threatens the stability of civil works and must be treated with special care and must not be confused with contaminated clays; they can have the same appearance but they do not have the same degree of risk in its mechanical behavior.

The follow-up of the effects of the organic matter content was performed through the definition of index properties, according to the relations:

I_w = flow index, T_w = Toughness index and, I_c = consistency index, being:

I_w= flow curve slop

T_w= PI/$I_{W.}$ ……….. toughness index.

I_C= (w-PL)/(LL-PL)= (W-PL)/PI……… relative consistency.

All these relation are determined for the corresponding gravimetric and volumetric relations.

2.2. Instruments and procedures.

2.2.1. Instruments.

In general, the following tools were used for the control of the gravimetric and volumetric properties of the different test specimens: a 320gr capacity, 0.01 gr sensitivity weighing scale, a 500 cm3 flask, and 800 gr capacity and 0.1 sensitivity weighing scale, vacuum pump, a 100° centigrade degrees +-5°c oven and dryer with drying silica material. And for the control of parameters that refer to the plasticity of soils, a Casagrande's cup (or liquid limit device) was used. Other additional instruments and tools were used, such as: electric grill, thermometers, plastic bottles, pipettes, funnels, containers, glass plates and drying paper.

2.2.2. Procedures.

Six test specimens were formed with different contents of peat, a high water- content, organic matter-formed soil, according to the following proportions: (a), (a+2), (a+ 6), (a+12), (a+20) y (a+30), where a=50 gr of clean clay, and 2, 6, 12, 20 and 30 gr, of peat with constant humidity, the test specimens were contaminated in a 0%, 0.40 %, 1.17 %, 2.33 %, 3.81 % and 5.62 %, respectively; each one of them had their gravimetric and volumetric condition established, as well as their Atterberg limits, and with them, their PI, I_w, T_w e I_c parameters, which reflect the plasticity of the soil. Different graphics that show the relations and index and mechanical trends of each soil with different degrees of organic matter contamination, were calculated and built with the information obtained from these tests.

3. RESULTS.

Two types of results were defined: the ones related to the gravimetric and volumetric conditions, and those corresponding to the plastic properties of increasing organic matter contaminated soil.

3.1. GRAVIMETRIC AND VOLUMETRIC CONDITIONS.

The properties of the inorganic soil and peat that were used in the preparation of the six test specimens, corresponded to humidity, w%, relative specific solid weight, S_s, and humid specific weight of materials, Υ_m, and they were: for illite clay, w%= 29.50%, S_s= 2.64 y Υ_m= 1.81 gr./cm^3, and for peat, w%= 297.58%, S_s= 1.95 y Υ_m= 1.18 gr/cm^3., respectively. With these data entries, the gravimetric and volumetric changes of the test specimens were determined. See Table No. 1.

3.2. PLASTIC PROPERTIES.

It is interesting to observe in this study, that applying the máximum contamination, there are soil trends that indicate the changes in plasticity of the contaminated soil, according to the following indexes; the approximation to its position according to LL and PI values to line A in the Plasticity Chart, fig.1; the sustained increase of the flow index I_w, fig. 2; the sustained increase in the plastic index, IP, fig,3; and the de-accelerated decrease of the toughness index, T_w, see fig. 4.

4. CONCLUSION.

With the maximum contamination with organic material, there was no significant approximation of the clay towards the behavior of an organic slit, according to its position in the Plasticity Chart, possibly due to the small percentage of contamination considered in this study. In spite of this, the increase of the plasticity index was notorious PI: but regarding the flow index, I_w, its increase was comparatively lower, which reflected important changes in the toughness index, and with it, significant changes in the soil's plasticity.

REFERENCES

Leonardo Zeevaert Wicher; Foundation Engineering For Difficult subsoil conditions, 1973; VAN NOSTRAND REINHOLD COMPANY; New York, U. S. A.

Collins, K. and Mc Gown, A., 1974; "The Form an Function of Microfabric Features in a variety of Natural Soils"; Geotechnique, Vol. 24, No. 2, 223-254.

Karl Terzagui and R. B. Peck; La Mecánica de Suelos en la Ingeniería Práctica, 1990; 3ª. Edición de la traducción al Español; edición El Ateneo, LIMUSA. España. Argentina. México.

B. K. Hough; BASIC SOILS ENGINEERING,1990; 4ª. Reimpresión; The Ronald Press Company. New York, U. S. A.

Grim, R. E.; Clay Mineralogy; 2a. Edición, 1993; Mc Graw Hill; New York, U. S. A.

Robert F. Craig; 2ª. Edición de la Traducción al Español, 1996; Logos Consorcio Editorial, S. A.; España. México.

Moo-Younq, H. K., and Zimmie, T. F., 1996; "Geotechnical Properties of Paper Mill Sludges for Use in Landfill Covers"; Journal of Geotechnical Engineering, ASCE, Vol. 122, No. 9, 768-775.
American Socety for testing and Materials, 1998; ASTM Book of Standards, Vol. 04.08; West Conshohocken, P. A.
J.N: Goodier and P.G. Hodge Jr.; Elasticicity and plasticity, 1998; 2a. Edición de la traducción al Español; John Wiley and Sons Inc. U.S.A.
Dimitri P. Krynine and William R. Judd; Principios de geología y Geotecnia para ingenieros, 2001; 2ª. Edición de la traducción al Español; Editorial OMEGA, Barcelona, España.
Harry R. Cedergren; Seepage, Drainage, and Flow Nets, 2007; 3ª. reimpresión en Español; John wiley and Sons, Inc.; New York. U.S.A.

Table No. 1

Test Specimen No.	Soil + peat Ratio	Wm (gr)	LL %	PL	IP	(OM) %
1	(a)	50	58.50	16.72	41.78	0.00
2	(a+2)	52	60.26	18.16	42.10	0.40
3	(a+6)	56	73.13	18.68	54.50	1.17
4	(a+12)	62	80.50	20.77	59.73	2.33
5	(a+20)	70	91.36	20.86	70.50	3.81
6	(a+30)	80	101.12	29.74	71.38	5.62

Table No. 2

Test Specimen No.	% of peat	(OM) %	IP
1	0.00	0.00	41.78
2	3.85	0.40	42.10
3	10.71	1.17	54.50
4	19.35	2.33	59.73
5	28.57	3.81	70.50
6	37.50	5.62	71.38

Table No. 3

Test Specimen No.	% de peat (gr)	(OM)%	Iw (Flow index)
1	0.00	0.00	10.21
2	3.85	0.40	10.68
3	10.71	1.17	15.50
4	19.35	2.33	17.60
5	28.57	3.81	21.36
6	37.50	5.62	22.30

Table No. 4

Test Specimen No.	% de peat	(OM) %	Tw
1	0.00	0.00	4.09
2	3.85	0.40	3.94
3	10.71	1.17	3.52
4	19.35	2.33	3.39
5	28.57	3.81	3.30
6	37.50	5.62	3.20

Figure 1.- A. Casagrande and R.B. Peck Plasticity Chart

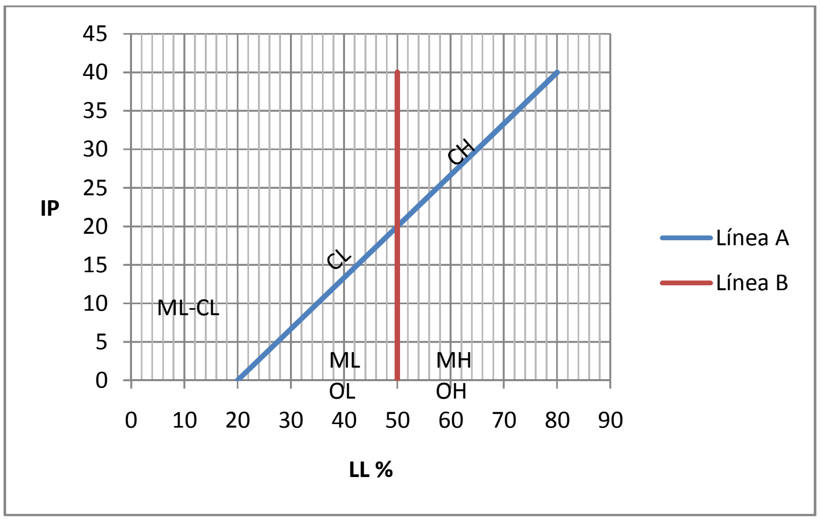

Figure 2.- Soil location in the plasticity curve, according to the organic matter content, (OM)%.

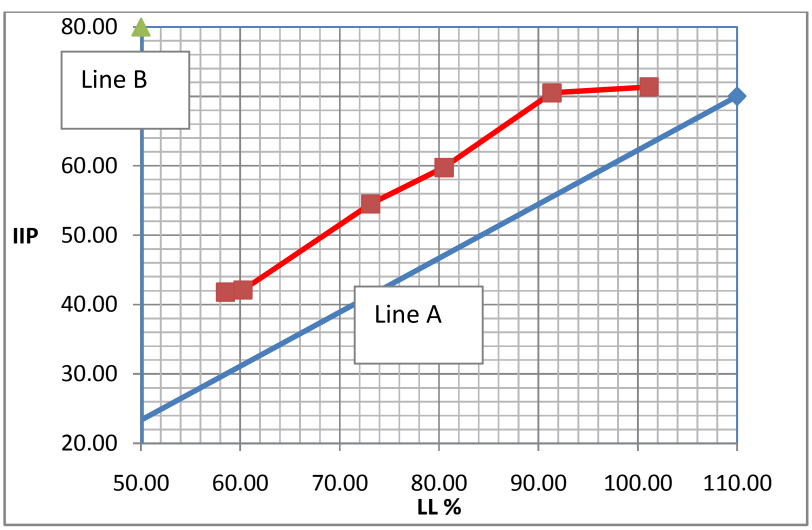

Figure 3.- Variation of the Iw, with the organic matter content (OM) %

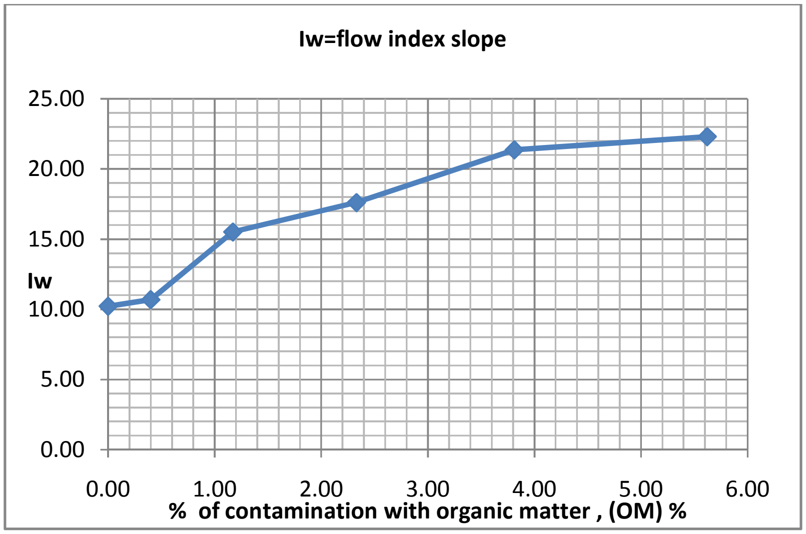

Figure 4 .- Variation of the IP , with the organic matter content, (OM) %.

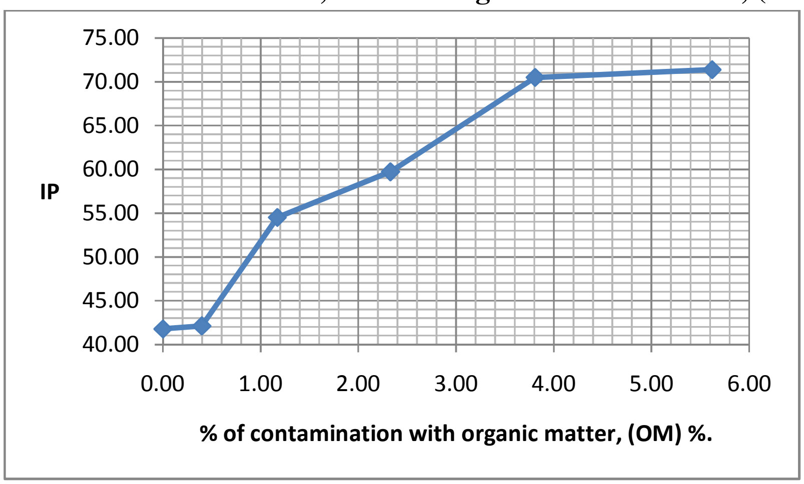

Figure 5.- Variation of the Tw, with the organic matter content (OM) %