Some experiences with clay soils in Southwestern of Ecuador

Quelques expériences avec des sols argileux dans le Sud-Ouest de l'Equateur

L. Marín-Nieto – *Department of Civil Engineering, University of Guayaquil, Ecuador*

ABSTRACT: During the costruction of a concrete lining - channel of 93 Km length and 44 m^3/seg flow, that goes through differente types of soils, it was necessary to zone the channel route according to its phisical properties for adjusting experimentally the design in particular for the expansion of some soils. During the research it was found that the Atterberg Limits correlated with the minerologic composition of the samples. allows a better approximation than other well-known methods for diagnosing behavior.

The studies for a transmision line of 230 KV - 500 Km length and levess for protecting 5000 Km^2 of flood plain, supplied important information for the research.

This paper describes the geotechnic characteristics of these soils, the research work and the results of itself.

RÉSUMÉ: Pendant la construction d'un canal de 93 Km avec revêtment de béton et un débit de 44 m^3/seg. traversant différents types de sols, il fût nécessaire de répartir en zones le trajet du canal selon ses propriétés physiques à fin d'adapter le dessin experimentalement, en particulier a cause du gonflement de certains sols. On a trouvé pendant la recherche que les Limites d'Atterberg en corrélation avec les minerals des sols permettent une meilleure approximation d'autres méthodes très connues pour appliquer son comportement.

Les études pour une ligne de transmission de 230 KV de 500 Km et des levées pour protéger 5000 Km^2 de bassins de crue ont proportionné d'importantes données pour la recherche.

Cet essai décrit les caractéristiques de ces sols, les travaux de recherche et leurs résultats.

1 INTRODUCTION

The Plasticity Chart of A. Casagrande (1932) includes the "A" Line which is a lineal regression of the Atterberg Limits test results disposed in that time. In this chart, Casagrande placed the clay soils over the "A" Line and under it, the inorganic silts and organic clays. During 60 years, the Plasticity Chart has been an important tool for the Engineer in the soil behavior diagnostic. In the sixties it was also discovered (Jiménez-Quiñonez & Deere, 1967) other clay soils, particularly of Tropic,that were under the "A" Line at par with the silts. Later were found residual clays composed of illite with Plasticity Index of 400 % under "A" Line(L.Marín-Nieto, 1975).

On the other hand, during many years, it was believed that some mechanic properties of clay soils such as expansion, compressibility and residual shear strength, had a direct relation with the Plasticity Index. (Ladd & Lambe, 1961).

Particularly, this proposition for expansive soils caused confusion and lost of money during 80s in the construction of irrigation channels.

Actually, it is known that montmorillonitic mineral is the originator of high potencial of clay soils expansion.

In order to find lab's methods that allow to correlate the Atterberg Limits with soil minerals, some researchs were made and the author presented them in different Panamerican Conferences (L.Marín-Nieto, 1991 and 1995).

This paper presents the final result of these research.

2 GEOTECHNIC CHARACTERISTICS OF STUDY SOILS

Figure 1 has placed aproximately Ecuadorian Geological regions studied before. In the most studied cases, were made mineralogic tests for determinating the predominant mineral of the soils. According to these test, soils are divided in two groups: In the first one, predominates the montmorillonite (File 5,8 and 14) and in the second one, the Illite (File 6,7,12 and 13).

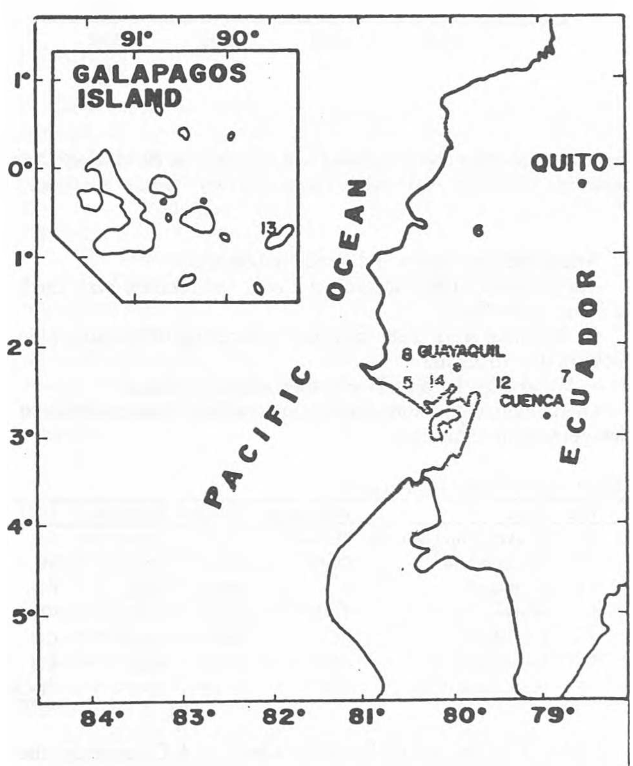
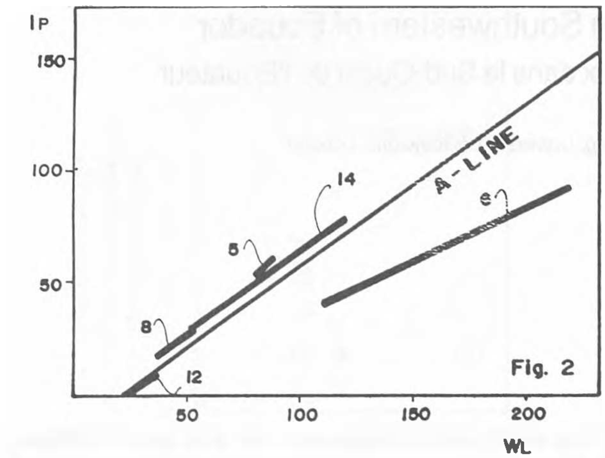
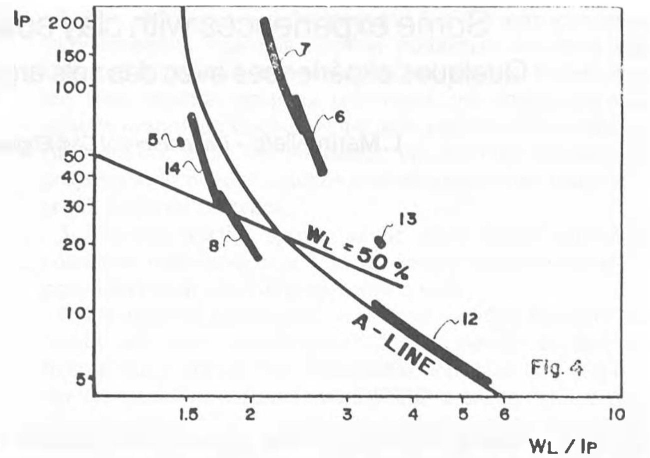


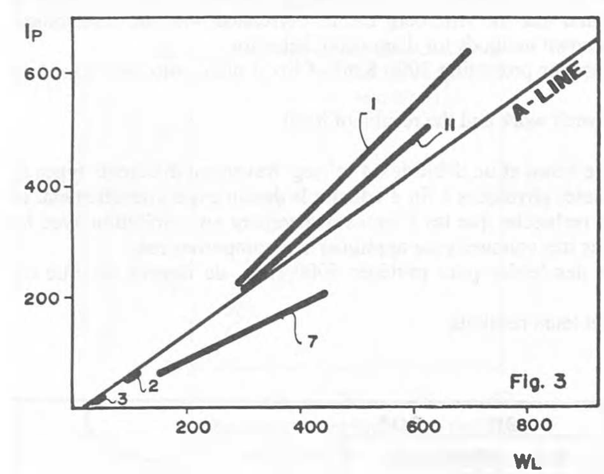
Figure 1. Ecuadorian Geological regions studied

In general, the information for the development of this research, was obtained in 3 tropical and subtropical regions geologically identified:

a. Deposits of weathered volcanic ash
b. Flood plains







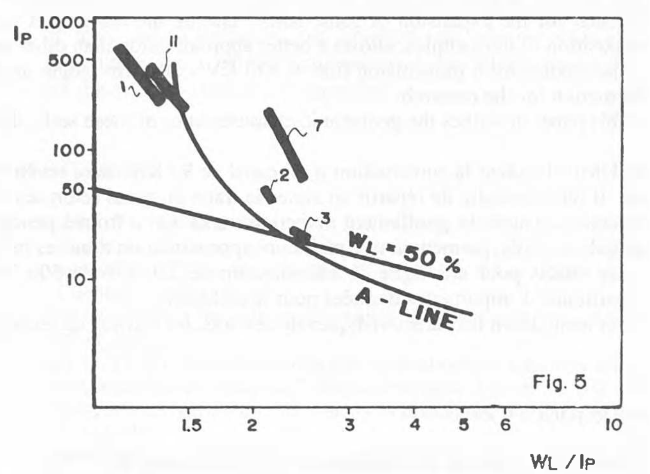


Figure 2. Strips of the principal studied soils in Ecuador in the Plasticity Chart. Figure 3 Strips of the main minerals contained in clay soils. Also has included the strips of the Mèxico City Clay and the Guarumales Clay. Figure 4 and Figure 5 Mineral Gradient Chart with the same soils of the figure 2 and 3.

c. Weathered clay shales and weathered basalts.

Addicionally, other interesting Lab's information was used, and they come from:

d. Residual soils that from the weathering of metamorphic rocks in the Amazonia.

e. Weathering basaltic lave in the Galápagos Island

The climatical and topographical geotechnic characteristics of that geological region are:

Table 1. Geotechnical Characteristics

#	File	Place	Altitude m.	°Celsius	Rain mm.	UC
a	6	Quevedo-Sto.Domingo	100-600	15-25	2000-3000	CH
b_1	12	Río Bulubulu	20-60	18-36	1500	ML
b_2	14	Guayaquil	4	18-36	1100	CH
c_1	5	Progreso	30-100	18-36	900	CH
c_2	8	Pascuales	60	18-36	1200	CH
d	7	Guarumales	1800	10-28	5000	CH
e	13	San Cristobal Island	100	10-30	1000	CL-CH

Figure 2, places in the Plasticity Chart of A.Casagrande, the principal studied soils in Ecuador. You may notice that each strip has an particular angle with regard to Liquid Limits - Axis. Part of this information was reported before (L.Marín-Nieto,1995).

Later, in the lab was determinated the expansion grade of the samples, that were correlated with the respective Mineral Gradient.

Figure # 3 has placed as well as in the Plasticity Chart, the strips of the main minerals contained in clay soils. (Montmorillonite, File 1; Illite, File2: Kaolinite, File 3). Also has included the strips of the Mexico City Clay (File 11) and the Ecuadorian Guarumales Clay (file 7), both considered for the author as very High Plasticity and Compressibility Clays. As it is known the Mexico City Clay is a Montomorillonitic Clay and the Guarumales Clay is a Illitic Clay.

3 THE MINERAL GRADIENT (W_L / I_P)

The Atterberg Limits of a soil geologically determinated are presented in the "A" Line through a restrictted strip between two extreme values of Liquid Limits and Plasticity Index.

Some times, it is probably that a geological zone has Atterberg Limit values out of that border. The mineral root stays almost constant and the Atterberg Limits vary inside those limits in the residual soils, because of the phisical-chemical intensity of the weathering proccess; and in the alluvial soils because of the hidrological proccesses in different periods. Those strips that are not extrapolating have an angle with the axle of the liquid limits. which cotangent (W_l / I_P) has been named "Mineral Gradient". (L.Marín-Nieto, 1991 and 1995). This value correlated with the Plasticity Index supplies a good identification of the soil mineral in the 80% of the cases. Some unsure tests of the Atterberg Limits do not allow this correlation.

Figures 4 and 5 present the Mineral Gradient Chart, which is a no-lineal version of the Casagrande Plasticity Chart where the "A" Line and the W_l= 50% line are ubicated. In Figures 4 and 5 have been ubicated the same soils of the Figures 2 and 3. As you may notice, there's a zone at left of "A" Line where are ubicated soils where predominates the Montmorillonite and at right predominates the Illite particularly.

4 MINERAL GRADIENT APPLICATION

In Ecuador, we have used with success the Mineral Gradient in the diagnostic of the expansion grade of soils during the construction of a irrigation channel of 100 Km length in the Santa Elena Peninsula which crossed many geological regions of the Cretaceous, Terciary and Recent Deposits. The same occurs during the construcction of levees for the flooding control at East of Guayaquil where the fill especifications of the levees obligate to not use silts but clay soils. Now it is described briefly the experience obtained.

4.1 *Channel in the Santa Elena Peninsula*

This is a channel that goes through the following geological regions:

- Basalt, granite, sandstone, siltstone of the Cretaceous, very fractured and Weathered. Piñon and Cayo Formations
- Clays Shales,limestone, sandstone, siltstone and conglomerate of Tertiary very fractured and weathered. Azucar, Progreso and Zapotal Formations.
- Clays gravel and sand recent deposits.

In this complication of more than 100 Km length, it was necessary to zone soils according to their index properties. The channel was built in excavation and fill using local materials and was covered with 10 cm of concrete-lining. The main problem during the construction was the soil expansion that varies between extreme values.

Here the use of the Mineral Gradiente Chart allowed to diagnostic the expansion grade starting from the Atterberg Limits. This allowed to improve the design in each case. Actually, the channel is in operation and the concrete-lining behavior has been good.

4.2 *Levees for flooding controls*

The especifications of these levees obligate the contractor to not use silts (ML). The region that goes through these rivers is a alluvial plain at the toe of a big alluvial fan in the Occidental Andes slopes. The plain extends 70 Km has been filled up by thick and thin alluvials and at the same time by volcanic ash deposits. Generally, thin soils are of low plasticity which make difficult to differenciate the silts (ML) from the low plasticity clays (CL) that abound through the rivers. Here, was necessary to look to the mineral gradient during the exploration works for assure to the contractor the disponibility of the specified material.

Later, the lab's staff learnt about the methodological for the field control using just the Atterberg Limits test.

4.3 *Another Mineral Gradient Applications*

Another applications have been made in the identification of the predominant mineral with fill material of rocks-joints during the tunnel excavation of 6,9 Km as a replacement method of the mineralogic tests.

In order to proove the valid of the Mineral Gradient Chart, in Figure 6 has been placed expansive soils of Ecuador and from other countries of the world, which results have been published. This Figure shows the expansion grade that we have used with success in the diagnostic of Ecuadorian expansive soils.

Other mineral gradient applications have ocurred in those cases where the mineral predominant of soil has an important effect in a particular behavior that the Soil Engineer whises to know. For example, the capacity of a soil for eroding. It is known that the soil mineral is an important piece in the surface degradation of natural sloped or excavated by man.

This is a similar case which may occur during the ambiental impact study on a topsoil of an unforest zone.

The author has had the oportunity of analyse the mineral effect variation of a Clay cover soil affected by leachate in a Municipal Solid Waste Landfill, using the Mineral Gradient.

Finally, we should say that the use of the Mineral Gradient allows the simultaneous use of the Plasticity Chart of A. Casagrande but also it adds the preliminary disgnostic of the predominant mineral on the soil which may be Montmorillonite, Illite or Kaoilin.

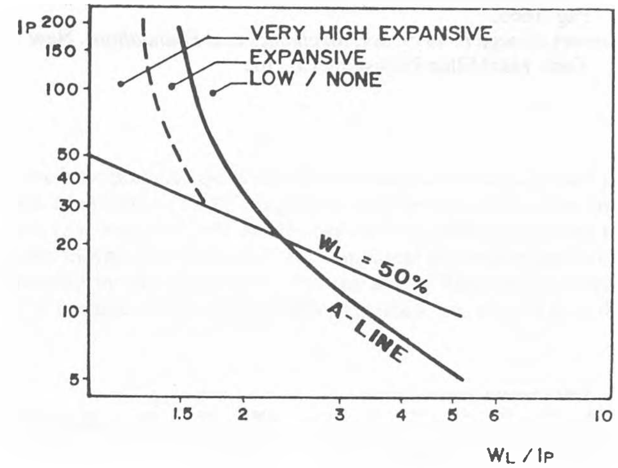


Figure 6. Mineral Gradient Chart show the expansion grade of de expansive soils of Ecuador.

5 CONCLUTIONS

1. The correlation between Atterberg Limits and the predominant mineral of clay soil has allowed the author the expansive potencial diagnostic with more success than the old methods where the expansion grade depends on the Plasticidy Index. It look that experiences obtained in Ecuador are applicable to expansive soils of other countries of the world.

2. The Mineral Gradient Chart is a no-lineal version of the Plasticity Chart of A.Casagrande which allows the use of it for classifying clay soils over or under the "A" Line.

3. It is probably that the Mineral Gradient Chart as is has been prooved in Ecuador, allows the identification of other properties in clay soils in the Environmental Geotechnics and also in cases where the predominant mineral has an important effect in the soil behavior.

REFERENCES

Casagrande A. 1932. *Research on the Atterberg Limits of Soils.* U.S.A.: Public Roads.Vol. 13 Pag. 121-136.

Jimenez-Quiñonez & Deere D. V 1967. *Physical Propierties and compaction characteristics of tropically weathered soil.* III Panamerican Conference on Soil Mechanics and Foundation Engineering. Caracas: Vol. I Pag. 333-382.

Marín-Nieto L. 1975. *Características de la arcilla residual Guarumales.* II Conferencia Ecuatoriana de Mecánica de Suelos. Guayaquil: SEMSIR.

Ladd C.C. & Lambe T. W..1961. *The identification and Behavior of Compacted Expansive Clays.* V International Conference on Soil Mechanics and Foundation Engineering. Paris.

Marín-Nieto L. 1991. *Arcillas Expansivas en Ecuador.* IX Panamerican Conference on Soil Mechanics and Foundation Engineering. Viña del Mar: Vol. I Pag. 169.

Marín-Nieto L. 1995. *Constitutive Equations for Tropical Soils.* X Panamerican Conference on Soil Mechanics and

Foundation Engineering. Guadalajara.

Progress Report.1985. *Peculiarites of Geothecnical Behavior of Tropical Lateritic and Saprolitic Soil.* Comitee on Tropical Soils of ISSMFE. Sao Paulo: Pag. 22.

Blondeau & Pilot G..1971 *Resistence au Cisaillement Residuelle des Sols Argileux en France.* Comité Francais de la Mécanique des Sols. Paris: Pag. 58-65

Mitchell J.K. et al..1991. *Ocurrence, Geotechnical, and special problems of some soils of America Residual Soils.* IX Pan. Conf. on Soil Mech. and Found Eng..Viña del Mar: Vol. IV Pag. 1666.

Sowers George F. 1979. *Soil Mechanics and Foundations.* New York: MacMillan Publishing Co., Inc.