Some geotechnical properties to characterize Mexico City Clay

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ABSTRACT
This report presents an overview of the results and findings of studies performed on the procedures and methods for defining the Engineering Properties of Mexico City Clay and, hence, to characterize them geotechnically. Research into this topic began formally in the 1950's and it is still on going. This paper summarizes the main aspects of these investigations. The author has recognized the impossibility of being exhaustive and has, instead, decided to describe mainly some of the results of research relevant to this topic in which he has participated directly and through some of his students, over the last 25 years or so. Index properties, compressibility and shear strength are all discussed from the view point of studies performed into these topics. The report also includes a brief discussion on the origins and effects of regional subsidence which affects the former lake area in the Basin of Mexico.

RESUMEN
En este trabajo se revisan los resultados y hallazgos de los estudios y métodos empleados para definir las propiedades ingenieriles de las Arcillas de la Ciudad de México y, consecuentemente, para caracterizarlas geotécnicamente. Las investigaciones sobre este tema comenzaron formalmente en la década de los años 1950 y continúan hasta nuestros días. Este artículo resume los aspectos más relevantes de estas investigaciones. El autor reconoce la imposibilidad de ser exhaustivo en este aspecto y por ello únicamente se describen los trabajos en los que él ha participado directamente durante los cerca de 25 años, con la participación de algunos de sus estudiantes. Se discuten las propiedades índice de estos materiales así como su interrelación con la resistencia y la compresibilidad. También se discuten brevemente los efectos del hundimiento regional que afecta a la antigua zona lacustre en las propiedades del subsuelo.

1 INTRODUCTION

The Basin of Mexico, sometimes called the Valley of Mexico, lies over a surface of about 7160 km2, surrounded by volcanic ranges. The lower parts of the basin, some 2050 km2, were once occupied by a system of interconnected lakes, the largest of which was lake Texcoco. The central part of Mexico City is set on the southwestern portion of the basin and it mainly rests over lacustrine clays. The lake system is practically nonexistent nowadays because it has been desiccated progressively over the last 400 years or so. The graph in Figure 1 illustrates this process.

Mexico City Clays were deposited as floccules of very small particles in lakes where salinity varied. In the northern portion, the Texcoco Lake water was rich in salts but in the south, the Xochimilco and Chalco lakes contained very small amounts of dissolved minerals. Sodium ions must have certainly had an influence on the micro structural array of these clays but research into these aspects is scarce. Pioneering investigations into these matters are due to Marsal and Mazari (1959) and P. Girault (1964) who found that the clays he studied were mostly amorphous.

2 GRAVIMETRIC AND VOLUMETRIC RELATIONSHIPS

Natural water contents and Atterberg limits in Mexico City Clays are notoriously large. These materials have been pointed out as extremely plastic clays which, correspondingly, display very low shear strengths and rather large compressibilities.

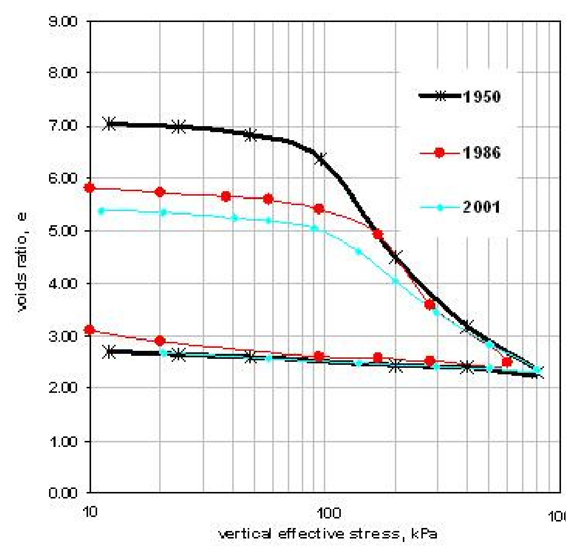

Figure 1. Compressibility curves obtained from one-dimensional compression tests on Mexico City Clay samples retrieved from the same site at three different dates.

The highest water contents in the city lake area are found in high the upper clay formation, down to a depth of about 20 m. Water contents in these clays vary considerably, depending on the location of individual sites. In general, soils towards the edges of the former lake are less humid than in the central part a situation that has been favoured by the existence of sands and sandy silts interspersed with the upper clays in the so called transition zone. Sites in the built area, having been subjected to external overburdens and exposed to the effects of regional consolidation have less pore water than the so called virgin clays which are typical of the less or newly urbanized areas, like those found in the former Texcoco Lake in which external loads have not been applied on the surface but in which regional consolidation has also had an important effect. The following data give an idea of the distribution of water content in the upper 20 m of the First Clay Formation, in different parts of the city:

- Downtown Mexico City (Cathedral) 150 to 250 %
- Densely built area (colonia Roma, first 20 m, 1986) 200 to 300 %
- Texcoco lake bed (2001) 400 to 600%

Pore water in the soils that deposited in the basin of Mexico contain dissolved minerals, mainly carbonates, bicarbonates and sodium chloride and, on occasions, small amounts of borum an element which is typical of magmatic waters (Marsal and Graue, 1969). Concentration of dissolved minerals in the clays that underlie the Mexico City urban area are generally low (say at the most 1% in weight with respect to the total amount of water) and bear no significant practical influence.

On the other hand, salt concentration in the former Texcoco Lake can be rather large. In its central and northern zones it can reach 54 000 mg/l in the first 60 m and it decreases gradually with depth and it also reduces towards the edge of the former lake area and towards the south. Maximum concentrations of salt in the Texcoco Lake may be as large as 18%, according to that provided by Murillo (1990). In any case, water content, specific gravity and every other related index properties can be corrected to account for the presence of dissolved minerals following Marsal and Graue (1969):

$$w' = \frac{w}{1-cw}$$

$$G_s' = \frac{G_s}{1+cw'} \qquad (1)$$

(2)

where w and Gs are the apparent (usual) values of water content and specific gravity; w' and Gs', are the same values corrected to account for the presence of dissolved minerals in the pore water; c is the concentration of dissolved salts or minerals, expressed as a fraction of the weights of dissolved solids with respect to the total weight of water.

2.1 Effects of regional subsidence on index soil properties

Effective stress changes brought about by the application of surface loads and, most notably, by pumping operations to extract water from the deep aquifers, have produced changes in water content, as the ensuing regional consolidation process in the Basin of Mexico goes on. These changes have also modified stress and stress-path dependent mechanical parameters, like compressibility or stiffness and shear strength. The effects of effective stress changes due to water extraction on index and mechanical properties have been discussed elsewhere (Ovando-Shelley et al, 2003, 2007). Summarily, changes in index properties can be estimated as explained in the following paragraphs.

$$w_f = w_i \left[1 - \frac{\delta(t)}{H_T} \left[\frac{1+e_i}{e_i} \right] \right]$$

Assuming that deformation of the clays is one dimensional, the following equations can be used to calculate the changes in water content from the amount of compression in the clay strata:

(3)

where wi and wf are the initial and final water content values of a clay layer of initial thickness HT; δ(t) is the vertical deformation suffered by this layer and ei is its initial void ratio. Application of equation (3) can be difficult in practice since the value of ei may at times be difficult to obtain. However, if full saturation of the clay is assumed,

$$\gamma_f = \frac{\gamma_i}{1-\delta(t)/h_i} \qquad w_f = w_i \left[1 - \frac{\delta(t)}{H_T} \left(1 + \frac{1}{w_i G_s} \right) \right]$$

, (4)

where Gs is the specific gravity.

Changes in bulk unit weights will be given by

. (5)

3 COMPRESSIBILITY

The graphs in Figure 1 show typical compressibility curves obtained from one dimensional compression tests on Mexico City clays. Samples were extracted from the urbanized area, from the same site and from the same stratum in three different dates, 1952, 1986 and 2001. The effects of regional consolidation are evident in that voids ratio of the latter specimens is lower and, correspondingly, their apparent preconsolidation pressure is larger. Yet, the virgin consolidation line of the three specimens tested is approximately the same. Further discussion into these aspects may be found in other publications (Ovando et al, 2003, 2007).

Soil samples from the Texcoco Lake subjected to one dimensional oedometer tests display qualitatively the same type of behaviour, but, as mentioned earlier, they generally have higher initial water contents and voids ratios.

3.1 Constant rate of strain tests

Result of tests performed on a strain-controlled oedometer are given in the graphs displayed in Figure 2, which have vertical effective stress as abscissae and liquidity index (LI) as ordinates (López, 2002). These tests were performed on samples retrieved from the urban area at a site belonging to the virgin lake, applying different strain rates. In general compressibility curves tend to move towards the right in σ'v -LI space as strain rate increases, which is a feature common to most soils but is more notorious in materials from the Basin of Mexico, thus reflecting their viscous character. Viscosity of the material is also evident in looking at the effects of strain rate on volumetric compressibility mv (Figure 3). From these tests the apparent preconsolidation pressure can be expressed in terms of strain rate, r, plasticity index, PI and liquidity index:

$$\sigma_c' = 45 PI (r)^{0.27 LI} \tag{7}$$

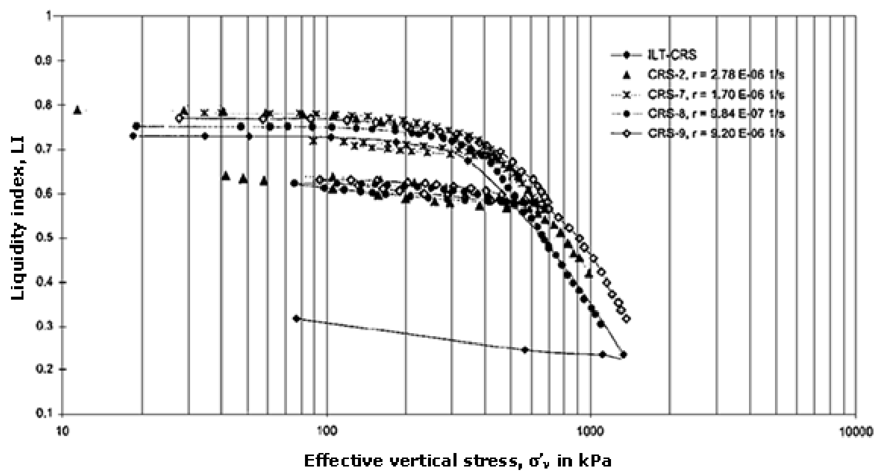

Figure 2. Liquidity index against Effective vertical stress (Tests at different strain rates)

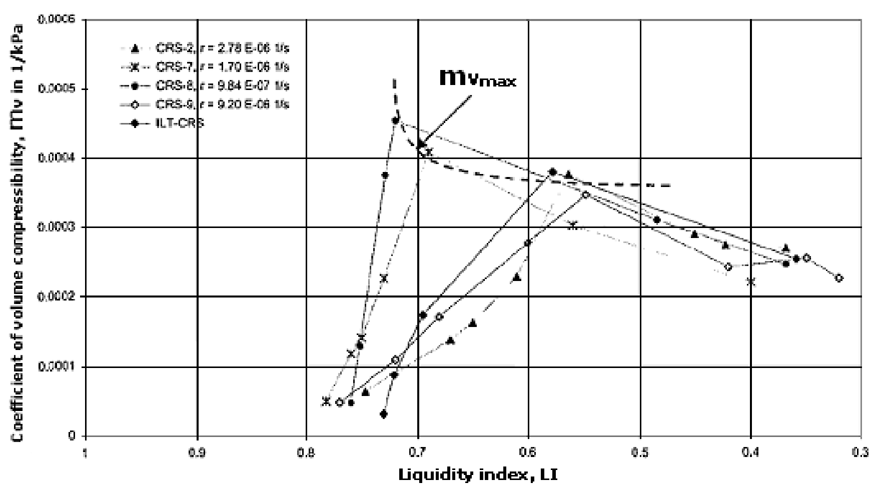

Figure 3. Coefficient of volume compressibility, mv, against liquidity index, LI.

Permeability and consolidation coefficients were related to liquidity index in Figures 4 and 5. As seen there, both kv and cv tend towards constant values as LI decreases.

The graphs displayed previously show the very large deformability of clays from the Basin of Mexico, a characteristic for which these materials have gained notoriety in the past. Large void ratios, very high water contents, young geological ages as well as the presence of highly amorphous minerals and of microfossils with large internal pores, are all the contributing factors to this extreme characteristic.

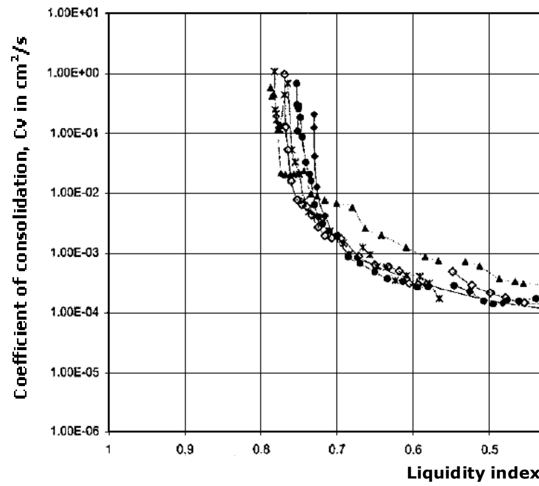

Figure 4. Coefficient of consolidation as a function of liquidity index

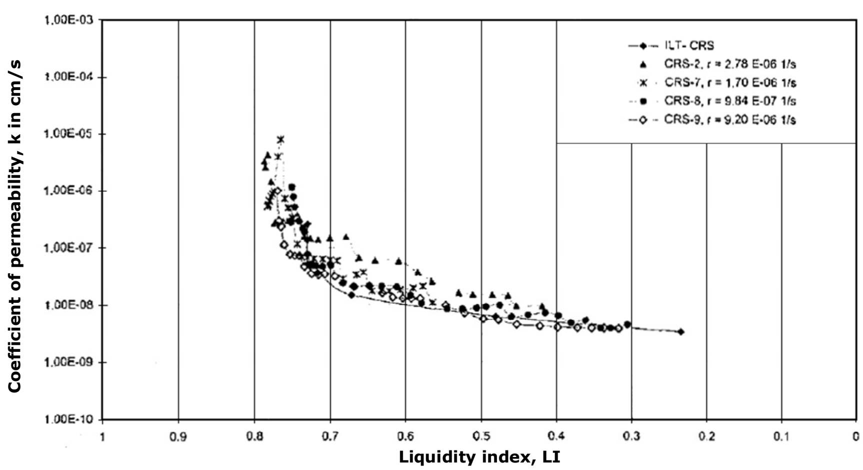

Figure 5. Permeability as a function of liquidity index.

3.2 Intrinsic consolidation properties

Intrinsic soil properties have been referred to the compressibility and strength characteristics that are inherent to the soil and independent of its natural state. They provide, according to Burland (1990), a reference framework for assessing and interpreting the significance of these same properties as exhibited by natural clays. Intrinsic soil properties can usually only be examined in reconstituted materials and the differences between these and the same properties obtained in natural materials provide a means to assess the influence of factors such as structure, bonding, cementation, ageing and stress-history.

In the paragraphs that follow we look at the intrinsic properties of the Mexico Basin Clays, as observed in the laboratory during sedimentation and one dimensional oedometer tests of reconstituted samples. Results of tests on natural clay samples extracted from the Mexico City urban zone and from Lake Texcoco. Figure 6 shows an example of compression curves obtained from tests performed on natural and reconstituted samples of clayey materials obtained at a site inside the Mexico City urban zone. The graph includes data for several European clays as well others from Bogotá and from marine clays from the Campeche Sound in the Gulf of Mexico.

Regarding the Mexican clays whose test results are shown there, the reconsolidation and testing procedures are described at length by Valderrama (2009); which were established following as closely as possible the reconstitution procedure suggested by Burland (1990). The procedure essentially postulates that the soils be reconstituted from slurries having water contents equal to one and a half times the liquid limit. The slurry is left to set in a large oedometer and afterwards vertical stress increments are applied stepwise. Loading times during consolidation/reconstitution should allow for primary consolidation to develop fully.

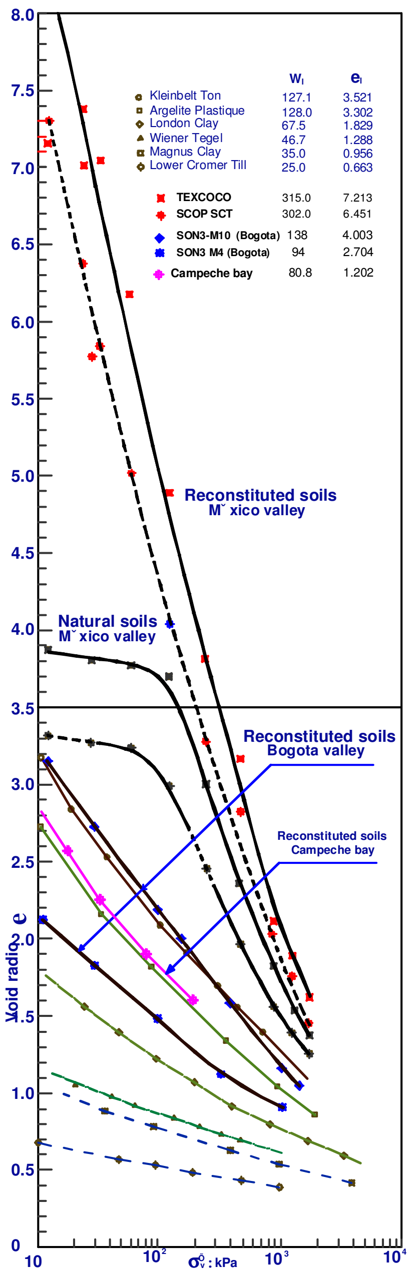

Figure 6. Typical compression curves of natural and reconstituted clays

Parameters with an asterisk (*) identify intrinsic properties. Terzaghi first defined the intrinsic compressibility constants e*100 and c*c as:

$$C_C^* = e_{100}^* - e_{1000}^* \tag{8}$$

where e*100, and e*1000 are reference values of voids ratio along a one dimensional (oedometric) compression line, corresponding to 100 and 100 kPa respectively. Another important parameter is void index, Iv:

$$I_V^* = \frac{(e - e_{100}^*)}{e_{100}^* - e_{1000}^*} = \frac{(e - e_{100}^*)}{C_C^*} \tag{9}$$

Normalized compression curves in Iv versus σ'v space can be plotted using void index as a normalizing parameter. The graph in Figure 7 was draughted using the same data as the previous figure, i.e, the normalized compression curves from a variety of sites published previously (Burland, 1990) including as a means for making comparisons, curves obtained from the testing of natural and reconstituted clays from Mexico City and Lake Texcoco; data from tests performed on Colombian clays from Bogota are also included. The intrinsic consolidation line (ICL) for the reconstituted materials is shown in Figure 7. I t has been shown previously that the ICL can be described by cubic polynomial:

$$I_v = 2.45 - 1.285x + 0.015x^3 \tag{10}$$

where x= log σ'v , with σ'v in kPa.

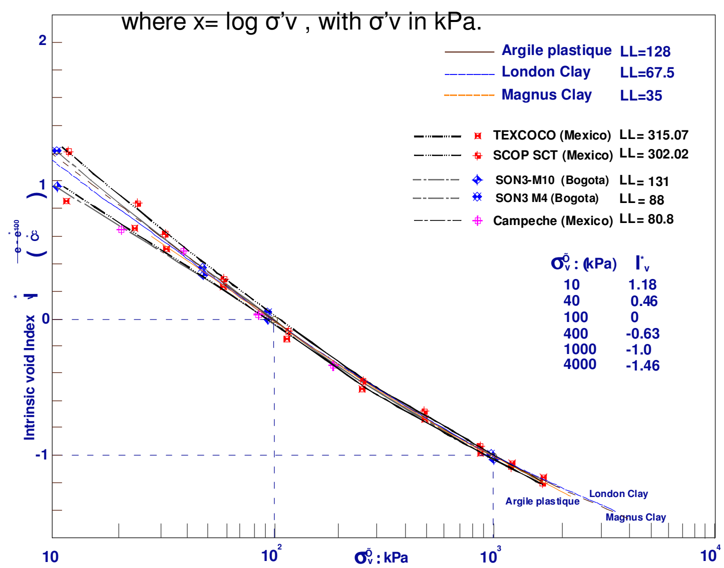

Figure 7. Normalized intrinsic compression line, Burland (1990). Added Data shown includes clays of the former Texcoco, Lake, from the urban zone in Mexico City (SCOP-SCT centre), the city of Bogota, Colombia and the Campeche Sound in the Gulf of Mexico.

According to Skempton (1970), the relationship between eo and σ'vo, in field sedimentation lines (SCL) is essentially linear and, as the effective vertical stress increases, all the curves tend towards a common limiting value of eo. Sedimentation compression lines refer to effective stresses in the field σ'vo and their corresponding voids ratios, eo;

$$I_{VO}^{*} = \frac{(e_O - e_{100}^{*})}{e_{100}^{*} - e_{1000}^{*}} = \frac{(e_O - e_{100}^{*})}{C_C^{*}} \quad (11)$$

As a result of an on-going investigation, Valderrama (2009) found that the correlations between the intrinsic compressibility constants and Atterberg's limits can be expressed as

$$e_{100}^{*} = -0.0082 e_L^{\ 3} + 0.1181 e_L^{\ 2} + 0.1983 e_L + 0.3868 \quad (12)$$

$$C_c^{*} = 0.0062 e_L^{\ 3} - .0272 e_L^{\ 2} + 0.2812 e_L \ - 0.0443 \quad (13)$$

where eL is the voids ratio at the liquid limit. Equations 12 and 13 differ from those put forth by Skempton (1944) whose data seldom exceded voids ratios larger than about 4.5 and, consequently, do not include extremely plastic clays like those found in the Basin of Mexico. The graphs in Figures 8 and 9 and plot values of e*100 and Cc* against eL as expressed by Burland (1990) and as determined in Valderrama´s (2009) research. Even though the data fits better to equations 12 and 13 than to Skempton´s, there is still some dispersion due, mainly, to uncertainties in the determination of eL.

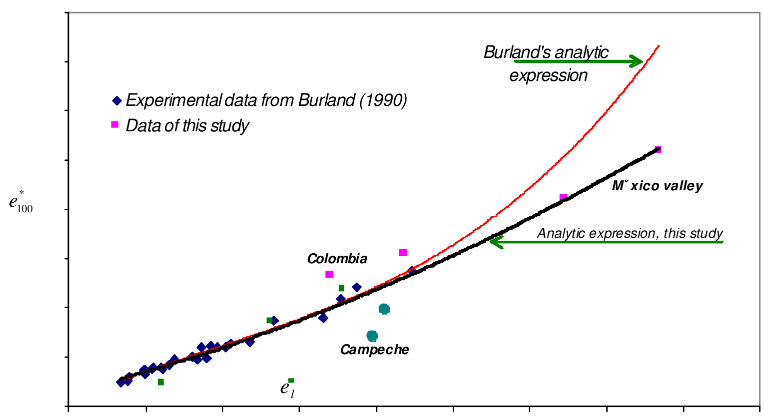

Figure 8. Reference voids ratio, e*100 as a function of eL.

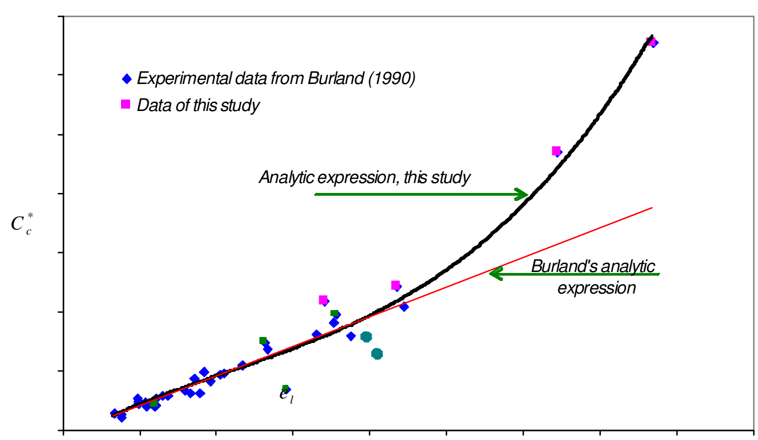

Figure 9. C*c as a function of eL.

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3.3 Secondary compression

Viscosity of the Basin of Mexico clays has a definitive influence on the behaviour of these soils during secondary consolidation. The subject is important for foundation engineering in the city since long term settlements due to secondary consolidation in these materials can be rather large as compared to those induced during primary consolidation. This topic has been studied by several authors in the past. When external loads are applied stepwise, in increments, it has traditionally been customary to separate the primary and the secondary stages of consolidation, implicitly assuming that both processes are uncoupled. This was the approach originally put forth, among others, by Zeevaert (1971) who developed a formulation based basically on assuming a Kelvin type rheological model for the Mexico City Clays.

Nonetheless, it has also been established that both processes, --primary and secondary consolidation—are coupled and that they occur simultaneously, assuming that the soil is a viscous material. One such model has been applied recently to study regional subsidence in the city (Ovando et al 2008). It is a one dimensional consolidation model in which the soil undergoing the consolidation process is assumed to be an elasto-viscoplastic material (Yin and Graham, 1994, 1996). In applying the model, the following set of differential equations must be integrated:

$$c_{ve}\frac{\partial^2 u}{\partial z^2} = \frac{\partial u}{\partial t} - \frac{1}{m_{ve}} g(u,\varepsilon_z) \qquad (14)$$

$$\frac{\partial \varepsilon_z}{\partial t} = -m_{ve}\frac{\partial u}{\partial t} + g(u,\varepsilon_z) \qquad (15)$$

$$g(u,\varepsilon_z) = \frac{\psi / v_o}{t_o} exp\left[-\left(\varepsilon_z - \varepsilon_{zo}{}^{vp}\right)\frac{v_o}{\psi}\right]\left(\frac{\sigma'_z}{\sigma'_{zo}}\right)^{\frac{\lambda}{\psi}} \qquad (16)$$

where, cve is a consolidation coefficient associated to elastic deformations, equal to k/(mveγw); k is the soil's permeability and mve is the volumetric compressibility along the elastic portion of the one dimensional stress-strain curve, equal to ∂εze/∂σ´z = (κ/vo)/(σ´z); κ/vo= Cve/2.3, where Cve□ is the slope along the compressibility curve in log time versus strain; finally κ/vo is the slope of a reference one dimensional stress-strain curve.

3.4 Correlations with other geotechnical parameters

Compressibility has been correlated empirically to shear strength. The theoretical basis for correlations between these two parameters may be stated summarily by means of expressions like the following, derived from classic Critical State Theory (Romo and Ovando 1989):

$$c_u(t) = \frac{M}{2}\left[p'_0 + \Delta u(t)\right]\exp\left(\frac{\Gamma - N}{\lambda}\right) \qquad (17)$$

where M=6sinϕ'/(3-sinϕ'); Γ and N are the ordinates in e versus p' space at a reference pressure corresponding to the critical state and virgin consolidation lines respectively; λ is the isotropic compressibility; p'0 is the initial mean effective stress and ϕ' the friction angle in terms of effective stress, The constants ϕ', Γ,λ and N are not affected by effective stress changes induced by regional consolidation.

As seen above, the relationship between shear strength cu and isotropic compressibility, λ, is exponential. Assuming that CPT strength can be correlated to the actual shear strength of soils and that λ is related to volumetric compressibility, mv, the relationship between qc and mv is thus justified. The graph in Figure 10 shows this correlation which includes additional data to not included in previous correlations (Tamez, 1992).

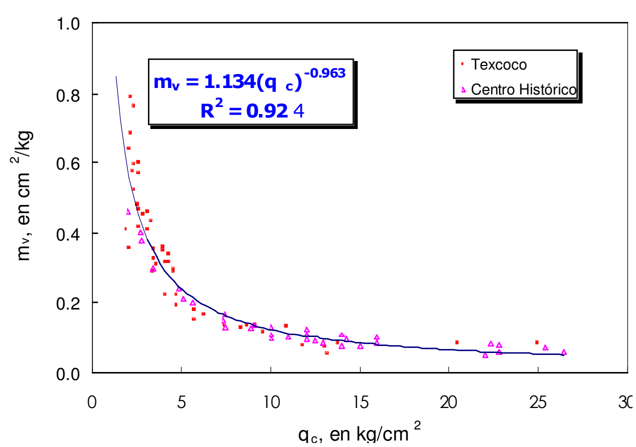

Figure 10. Correlation between penetration resistance (CPT) and volumetric compressibility, mv

4 SHEAR STRENGTH AND UNDRAINED BEHAVIOUR

Most bearing capacity problems in common foundation engineering practice in Mexico City are usually solved relying heavily on estimations of undrained shear strength from traditional UU compression tests. Shear strength in the lacustrine clays from the Basin of Mexico is typically very low, as it can be expected a priori given the extremely high water contents found in these materials. CU test results are the basis for performing

Given the geological conditions prevailing in the former lake bed and the recent effective stress increments produced by water pumping from the aquifer, the clays in Mexico City can be assumed to be normally consolidated. Consequently, shear strength can be written as

$$c_u(t) = \alpha_c \sigma'_v = \alpha_c\left[\sigma'_{v0} + \Delta u(t)\right] \qquad (18)$$

where cu(t) is the undrained shear strength, expressed as a function of time; αc is a constant; σ'v is the field vertical effective stress acting at time t; σ'v0 is a reference (initial) effective stress at time t0 and Δu(t) is the pore pressure decrement produced by water pumping during the interval t – t0.

4.1 Relationship with water content

Water content can be related to undrained shear strength from UU tests, as shown in Figure 11 (Mazari, 1996). The data presented there is a collection of a large number of experiments performed during the late 50's and early 60's on samples retrieved at different locations in the former lake zone in the central part of the city. Dispersion is so large that only allows for the identification of a general trend with a rather wide range of variability which can be attributed mainly to natural randomness of sample properties and characteristics and to sampling disturbance effects. Care was taken to minimize the latter factor.

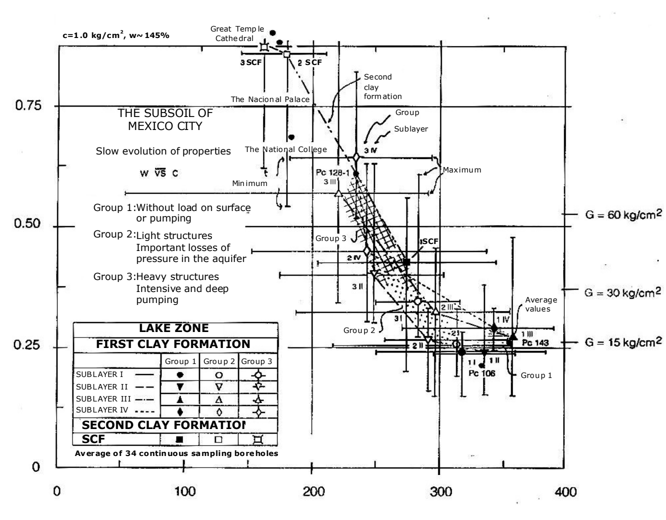

Figure 11, Shear strength from UU tests as a function of water content (Mazari, 1996)

Another influencing factor is stress history, which is not fully accounted for in relating any property to water content alone, i.e. normally consolidated and overconsolidated soils cannot be discriminated by merely considering water content albeit, Mexico City clays are mostly normally consolidated or slightly overconsolidated.

4.2 Observed behavior from CU tests

CU compression tests show that φ (total stress) values range from about 16° to slightly more than 22°. CU tests with pore pressure measurement yield φ' values that often exceed 40° as seen, for example, in Figure 12. That figure presents the results, in terms of effective stress paths, of a suite of three CU tests performed on normally consolidated samples of Mexico City Clay reconsolidated isotropically in the laboratory. It is evident from that figure that the stress paths shown there can be normalized and, indeed, the complete stress-strain behaviour can be normalized in the manner suggested by, inter alia, Wood (1990).

From the results of a set of CU tests carried out in order to investigate the applicability of the Modified Cam Clay model, based on classical plasticity, to Mexico City Clay (Giraldo, 1996), it was concluded that classical elastoplastic models can be used to model the behaviour of isotropically consolidated Mexico City Clay in a normally consolidated or a slightly overconsolidated state. The model did not work well for highly overconsolidated samples (say OCR>4). A natural implication of this finding is that Critical State concepts can also be used to interpret some of the aspects os the behaviour of the Clays from the Basin of Mexico.

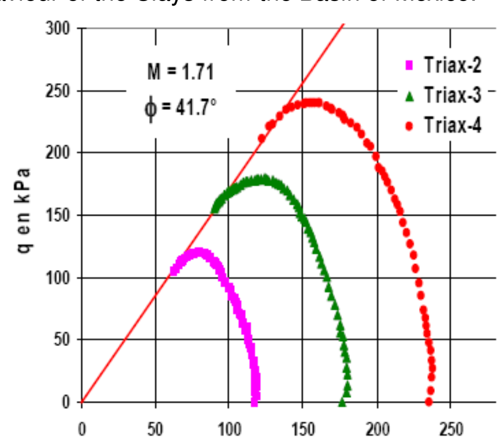

Figure 12, Example of effective stress paths for Mexico City Clay specimens. Normally, isotropically consolidated materials.

4.3 Effective shear strength from undrained tests

The following paragraphs are based on the work by Romo and Ovando-Shelley (1989):

For non-brittle normally consolidated soils and for lightly overconsolidated materials the following expressions may be used to estimate approximately their undrained strength:

$$c_u = \frac{M}{2} p'_0 \, exp\left[\frac{\Gamma - N}{\lambda}\right] \tag{19}$$

$$c_u = \frac{M_{0c}}{2} p'_1 \, exp\left[\frac{\Gamma - N_{oc}}{\lambda}\right] \tag{20}$$

where p' is the mean effective stress; λ is the isotropic compressibility parameter in v (=1+e) versus p' space; N and Γ are the values of v along the virgin consolidation line and the critical state line in that same space at a reference pressure; M is the slope of the critical state line in q-p' space. NOC, and MOC refer to these same values but measured along a line parallel to the virgin consolidation line in which the value of OCR is constant, as seen in Figure 13.

From the geometry of Figure 13, the value of pore pressure at failure can be estimated with the following expression:

$$u_f = p_f - p'_0 \exp\left[\frac{\Gamma - N}{\lambda}\right] \tag{21}$$

An analogous expression to equation 21 may be derived to evaluate ufo for overconsolidated materials making use of the reference line OCL (see Figure 13):

$$u_{fo} = p_f - p'_1 \exp\left[\frac{\Gamma - N_{OC}}{\lambda}\right] \tag{22}$$

Equations 21 and 22 are useful for defining effective stresses at failure from conventional CU tests where with no pore pressure measurements as it is commonly the case in local practice in Mexico.

$$M = M_t \frac{p_f}{p'_0} \exp\left[\frac{N - \Gamma}{\lambda}\right] \tag{23}$$

where Mt is the value of M in total stresses (6sinφ/(3-sinφ). Having M, φ' can be estimated from a total stress CU from:

$$\sin \varphi' = \frac{3a}{6 + a} \tag{24}$$

where

$$a = M_t \frac{p_f}{p'_0} \exp\left[\frac{N - \Gamma}{\lambda}\right] \tag{25}$$

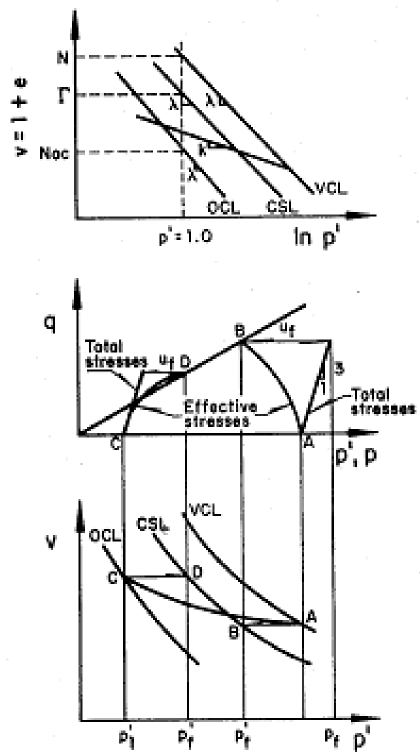

Figure 13. Some basic definitions from Critical State Theory.

4.4 Other useful relationships

The key parameters for describing the behaviour of a soil according to Critical State Theory are λ, N and Γ. As seen in Figure 14 (Echeverri,1996), and using the results of tests on Mexico City Clay and other Mexican soils, the isotropic compressibility, λ, may be related to natural water content, wn, and liquid limit, LL, by means of:

$$\frac{\lambda}{w_n} = \exp[0.508LL - 1.693] \tag{26}$$

Regarding N and Γ, experimental data show, as illustrated in Figure 15, that there also exists a relationship between them (Romo and Ovando-Shelley, 1989):

$$\Gamma = 0.2616 + 0.8138N \tag{27}$$

Finally, Figure 16 shows the relation between N and NOC, for different overconsolidation ratios.

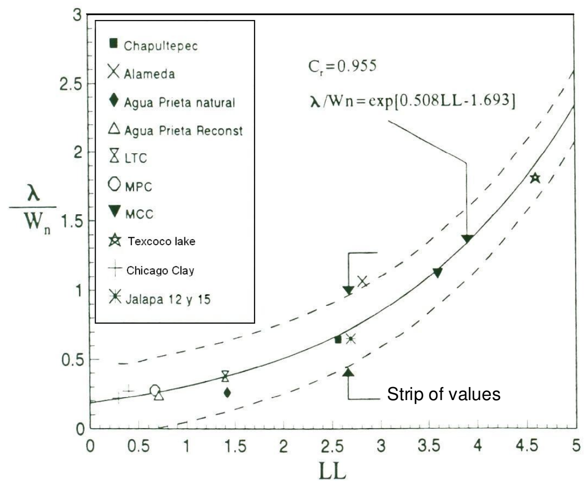

Figure 14. Relationship between λ/ων and liquid limit (after Echeverry, 1996).

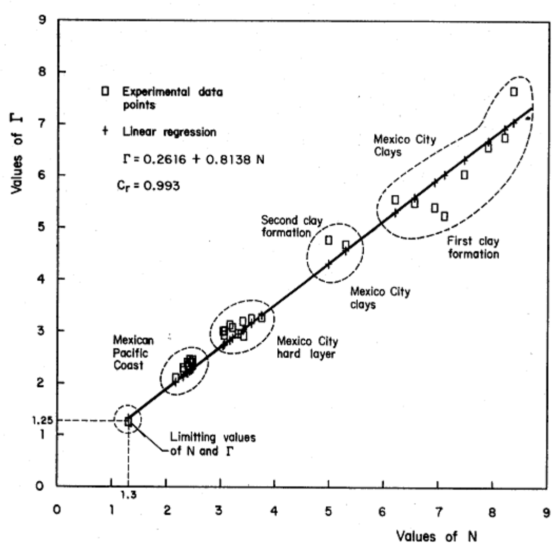

Figure 15. Relationships between Γ and N

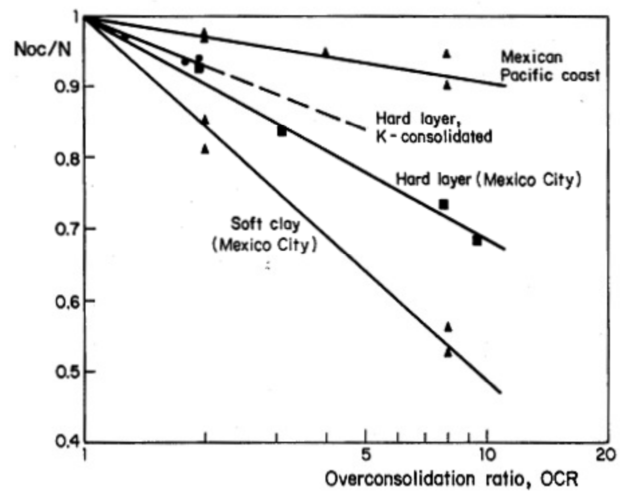

Figure 16. Relationship between N, NOC and overconsolidation ratio

4.5 Undrained strength from CPT penetration resistance

Cone penetration tests have been used widely to estimate undrained shear strength from them. A number of empirical correlations have been put forth, most of which include a measure of the in situ vertical stress. The general form of them is:

$$c_u = \frac{q_c - \sigma_v}{N_k^*} \tag{28}$$

The graphs in Figure 17, obtained from field and laboratory data performed on three sites and samples from the former Texcoco Lake (Alanís, 2003) show that the actual value of the correlation factor Nk* is site dependent thus suggesting that using expression 28 requires calibration and corroboration at each individual location.

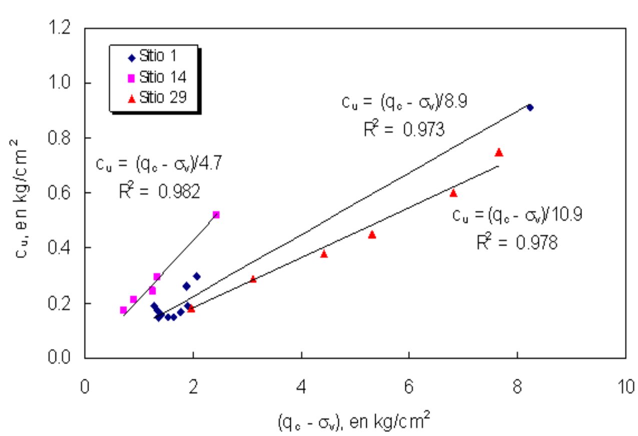

Figure 17. Site dependent correlations between shear strength and CPT resistance.

However, another empirical correlation has proven to provide much better estimates of shear strength from CPT tests, for the case of Mexico and Texcoco Clays. The correlation, which can be considered to be of general applicability for the Basin of Mexico clays, is simpler than expression 28 and it was due to Santoyo et al (1989):

$$c_u = \frac{q_c}{N_k} \tag{29}$$

A large number of field and laboratory determinations shows that a very good agreement between shear strengths estimated with equation 29 and actual laboratory measurements (UU tests) is obtained when Nk = 13. The graph in Figure 18 (Alanís, 2003) provides an example to justify this assertion.

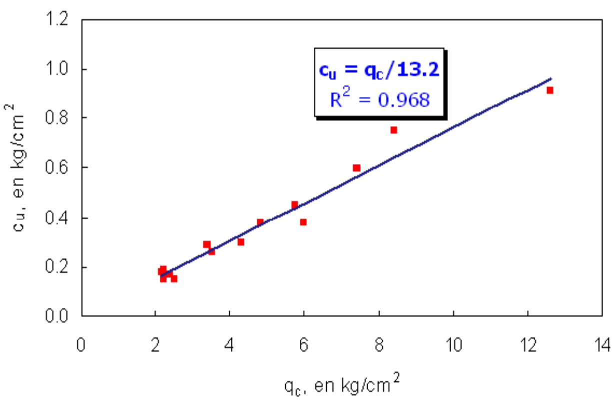

Figure 18. General correlation for estimating shear strength as a function of CPT resistance for the clays from the Basin of Mexico

5 FINAL REMARKS

The totality of the area formerly occupied by lakes is now sinking on account the intense exploitation of the aquifers that underlie the soft clayey soils. Deep well pumping produces the depletion of pore water pressures and that, in turn, increases effective stress in the clay masses. The ensuing consolidation process changes the index and mechanical properties of the soils, both under static and under dynamic conditions.

Compressibility of these clays is very large and depends strongly on loading patterns and strain rate, as described here. Viscosity is shown to be a parameter of major importance in describing consolidation under one dimensional loading of these materials. Intrinsic properties of soils from the Basin of Mexico are scarcely known but the results presented in this report corroborate that, indeed, these materials are amongst the most compressible and deformable. Results shown here also confirm the existence of a unique, normalized compressibility curve expressed in terms of the intrinsic voids index. This curve appears to be valid for a large variety of soils, as demonstrated here.

Shear strength is also rate dependent but some of the main features of the static undrained behaviour of these soils can be modeled reasonably well with classical plasticity models. As shown here, that finding can be used advantageously to interpret the results of total stress CU tests, as performed routinely by geotechnical consultants in Mexico City.

Plasticity index and relative consistency were shown to be key parameters in defining some of the most relevant features for defining shear strength and compressibility. Data shown here also confirm the validity of empirical correlations between these two properties and results from cone penetration tests.

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