A comparison between C_α/C_c obtained through parametric studies and laboratory tests

Une comparaison entre le rapport C_α/C_c déterminé par paramètres et par des essais de laboratoire

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ABSTRACT: According to Mesri and Godlewski (1977) for any soil there is a unique relationship between secondary compression index C_α and compression index C_c wich value is in the range of 0.02 e 0.10. This relationship has been confirmed for several authors. This paper presents values of C_α/C_c determined for two clay deposits in Baixada Santista (São Paulo-Brazil) using two procedures. In the first procedure, a parametric analysis based on stress history was performed (related with geologic history of the region), and there were used results of oedometer tests (preconsolidation pressures) and field record settlements of a higway embankment. In the second procedure the C_α/C_c relationship was determined through oedometer tests conducted on other clay samples of the same region. The results obtained for both procedures were similar and compactible with this kind of soil.

RESUME: Mesri et Godlewski (1977) ont dit que pour quelque sol il y a seulement une relation C_α/C_c, laquelle est comprise entre 0.02 et 0.10. Cette relation a été confirmée par plusieurs auteurs. Cette communication montre valeurs de C_α/C_c obtenus pour deux dépots d'argile de la Baixada Santista (São Paulo-Brésil) par deux procès. Dans le premier cas, on a utilisé une détermination paramètrique embasée dans l'historique de tensions (qui est relacionée avec l'histoire de la région) et résultats des essais oedomètriques et lectures de tassements faites dans un remblai routier. Dans le second cas C_α/C_c a été obtenu par des essais du laboratoire, qui ont été realisés avec d'autres échantillons d'argile de la région. Les résultats obtenus ont été semblabes et compatibles avec ce type de sol.

INTRODUCTION

According to Suguio and Martin (1978), the sea level fluctuations during the Quaternary, constitutes the main mechanism of formation of marine sediments along the coast of São Paulo (Brazil). The formation of these soils is connected with two transgressive phases: the Cananéia transgression, ocurred in the Pleistocene, and the Santos transgression, ocurred in the Holocene. The final part of the latter transgression has been studied in detail, utilizing more than 125 radiocarbon datings. From these datings, and other data, Martin et al. (1978) have outlined sea level fluctuations curves for the last 8,000 years for several parts of this coastline. The soils which had been formed in the Santos transgression, called Fluviatile-Lagoonal and of Bay origin clayey-sandy Sediments (denoted by FSL in this paper), were submitted to *sui generis* sea level fluctuations. Eight thousand years ago all the Brazilian coast was submitted to a submersion process that continued until near 5,000 years ago. After this period started the emersion process, alternated by the sea level negative fluctuations. The duration of each event and also maximum and minimum sea level fluctuations suffered small local variations during this process.

The origin of the overconsolidation of FSL was related with the sea level negative fluctuations (Massad 1985). Using a sea level fluctuation curve of the coastline between Itanhaém and Santos, Pérez (1995) gave an explanation of the overconsolidation of these soils, by means of a stress history model related to geologic history of these sediments, associating the aging phenomena with the sea level negative fluctuations. To analyse this, it was performed a parametric analysis regarding as variables the C_α/C_c relationship and the amount of sea level negative oscilation (x). The C_α/C_c value obtained by this procedure was compared with the value of C_α/C_c obtained through oedometer tests on other clay samples of the same region (Gonçalves 1992). These tests were reinterpreted to elaborate this paper.

2 METODOLOGY

Through an end of primary (EOP) e-log σ'_v curve and assuming values of C_α/C_c, there were calculated time lines corresponding to secondary compression [void ratio (e)-log effective vertical stress (σ'_v) curves for different times] using the procedure proposed by Mesri and Godlewski (1977). At this diagram the geologic history of some fluviatile sediments was simulated. The preconsolidation pressures σ'_p, due to the effects of both the sea level negative oscilations and the aging, were estimated using the Equation 1 (Pérez and Massad 1996):

$$\sigma'_p = (\sigma'_{vo} + \gamma_w x)[1 + C_\alpha / C_c . \ln(t / t_p)] \qquad (1)$$

where σ'_{vo} = effective vertical stress before the sea level negative oscilation x; γ_w = unit weight of water; t_p = time required for the completion of primary consolidation that was found to be 1 year approximately in the field when a stress increment yields a stress greater than σ'_p; and t = time of aging adopted to be 150 years. The value of C_α/C_c was assumed to vary in the range of 0.03-0.06 that corresponds to inorganic soft clays and highly organic plastic clays (Mesri and Godlewski 1977). The value of x varied in the range of 1-2 m.

The analysis above was performed on three deposits of FSL (Pérez 1995) only one of them is presented in this paper. It is a 3 m high earth embankment that had been built for the Imigrantes highway (Cubatão-Baixada Santista, São Paulo) from which there are measurements of settlements. The local subsoil is constituted of 17.8 m thick of FSL over a fine organic sand layer. Before the embankment was built, 8 clay samples were removed from different depths into the deposit of FSL and convencional oedometer tests were carried out. From the results of the parametric analysis, were made graphics presenting values of σ'_p calculated for each C_α/C_c adopted and different x values as a function of the depht z. On these diagrams were plotted the σ'_p

values obtained from the oedometer tests. The σ'_p - z - C_α/C_c -x curve that best fits the σ'_p values obtained from the oedometer tests determines C_α/C_c and x.

Another procedure for the determination of C_α/C_c was based on data of convencional oedometer tests performed on clay samples obtained from Santos region (Gonçalves 1992). All the load increment stayed in each sample for enough time to cause more than one cycle of secondary compression. Some of these tests were reinterpreted to determine C_α/C_c, and then it was compared with values obtained from the parametric analysis.

3 RESULTS

The results are shown in Figures 1 and 2 for the Cubatão soft clay . Figure 1 shows σ'_p - z curves as function of C_α/C_c and x obtained from the parametric analysis, and the σ'_p values got from the oedometer tests. It is observed that the σ'_p - z curve which best fits the σ'_p values obtained from the oedometer tests, correponds to x = 1.5 m for a C_α/C_c = 0.05. The primary settlements were estimated using the σ'_p values obtained from the parametric analysis. The primary settlement calculated was 14 % higher than the observed settlement on the embankment, showing a good enough agreement.

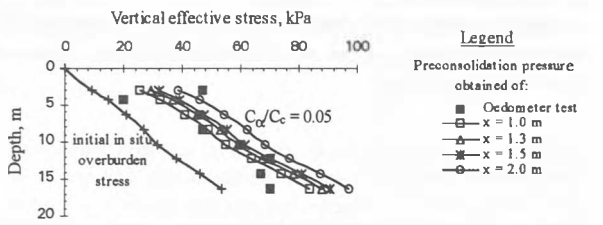

Figure 1. σ'_p-z-x curves of Cubatão clay (Pérez 1995)

Figure 2 shows a plot of C_α versus C_c obtained from Gonçalves' data tests performed on Cubatão soft clay. As the clay samples were not of a very good quality, it was only used the data corresponding to stresses 3 times higher than the preconsolidation pressures. This procedure was based on the hypothesis that to a stress higher than the preconsolidation pressure, the determination of C_α and C_c is just a little influenced by the quality of the samples. The data points lead to a relationship C_α/C_c = 0.057 (the regression coefficient R^2 is 0.65). This confirmed the C_α/C_c value obtained through parametric analysis.

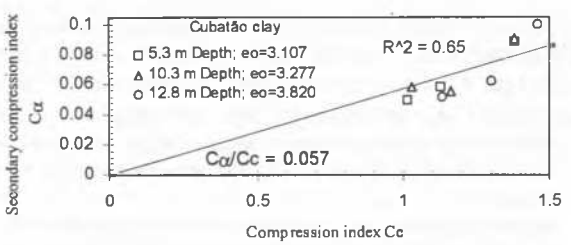

Figure 2. Values of Cα = δe/δlog t and Cc = δe/δlog σ'v for Cubatão

There were also analysed tests carried out on a very organic soft clay specimens obtained from an unique block from Guarujá (city of Baixada Santista). The sample of this material was obtained by hand excavation of a large block at a depth of 3.1 m. Two tests were performed on 42 mm height specimens and two tests were performed on 30 mm height specimens. This soil is a very heterogenous one; the natural void ratios (e_o) of these specimens varied in the range of 2.48-4.98. However, the preconsolidation pressure σ'_p can be considered equal to 85 kPa, value determined on three out of the four tests conducted.

Figure 3 shows a relationship between C_α and C_c for specimens of Guarujá clay. The C_α/C_c value obtained was 0.089 which corresponds to highly organic soils. For this deposit of clay, it was not possible to do a parametric analysis due to the lack of data.

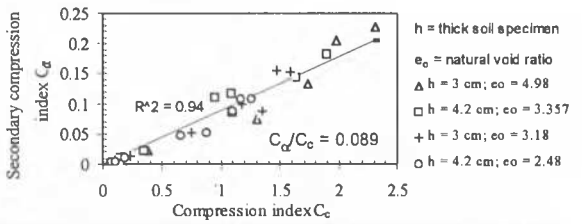

Figure 3. Values of C_α = δe/δlog t and C_c = δe/ δlog σ'v for Guarujá soil

4 CONCLUSIONS

The present paper confirms the hypothesis that the oveconsolidation of the fluviatile sediments (FSL) in Baixada Santista (São Paulo-Brazil) is related to two mechanisms: the sea level negative fluctuations and the aging. Through parametric analysis based on geologic history, it was possible to estimate the C_α/C_c = 0.05 value for the Cubatão clay. Similar value was obtained by means of laboratorial data tests. Furthermore, the C_α/C_c value for tests conducted on Guarujá specimens is 0.089.

The relationship C_α/C_c, determined on both soils, belongs to the range of values found for several authors in these kinds of clays.

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