Effect of Preloading on Secondary Consolidation of Peaty Clay

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ABSTRACT: Special consideration should be given to secondary consolidation settlements during service in the construction of high road embankments in lands underlain by thick layers of soft peaty clay. Usually a preloading design will be done to ensure that the peaty clay will remain in an over consolidated state during the operation of the road. At a stage of surcharge removal the in service settlement has to be estimated. In a preloading design the practically achievable over-consolidation ratios are in the range of 1.1 to 1.2. Effectiveness of such over-consolidation ratios (OCR) in keeping the long term in service secondary consolidation settlements within acceptable limits was studied in this research. Oedometer tests were done simulating the process of loading-unloading-reloading. Further tests were done on undisturbed samples obtained from preloaded peaty clay layers in two different projects. Results illustrated that the level of reduction of C_α is related to the achieved OCR.

1 INTRODUCTION

Limiting the consolidation settlements within acceptable limits during service is a major challenge faced by geotechnical engineers in the construction of high road embankments in lands underlain by thick layers of soft peaty clay. The preloading design will involve the application of a surcharge to ensure that the peaty clay will remain in an over consolidated state during the operation of the road. During the construction, the loading would be applied in stages to prevent shear failures. Prefabricated vertical drains would be used to accelerate the process of consolidation.

When the decision to remove the preload is taken, the possible primary and secondary consolidation settlements during service will have to be estimated. In this estimation process the over consolidation ratio that would prevail during the operation would be estimated. Peaty clays are known for high secondary consolidation settlements and the reduction of secondary consolidation caused by the over consolidation effect is a very important aspect in this decision making. The coefficient of secondary consolidation C_α is the key parameter in this analysis.

2 METHODOLOGY

Practically, with thick layers of peaty clay and high embankments, the over consolidation ratios achievable in the field will be around or below 1.2. In order to assess the changes to the coefficient of secondary consolidation caused by over consolidation effect, tests were done in Oeodometer with loading unloading and reloading increments.

Several such series of tests were done on remoulded samples of peaty clay. These tests were referred to as “Simulated Tests” in this paper. Loading durations of both one and three days were used. Mostly loading increments of three day duration were used. Non decayed pieces of wood and other impurities such as gravel particles were removed and peaty clay was remoulded to ensure uniformity. Remoulded sample was left in bucket for four weeks to allow for thixotropic strength gain before the testing commenced.

After loading the sample to some stress level, loading ratios of the order of 1.05 to1.1 were maintained instead of doubling as in the conventional test. After unloading the sample to a pre-decided stress level reloading was also done along same stress values as in the loading increments. With this procedure OCR values in the range 1 to 1.2 could be achieved in the re-loading increments.

A typical sequence of loading increments used was;0-7-13-27-52-57.2-62.92-69.21-76.131-83.74-92.13-kNm^2 unloaded to 27 kNm^2 and reloaded on 52-57.2-69.21-76.13-83.74-92.12-101.13.

Subsequently, tests were done on undisturbed samples obtain from two projects where the peaty clay layer had been subjected to a load of a fill for some time. The two projects are the Colombo Katunayake Expressway (CKE) and Colombo fish market project. In these cases the loading duration was of one day only. Stress level was doubled in each loading increment in the conventional manner.

3 SIMULATED TESTS WITH REMOULDED PEATY CLAY

The e vs log (σ) plots for loading/unloading/reloading increments obtained from three samples are presented in Fig. 1, for tests with three day load duration. A plot for the tests with one day load duration is presented in Fig. 2. The e Vs log (time) plot for two typical early loading increments (where loading was doubled) are presented in Fig. 3 and Fig. 4.

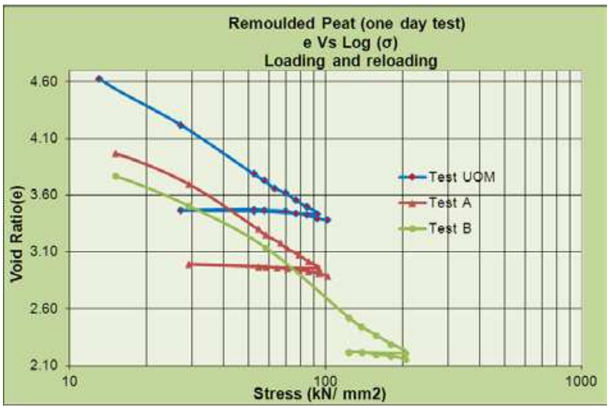

Fig. 1 Void ratio Vs Log σ for different samples (three day test)

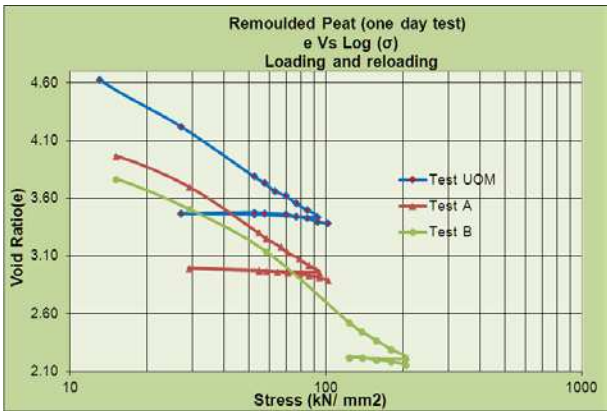

Fig. 2 Void ratio Vs Log σ (one day test)

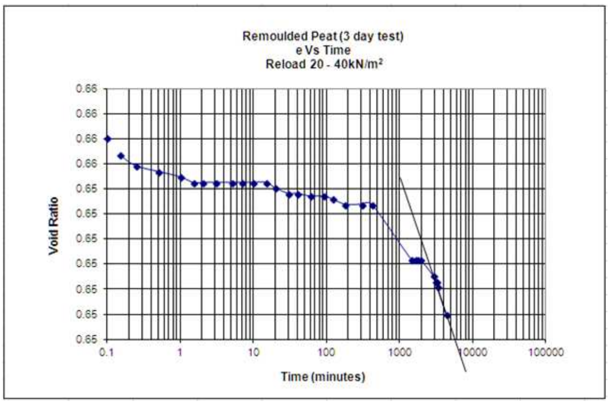

Fig. 3 e Vs log(time) plot (3 day test) initial increments

Due to the effect of high secondary consolidation, the gradient of the e Vs log (time) graph did not reduces with time as in inorganic clays.

At later stress increments of the test the load was increased by ratios of 1.05 -1.1instead of doubling. This also had an influence on C_α as seen in Fig. 5 and Fig. 6. A sudden increase of the gradient of the graph could be seen towards the end of the load increment. The effect is very pronounced in three day tests.

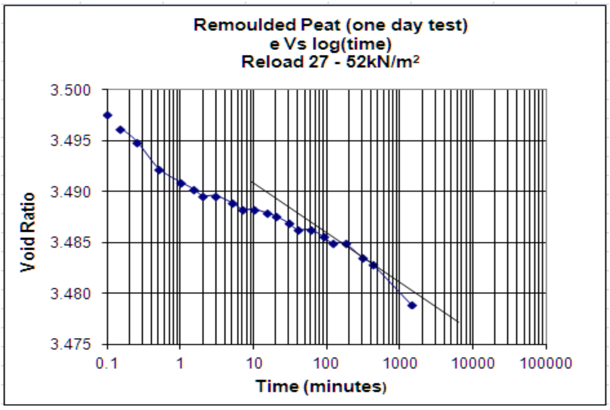

Fig. 4 e Vs log(time) plot in 1 day test –Initial increments

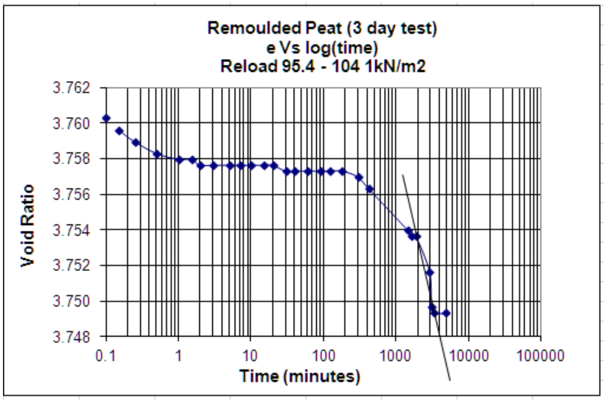

Fig. 5 e Vs log(time) plot(3 day test)-late increments

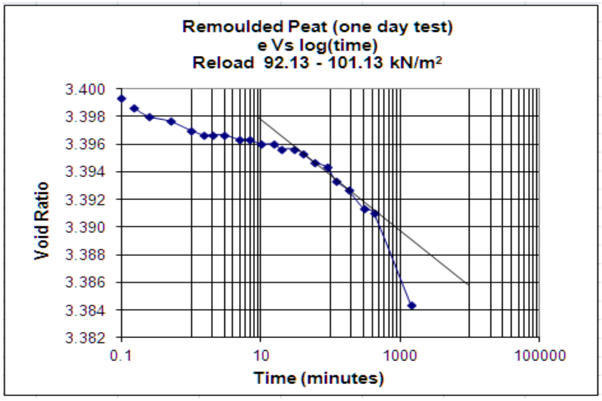

Fig. 6 e Vs log(time) plot (1 day test)-late increments

Using these basic data the variation of C_α with stress level for one and three day load durations in loading and reloading increments were evaluated. A typical plot for a three day tests is presented in Fig. 7 and for a typical one day tests is presented in Fig. 8.

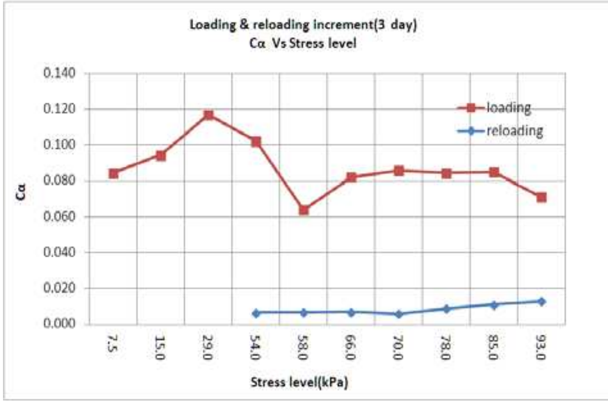

Fig. 7 Variation of Cα with stress level in loading and reloading increment (A typical three day test)

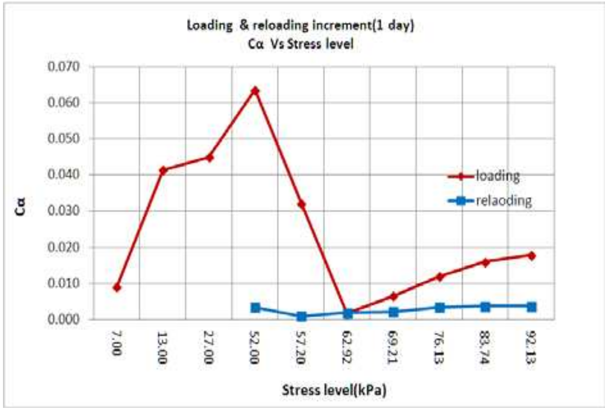

Fig. 8 Variation of Cα with stress level in loading and reloading increment (A typical one day test)

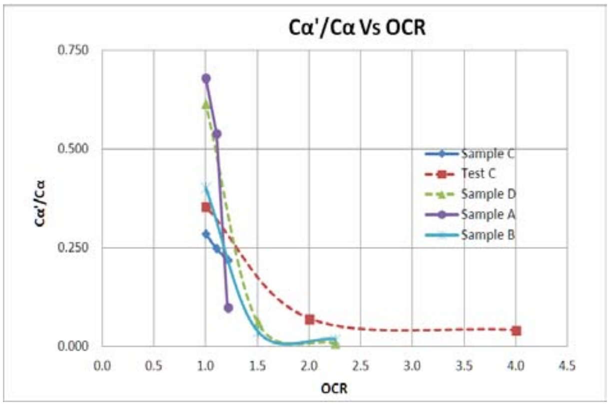

Fig. 9 Reduction of Cα with OCR (3 day tests)

In a typical test a sample was loaded to a stress level (92.13 kN/m^2) unloaded (27 kN/m^2) and then reloaded along increments 52-57.2-69.21-76.13-83.74-92.12-101.13. Using this data an over-consolidation ratio was computed for the reloading increments. The values of OCR are; 1.77, 1.61,1.33, 1.2 and 1.1.The C_α value of a reloading increment was denoted here by $C_\alpha^{/}$ and that of the corresponding loading increment was denoted by C_α. With this the ratio $C_\alpha^{/}/C_\alpha$ which reflects the reduction was calculated and plotted against the corresponding over-consolidation ratio. A plot done using data obtained from five different series of tests of three day duration is presented in Fig. 9. A plot for one day tests is presented in Fig. 10.

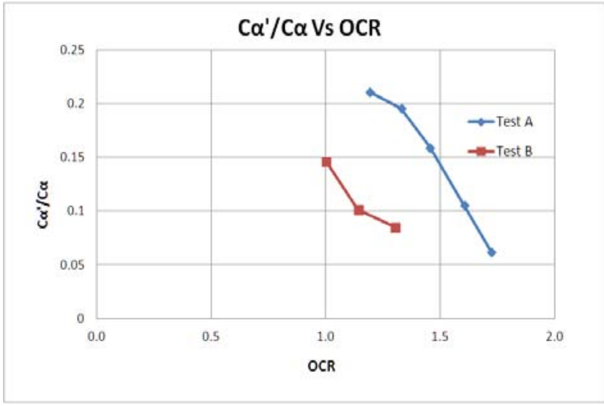

Fig. 10 Reduction of Cα with OCR (one day tests)

The results clearly indicate that the coefficient of secondary consolidation could be significantly reduced even if an over consolidation ratio of 1.1-1.2 is achieved. The reduction is greater with greater values of OCR. The data are with some scatter but the trend is quite clear. Mesri et al (1997) presented the reduction of C_α of Middleton Peat (a fibrous Peat) due to surcharging. The peaty soils encountered in Sri Lanka are amorphous with a greater degree of degradation and are mixed with clays. The organic contents are of the order of 20-40% and they are termed peaty clay. Mesri and Godlewski(1977) presented the concept of C_α/Cc and the highest values of the ratio were observed 0.06 for fibrous Peats. For Sri Lankan Peaty clay which are amorphous and mixed with inorganic clays (with organic contents of the order of 30-40%), this ratio is around 0.0338(Thvasuthan and Thilakasiri 2011) when there is no over-consolidation effect. When there is an over consolidation effect the C_α value is much lower and depends on the prevailing OCR.

3 TESTS ON PEATY CLAY FROM CKE

The Colombo-Katunayake Expressway connecting the city of Colombo to the airport at Katunayaka traces through the marshy lands of Muturajawela. Extremely soft peaty clay layers of thicknesses ranging upto 12 m were encountered. Ground improvement techniques such as; preloading, preloading with prefabricated vertical drains, use of sand compaction piles and use of crushed stone piles were adopted during the construction. In order to assess the improvement achieved number of bore-hole were done and undisturbed samples were taken prior to the placement of the road pavement. Number of conventional consolidation tests were conducted on the samples obtained. As revealed by a typical e vs log (σ) plot (Fig. 11) these samples possess significantly high pre-consolidation pressures. Therefore at initial load increments the sample is having a high OCR. It should be noted that these tests are done with loading and un-loading increments only. There were no reloading increments. Therefore, using e Vs log (time) plot of the load increment closest to the pre-consolidation pressures C_{α} was obtained (termed C_{α}) and compared with the C_{α} values corresponding to the load increments lower than the pre-consolidation pressure (termed $C_{\alpha}^{/}$) Following the notation adopted with simulated tests a ratio of $C_{\alpha}^{/}/C_{\alpha}$ and a corresponding OCR value was calculated. The plot of $C_{\alpha}^{/}/C_{\alpha}$ Vs OCR obtained for different UD samples is presented in Fig. 12. Only Peaty clays with an initial water content greater than 200% were used in this plot. Although the data are with some scatter the reduction of C_{α} with the OCR is quite evident..

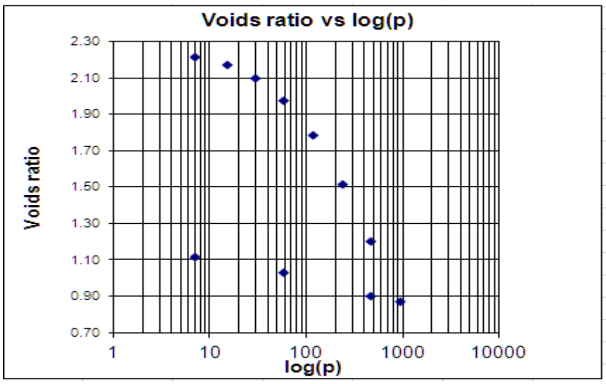

Fig. 11 Variation of Void ratio (e) with log (σ)

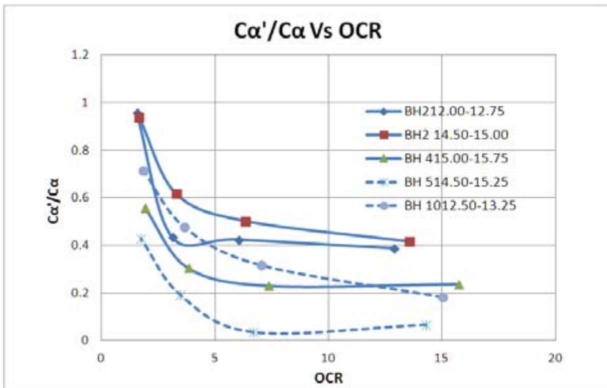

Fig. 12 Variation of $C_{\alpha}^{/}/C_{\alpha}$ with OCR in moisture content values in between 200-300%

4 TESTS ON PEAT FROM FISH MARKET SITE

New fish market complex was constructed on a site underlain by peaty clay layer of thickness around 5-10m. All the buildings were constructed on piles but the access roads and surroundings were simply filled up. There were large settlements in the site and access roads and a detailed investigation was done with several boreholes and undisturbed samples. Samples were obtained from locations under the fill and from locations in the virgin ground. The results obtained from the consolidation tests conducted on these samples were also used to find the effect of OCR on C_{α}. The results are summarized in Fig. 13.

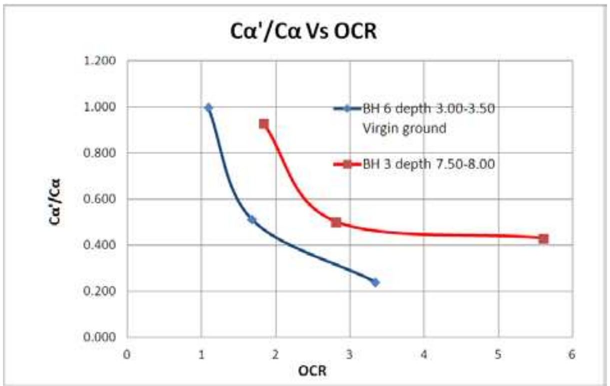

Fig. 13 Variation of $C_{\alpha}^{/}/C_{\alpha}$ with OCR

5 CONCLUSIONS

The effect of pre-consolidation (achieved over consolidation ratio) on the coefficient of secondary consolidation was studied in laboratory by; simulated testing and testing of undisturbed samples of preloaded peaty clay. The results revealed that significant reductions of C_{α} could be achieved even with OCR values of the order of 1.1- 1.2. As these values are with some scatter based on parameters such as intial moisture content, organic content it is recommended to conduct simulated tests to establish the relationship for the peat encountered in a particular project. If the settlement monitoring in the completed highways are continued for a long time, field verifications could be obtained.

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