The influence of delay time on the quality of a compacted soil-cement

L'influence du temps de délai sur la qualité d'un sol-ciment compacté

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SYNOPSIS: This paper presents a study on the influence of delay time - the time elapsed between addition of cement to soil and the end of compaction of the mixture-on the properties of soil-cement produced with a lateritic soil. Several series of test specimen were molded in the laboratory and the delay time was checked. Unconfined compression tests were carried out on samples moulded in the laboratory, as well as in samples taken from finished layers after compaction in the field.

The results obtained show that the effect of quality loss with time noted in laboratory seems not to occur with the same intensity in the field. Only a reduction in the homogeneity of the compacted mixture could be noted.

1 INTRODUCTION

Soil-cement as earth dam slope protection is an alternate solution to rock rip rap. Application of this material started in North America in the sixties and is a current technology today (Hansen, 1986). In Brazil, the need to use lateritic soils in these protections has created interest in new research aiming at adequating these methods not only to soils but also to the conditions peculiar to tropical regions. Thus borrow materials of Rosana dam (already built) and Porto Primavera dam (in construction), both situated in the far west of São Paulo State, form the subject of this paper.

2 SOILS OF ROSANA AND PORTO PRIMAVERA DAMS

The borrow materials used for the construction of Rosana and Porto Primavera are situated in the colluvial deposits associated with Caiuã sandstone and consist of red clayey sands.

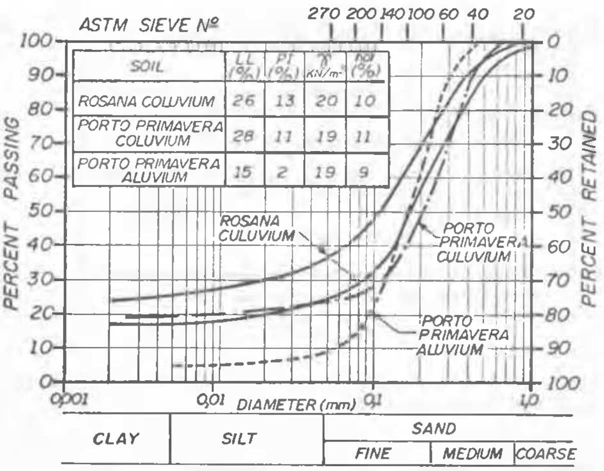

Figure 1. Rosana and Porto Primavera soils.

The grain size distribution range of the soil used in Rosana slope protection, the representative curve of the material in the borrow area of Porto Primavera as well as their index properties are presented in figure 1.

It can be seen, that these two soils are similar from a geotechnical point of view, a feature which, associated with the same geological origin of both, allows a comparative analysis which is made here.

The lateritic soils have geotechnical properties known to be more favorable than non-lateritic soils. Table 1 shows the results of unconfined compression tests carried out on soil-cement samples from Porto Primavera soils. In both cases, mixtures were prepared with 8% (by weight) of normal Portland cement (28 days compressive strength equal to 32 MPa). The results indicate that colluvial soil shows greater strength and lesser weight loss than alluvial soil, confirming its superiority in relation to non lateritic soils. This led to the choice of colluvial soil for Porto Primavera as well as for Rosana, where there was no difficulty in pulverization in spite of its plastic characteristics. Cement content specified for Rosana dam protection was 6%.

Table 1. Soil-Cement prepared with Porto Primavera Soils.

SOIL TYPE	SOIL		SOIL-CEMENT		
	W_L (%)	PI (%)	DURABILITY (%) F-T	DURABILITY (%) W-D	σ_{c7} (MPa)
Alluvial soils	15	2	9,0	9,5	2,6
Lateritic colluvium	28	11	2,0	2,2	4,2

3 TEST RESULTS

3.1 Generalities

Due to the large extensions of the Rosana and Porto Primavera dams with 2 and 10 km respectively, time elapsed between addition of cement to soil and compaction of the mixture at application site could become a conditioning variable. There are some recommendations that limit this time from one (PCA, 1976) to two hours (Hansen, 1986). However, in order to obtain a better assessment of the influence of time on the properties of lateritic soils in soil-cement mixtures, an analysis was made on the results of tests carried out on samples obtained in the field and samples molded in the laboratory.

3.2 Samples moulded in laboratory

Specimens were prepared from samples of soil from Porto Primavera - whose grain size curve is shown in figure 1 - with 7% by weight of Normal Portland cement. After adding cement to the soil, the homogenized mixture was kept in a humid room for time periods ranging from zero to two hours. After that, the test probes were moulded under the conditions indicated below.

A series of specimens were prepared according to procedures established by Standard Proctor test, resulting in constant compaction energy. It was aimed to reproduce the conditions which normally occur in the field by fixing the number of passes of compacting equipment. Figure 2 shows the results of these tests which demonstrate that the specimen moulded one hour after adding cement only reaches 97% of maximum dry density of Standard Proctor. For longer delay times, the results indicate an increase in the reduction of the percent compaction, with a value less than 93% of Standard Proctor for a 1/2 hour period.

Specimens obtained after compaction above were submitted to unconfined compression tests. The results shown in figure 3 clearly demonstrate an overall tendency to reduction of soil-cement strength.

Four series of specimens were also prepared for a constant percent compaction. In this way, for specimens moulded during time periods greater than zero, compaction energy showed to be greater than Standard Proctor.

Variation of 7-day compressive strength for percent compaction between 93 and 102% is shown in figure 4. In spite of the somewhat erratic results, one can say that there is a slight overall tendency of loss of strength with time. This loss, in spite of being small, seems to confirm the phenomenon observed in the case of constant compaction energy (figure 2).

Figure 5 presents the evolution of 7-day compressive strength for specimens moulded with Standard Proctor energy for delay times equal to zero and one hour. The results seem to suggest that there is no tendency to any loss of strength with this variable.

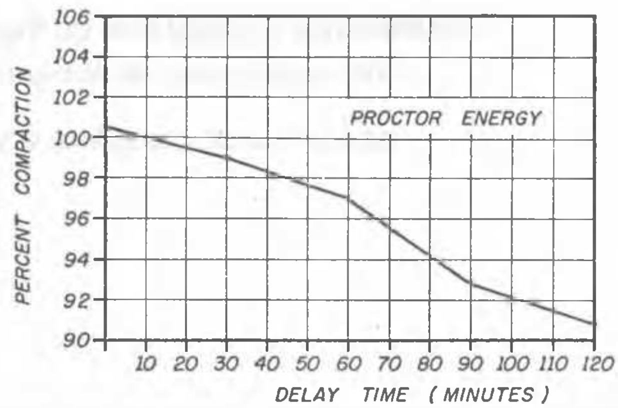

Figure 2. Compaction results obtained from constant moulding energy-Porto Primavera laboratory samples.

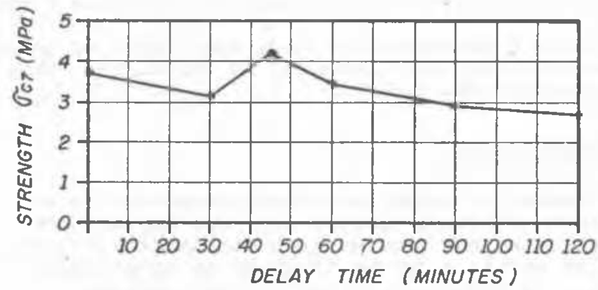

Figure 3. 7-day unconfined compressive strength test Porto Primavera laboratory samples.

The increase in strength with percent compaction is remarkable but, curiously, it is not so significant as one could expect, mainly considering percent compaction as low as 93%. The large erraticity of the results, however is even larger than the variations to be measured. It should also be noted that only one specimen was tested for each moulding condition and that test procedures used were the ones established by standards and usually used by soil laboratories.

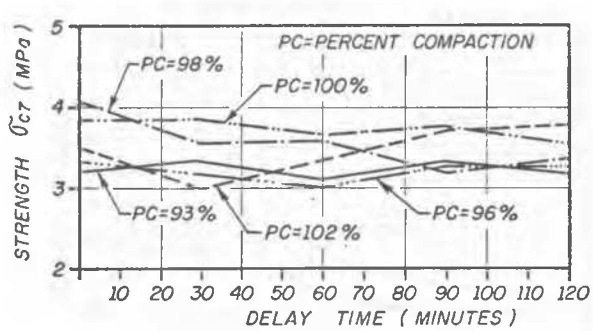

Figure 4. 7-day unconfined compressive strength Porto Primavera samples.

3.3 Samples obtained in the field

During construction of Rosana soil-cement protection the time elapsed between cement addition to soil in the plant and the end of layer compaction were measured. These times include: transportation of soil to application site, discharge, spreading, compaction and delay occuring between the various activities. The results obtained (figure 6) demonstrate that the average percent compaction, although decreasing with time, decreases less in the field than in the laboratory (figure 2). In fact, in the first case in which the energy applied to the specimens is constant, the loss of percent compaction occurs at the rate of 1% every 15 minutes up to the first hour and 1% at every 7 to 10 minutes during the second hour. Field results show an average loss in density of 1% every 40 minutes.

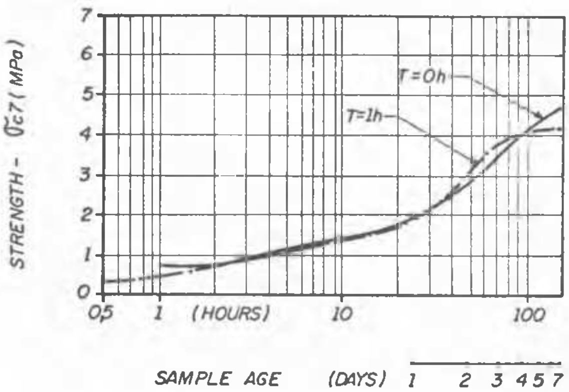

Figure 5. Evolution of 7-day unconfined compressive strength-Porto Primavera laboratory samples.

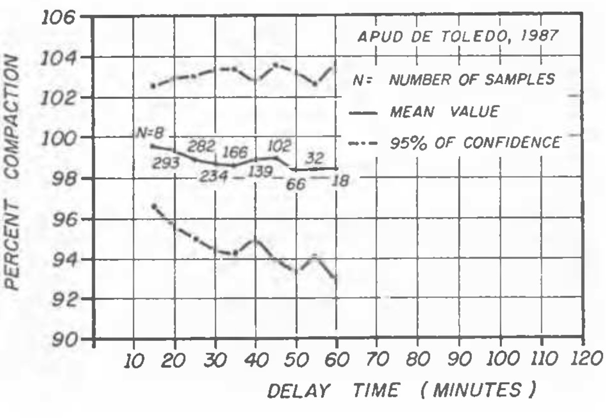

Figure 6. Compaction control-Rosana field test

Although the average percent compaction showed low reduction with time, an increasing dispersion was observed, bringing into evidence the decreasing homogeneity of mixture. It is to be noted that the ideal laboratory conditions are different from the real conditions in the field as, for instance, in the case of humidity loss. This fact would suggest less favorable results for the field samples. Field compaction, which uses a kneading process, could facilitate breakage of crystals under formation from the moment cement is added to the soil.

In the same way, in the field, the time during which the soil is worked upon tends to be greater than in the laboratory since the soil is stirred up in intermediate stages before the end of compaction. In the laboratory, on the other hand, during indicated times, loose soil remains absolutely at rest facilitating crystal formation.

Last, but not least, cement mixing processes are different in the laboratory and in the field. In the laboratory, mixing is intensive since it is done manualy. On the contrary, in the field specifications require pulverization to at least 80% less than 4.8 mm which means that the size of soil lumps without cement, in general, reaches a few millimeters. The soil lumps are only covered by a cement film which, in spite of the crystallization process already going on, does not prevent its densification.

In the field, there is still the possibility of increasing the compaction energy by an increase in the weight of equipment or the number of passes, until higher densities are obtained. This procedure, however, was not used in Rosana.

Undisturbed specimens, extracted from layers of Rosana slope protection just after their compaction, were submited to unconfined compression strengh, after being cured during 7 days in a humid chamber. Figure 7 shows the average values obtained as well as the confidence interval, assuming a normal distribution. Results show that up to one hour after compaction, compressive strength did not suffer any reduction with time. Furthermore, from after the first 25 minutes, dispersion is approximately constant.

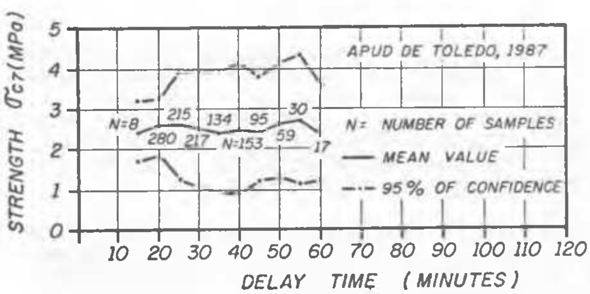

Figure 7. 7-day unconfined compressive strength test-Rosana field samples.

Similar results were obtained with durability tests as shown in figure 8 where losses by wetting and drying are around 3%. Dispersion of these results - relatively higher because of dependency on human factor (manual brushing) - does not show to be widely affected by time.

The range of percent compaction used in laboratory tests at Porto Primavera (figure 4) corresponds approximately to the dispersion range of field results at Rosana (figure 6), allowing a comparison of the results. The average compressive strength obtained with field samples is 2.5 MPa which corresponds to about 70% of average laboratory values.

Thus, although field results also indicate a reduction in percent compaction with time, the

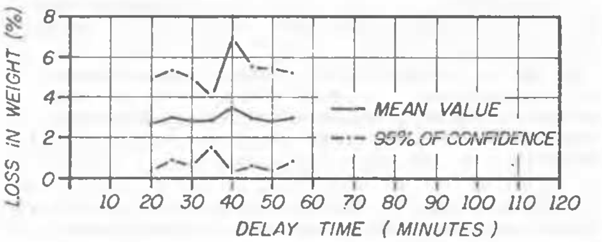

Figure 8. Wetting and drying test results-Rosana field samples.

quality of the product obtained - measured by its compressive strength and durability - is mantained.

Results of laboratory tests can be useful to explain this observation. In effect, for a constant compaction degree (figure 4), the influence of time can be considered negligible.

4 CONCLUSIONS

Compacted soil-cement, on the average, does not seem to suffer any loss in quality with time when time elapsed between addition of cement and compaction is limited to one hour. The decrease in the homogeneity of the mixture, did not appear to be critical.

If the time variation trend is mantained for longer periods, the above observation permits the statement that a larger delay time may be acceptable. However, an experimental fill should confirm this assumption.

Laboratory tests on samples moulded with constant compaction energy that indicated a quality loss of the soil-cement with time are not representative of field conditions. Tests which keep the percent compaction constant, on the contrary, are more representative in spite of the large dispersion of the results.

Heterogeneity of specimens used, possibly owing to heterogeneity of the moulding process as well as of the soil used, are probably responsible for the dispersion of results.

Differences between conditions of producing soil-cement in the field and in the laboratory seem to justify the non-equivalence between results of tests carried out with both types of samples.

It may be concluded that, at a constant compaction degree of soil-cement, there seems to be no evidence that this material suffers loss of quality with delay time. This conclusion is evidently limited to the time intervals considered here.

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