Preliminary Findings and Future Programming Of a Basic Research Project Involving Calcium Chloride with Pure Clays

FLOYD O. SLATE, Cornell University, Ithaca, New York

The ultimate purpose of this project is to devise a method for predicting the effect of calcium chloride on stabilization of natural soils. In past and current practice, empirical testing is done for each soil in question; this procedure is most inefficient, and gives little or no basic knowledge of the principles involved.

It is proposed to study the effect of calcium chloride on each of several pure ion types of each of three pure clay minerals. After effects are known (both physico-chemical changes occurring and their related changes in physical and mechanical properties) for each pure sample, these results will be used to predict effects on mixtures of pure samples, and these predictions will be checked by experiment. Finally, the same procedure will be used for naturally occurring soils that have been carefully analyzed.

Thus, it may be possible ultimately to analyze a natural soil, and predict with reasonable accuracy the effect of calcium chloride on that soil, by referring to results on the pure constituents making up that soil. Perhaps more important, such a study would add to the store of knowledge of the principles governing soil stabilization.

Preliminary results showed that treating a sodium montmorillonite clay with 4 percent calcium chloride gave an increase in maximum dry density of about 11 percent.

● PREVIOUS WORK in this field has been almost entirely empirical. Laboratory studies have used natural soil samples of unknown composition; field studies have done the same thing. On some soils, the chemical has shown marked beneficial effects; on others, it has had little effect; and in a few cases, detrimental effects have been suspected. This empirical approach leads to the individual testing of every sample of soil proposed to be used with the chemical — a most inefficient approach. Every sample, not just every engineering or agricultural type of soil, must be tested because the engineering and agricultural classifications are not based on the physico-chemical properties involved in stabilization with calcium chloride.

OVER-ALL PLAN

It is proposed that the effects of calcium chloride be studied on pure ion types of pure clay minerals, one-by-one. This would involve obtaining relatively pure samples (in large quantity) of each of the major types of clay minerals. Each mineral type would have to be purified in the laboratory, then converted to each of several pure ion types, by base exchange procedures. It is expected that the ion types to be prepared and studied would include the following: H^+, Na^+, K^+, Ca^{++}, Mg^{++}, Al^{+++}, and Fe^{+++}. Preparation of pure ion types of pure clays is time-consuming and expensive. In some cases, the H^+ ion types may be unstable after short periods of time.

The effects of calcium chloride would then be studied on each ion type of each clay mineral; the samples being studied would represent the colloidal fraction of naturally occurring soils. Presumably, some samples would be reactive (good or bad) and others would not. The extent of reaction, and the amount of chemical required for certain desired effects could be determined. Analysis by base exchange procedures would tell how much of the Ca^{++} (from the calcium chloride) reacted, with what it reacted, and how much of another base was released. Electrical, physical, and mechanical properties of each sample would be determined, both before and after treatment with calcium chloride, and correlated with the base exchange observed.

It is, of course, being assumed that the primary stabilization effects of the chemical are almost entirely centered in the clay fraction of the soils, except for moisture control which is being considered as a separate and distinct effect. The evidence justifying this assumption is very strong.

The information accumulated by the studies described would reasonably be expected to provide a key whereby the action of calcium chloride could be predicted for any mixture of the pure materials studied. Later stages of the study would have to include tests on mixtures of the pure samples to determine if any side effects occur because of the simultaneous presence of two or more materials. Mixtures of the pure samples would be reacted with the chemical to test the accuracy of the predictions.

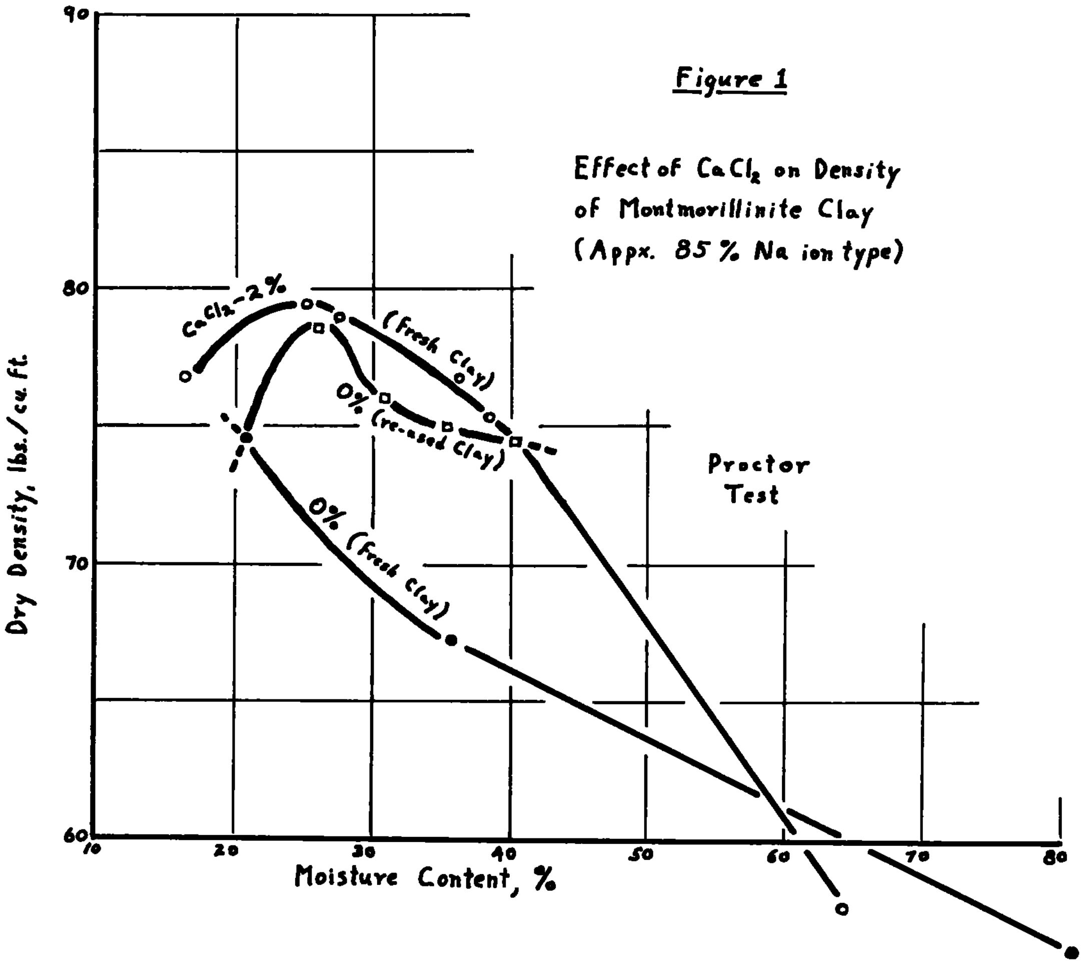

Figure 1. Effect of $CaCl_2$ on density of montmorillonite clay (approximately 85 percent Na ion type).

If the predictions on mixed pure samples were reasonably accurate, the next step would be to obtain naturally occurring "impure" clays, analyze them for type of clay minerals present, and for the ion types present, then predict the action of calcium chloride on the naturally occurring clay, on the basis of the known action of the chemical on the various pure components that make up the clay being studied. The prediction would then be tested for the naturally occurring clay.

Finally, naturally occurring soils of various kinds, with various clay contents, would be obtained and analyzed for amount of each clay mineral, and for the amount of each ion type of each clay mineral. Then a prediction would be made as to changes in physical and mechanical properties that would be caused by various amounts of calcium chloride, based upon the keys established from the original studies. The predictions would be checked.

Assuming that this scheme was found to work, a recommendation could be made that calcium chloride be used with a certain soil; that a specific amount be used for certain predictable effects; or that the chemical not be used at all if the composition of the soil were known, in terms of the pure components that had been studied. Since the chemical action is primarily confined to the colloidal fraction of the soil, the composition analysis would have to include: percentage of clay present, type of clay minerals present in approximate percentages, and the ion types of the clay (or the ratio of ion types).

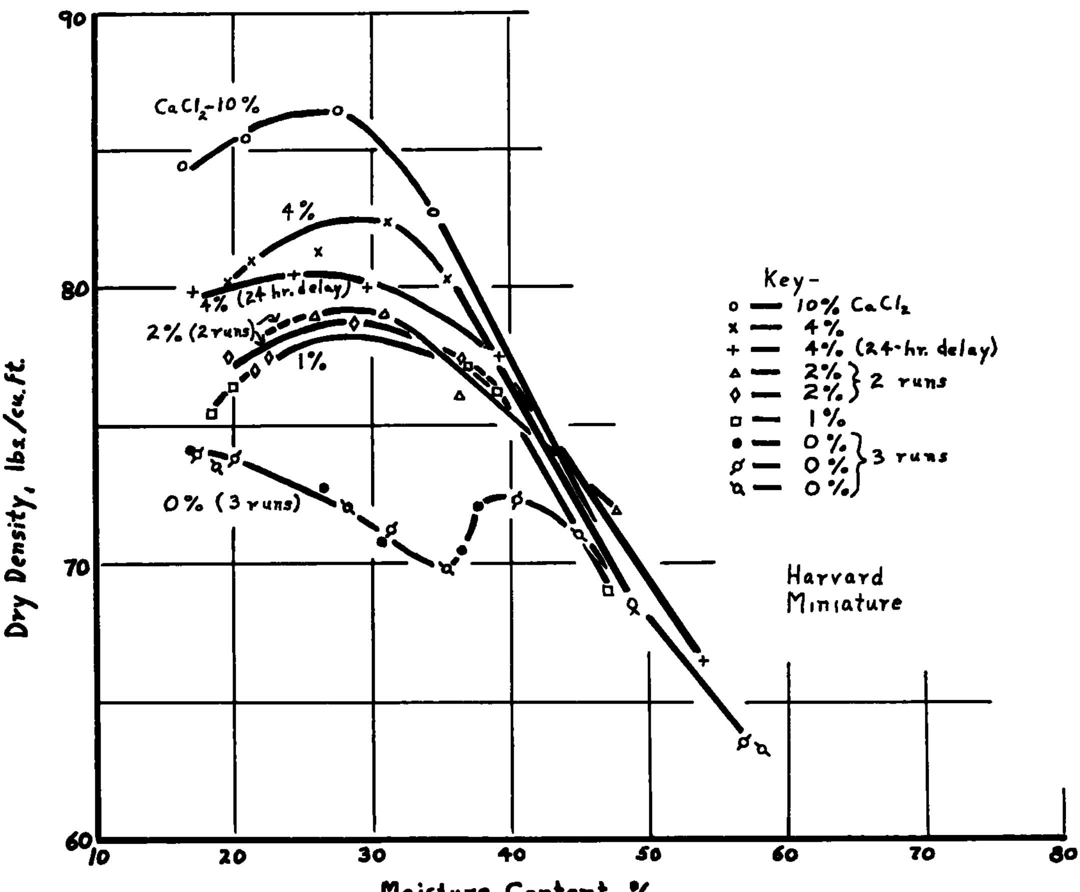

Figure 2. Effect of $CaCl_2$ on density of montmorillonite clay (approximately 85 percent Na ion type).

This entire argument is based on the assumption that it is much easier to determine the composition of a soil than to run a series of empirical stabilization tests on that soil. Much simpler methods of determining soil composition are continuously forthcoming, and in the not far-distant future, analyses of composition may become routine as part of the general classification of soil types.

The proposed scheme is difficult to execute. The attempt to find keys for classification of soils to be treated or not to be treated, and in what amounts, might fail. However, it is almost certain that valuable information would be provided about how the chemical works — a type of information not provided by the popular empirical tests. If that information were available, any number of approaches to more intelligent use of the chemical might become evident.

Work on the project has been started, and some preliminary results have been obtained.

PRELIMINARY EXPERIMENTAL WORK

The objective of the preliminary experimental work was to determine whether or not it is feasible to carry out the large-scale program of study of effects of calcium chloride on pure-ion types of pure clays. If no appreciable effects are noted, it might be fruitless to proceed; if appreciable effects are noted, an extended study seems

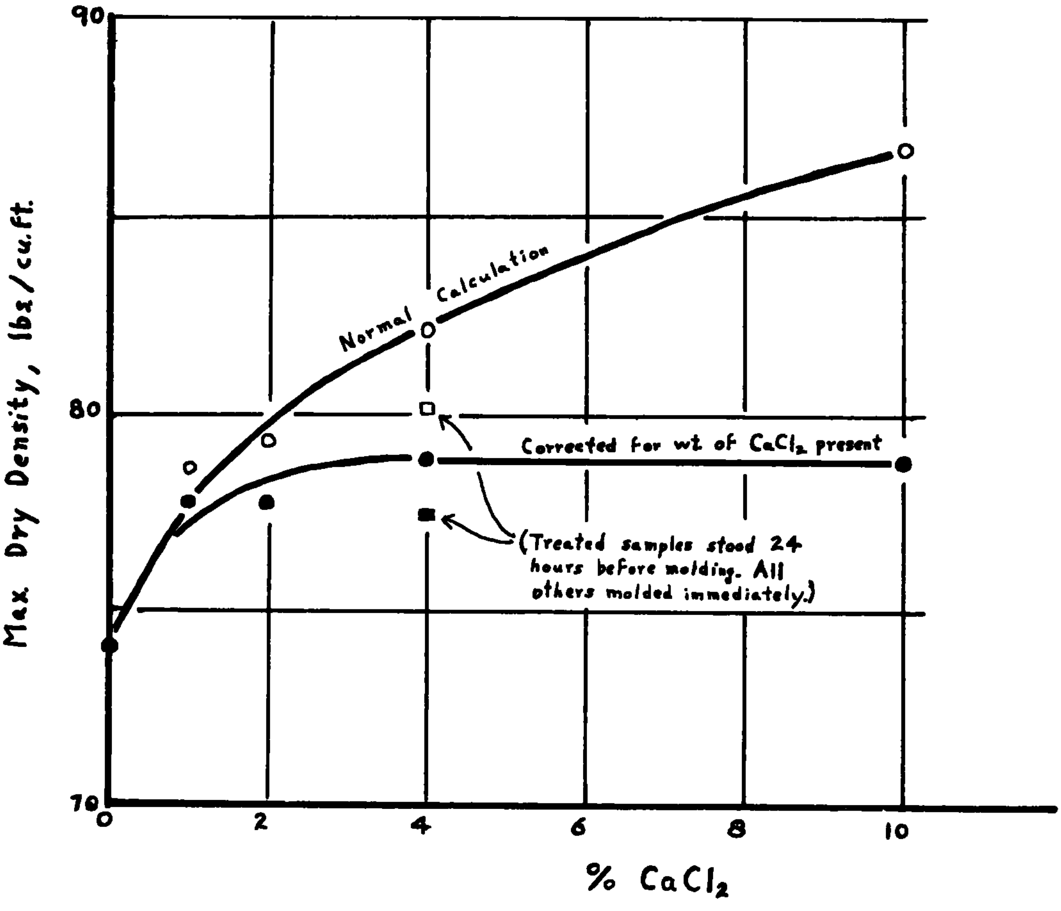

Figure 3. Effect of $CaCL_2$ on density of montmorillonite clay (approximately 85 percent Na ion type).

justified. Some people still contend that base exchange reactions are not involved appreciably in stabilization with calcium chloride, that moisture control only is involved, that an increase in density is caused merely by the weight of the chemical added, or that other mechanisms account for most of any changes in physical and mechanical properties.

The specific purpose of this preliminary experimental work was twofold: (a) To determine definitely whether or not the addition of calcium chloride to a predominately sodium-type montmorillonite clay will change its maximum dry density in a Proctor-type test, and if so, by how much; and (b) To determine whether or not the Harvard miniature compaction apparatus will give highly reproducible results with pure clay minerals. (It is desired to use as small a sample as possible, for the expensive, pure-ion types of pure clays to be used later.)

Materials

The soil used was Volclay, consisting of about 90 percent montmorillonite, having exchangeable bases approximately as follows: calcium 22, and sodium 85 milliequivalents per 100 (these two bases constituted almost all the exchangeable bases, and represented a clay that was primarily, but far from completely, a sodium clay). The moisture content of the air-dry clay was about 4.5 percent.

Distilled water and chemically pure calcium chloride were used.

Procedure

Proctor Compaction Test. — The calcium chloride was dissolved in the water to be added to the clay. The water was added to the clay as a spray, to aid in mixing. The clay and water were thoroughly mixed by spatula and by kneading by hand. The wet clay was compacted as follows: A hammer weighing 5.5 lb was dropped 12 in. to compact $\frac{1}{30}$ cu ft of clay in 3 layers, with 25 blows per layer. About 4 lb clay was required per test. The materials were used and tested at room temperature. It was noted that when water was added to the Volclay, the temperature of the mix rose about 10 F above room temperature. Exact moisture contents were determined by running moisture contents on portions of the compacted samples, rather than by trusting the weights of water added to a given weight of soil, and assuming zero evaporation.

A comparison was made between using fresh material for each moisture content, and re-using the initial compacted sample for the higher moisture contents, all with no calcium chloride. The startling difference in results is shown in Figure 1. For all other tests, fresh samples were used for each moisture content.

Use of 2 percent calcium chloride increased the maximum dry density (for fresh samples, and for the driest clay — without the chemical — which could be readily compacted) from 74.5 pcf to 79.2 pcf, an increase of 6.3 percent - Fig. 1).

Harvard Miniature Compaction Test. — The general procedure followed that described for the Proctor testing. Compaction was done in three layers, 25 blows per layer, with the spring set to give a force of 30 lb for each pushing blow. The amount of clay required for each test was only 100 gr, compared to 4 lb for the Proctor test. Results checked reasonably closely with those for the Proctor test (curves for 2 percent calcium chloride and for 0 percent calcium chloride (fresh material) in Fig. 1 and 2).

Apparently the montmorillonite continues to swell, with added water, as expected, when no chemical was added. A "hump" was observed (Fig. 2) at about 40 percent water with the Harvard miniature test; the presence of this hump was confirmed by three closely checking runs, at 0 percent calcium chloride. It is probable that this hump was not observed in the Proctor test merely because no data points were taken in the pertinent range.

It was noted that the presence of calcium chloride greatly increased the ease and speed of wetting of the dry montmorillonite.

Figure 2 shows that when calcium chloride is present the montmorillonite gives "normal" Proctor-type curves, although the tops of the curves are fairly flat. Increase in the percentage of the chemical seems to cause the curves to have a sharper peak.

The reproducibility of the results from the Harvard miniature was excellent, although it should be stated that considerable care was used in the experiments. Three check runs were made at 0 percent, and two check runs at 2 percent chemical, with extremely close checking. Of a total of 45 data points, all points were well within 1 percent of the expected position (with respect to a curve), except for two points, which varied about 1.3 percent from the expected values. Variations inherent in the test procedure are apparently very small in comparison with variations caused by deliberate change of variable.

Only one run was made to check the effect of delay of time between addition of the water and chemical, and molding of the specimens. The results are shown in Figure 2 for 4 percent calcium chloride. This cursory check indicated that the effect may be appreciable. The chemical reactions involved in base exchange are not necessarily first-order reactions, and a time effect may be expected. This could be of vital imporatance in field applications, and should be studied intensively. In addition, previous work has indicated that certain favorable "curing" actions may follow appreciably after application of calcium chloride. Study of these time effects will increase the number of variables to be studied, and greatly increase the magnitude of a complete study, but they must not be ignored.

The effect of calcium chloride on maximum dry density of montmorillonite is summarized in Figure 3. An appreciable increase in density is caused by the chemical. Calcium chloride in amount of 4 percent by weight increased the maximum dry density by about 11 percent (by normal calculation), or by about 7 percent (after subtracting out the weight of the calcium chloride added). Apparently additions of the chemical in amounts above 4 percent made no further increases in density of the soil, except for that caused by the weight of the chemical itself.

It can be conclusively stated that the use of calcium chloride results in appreciable increases in the maximum dry density of sodium montmorillonite, and that the Harvard miniature compaction apparatus can be used for careful work with the pure clays.

ACKNOWLEDGMENT

The author wishes to thank Mohsen Tewfik for his help in the experimental work reported in this paper. In lieu of numerous references pertinent to this paper, the author refers the reader to HRB Bibliography 24, "Stabilization of Soil with Calcium Chloride," 1958, by Floyd O. Slate and A.W. Johnson.