

Iowa

Engineering Experiment Station

EVALUATION OF CARBIDE WASTE LIME

FOR SOIL STABILIZATION

by

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REPORT

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**Iowa State University
Ames, Iowa**

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INTRODUCTION

A lime by-product from the manufacture of acetylene from calcium carbide will be commercially available in Iowa. Since the cost of carbide waste lime f.o.b. source is only about half that of ordinary commercial lime, this material was investigated for potential uses in soil stabilization. The by-product lime is calcium hydroxide in a water slurry with approximately 40% solid concentration. Its effectiveness at stabilizing soils was checked by comparing with commercial high-calcium and dolomitic monohydrate varieties of lime. This was done by soil strength and plasticity tests in addition to studies of the reaction products by X-ray diffraction and chemical methods.

CONCLUSIONS

Carbide waste lime is comparable to commercial high-calcium hydrated lime in reducing soil plasticity and increasing soil strength, and the mechanisms involved in soil lime stabilization appear to be identical. The use of carbide waste lime is therefore mainly a matter of cost and transportation distance. Usefulness of the slurry form of application is a secondary consideration,

because it is an advantage for avoiding dust, but a disadvantage with wet soils which must be dried prior to compaction. For example, addition of 4% lime in a 40% slurry means the addition of 6% water.

MATERIALS USED IN THIS INVESTIGATION

Soils

A highly plastic gumbotil soil was used for the liquid limit and plastic limit tests. This soil, a paleo B horizon developed in Kansan age till, contains about 60% montmorillonitic clay and is very difficult to manipulate in the field.

Two Wisconsin-age⁶ loess soils were used for strength studies. These were selected to represent a friable, calcareous loess and a plastic, leached loess.

A field description and physical and chemical properties of each soil are given in reference 8.

Lime

The by-product lime hydrate from the acetylene generation process was in a slurry form with approximately 40% solid concentration. Chemically this lime compares with high-calcium limes; a typical chemical and particle size analysis of the solids is given in Table 1 and 2, respectively.

Table 1. Typical chemical analysis of the waste lime.*

Ca(OH) ₂	95
CaO Equivalent	72
CaCO ₃	1.5
MgO	0.25
R ₂ O ₃ (Fe ₂ O ₃ & Al ₂ O ₃)	1.6
Insolubles	1.1

Table 2. Particle size distribution.*

Sieve No.	% Passing
20	99.9
48	99.2
100	97.0
325	85.0

* Data furnished by the lime manufacturer

METHODS OF INVESTIGATION

The methods used to investigate plasticity and strength properties of soil waste-lime mixtures were essentially identical to those of reference 8, except that the waste lime was added in the form of a slurry rather than as a powder. The amount of slurry added was based on the quantity of dry lime desired. Additional distilled water was added, when necessary, to bring the soil-waste lime mixture to the desired moisture content for compaction.

RESULTS

Modification of Soil Plasticity

The results of plasticity tests on the gumbotil are shown in Fig. 1, together with results from a previous study on high-calcium and dolomitic monohydrate limes (8). The shape of the curves is characteristic of montmorillonitic clay soils treated with lime; the liquid limit gradually decreases when the lime content is increased, and the plastic limit increases with an increase in lime up to a certain point, termed the lime retention point. At that point further increases in amount of additive do not further affect the plastic limit.

The curves in Fig. 1 show that the effectiveness of the different types of lime in raising plastic limit of a soil is very nearly the same. The maximum difference is only 4%, and occurs at about 4% lime content. Considering the method of Atterberg limit tests and the difficulties in field control, this difference does not have much practical significance in the degree of improvement in workability of a plastic soil.

Strength Tests

Maximum strengths obtained with soil-waste lime mixtures are shown in Figs. 2 and 3. The waste lime mixed with plastic loess gave higher strengths than were obtained with high-calcium lime after 7 days of moist curing at room temperature, and gave almost the strength with dolomitic monohydrate lime in longer curing periods. With friable loess, strengths with waste lime were comparable to those with high-calcium lime.

Reaction Products Study

The strength gain of soil-lime is attributed to the formation of calcium silicate and aluminate hydrates. The amounts of silicates and aluminates formed may be determined by chemical means because the reaction products are soluble in dilute HCl. The method of analysis is described in detail elsewhere (6).

Figure 4 shows the amount of silicate and aluminate reaction products, in milligrams per 100-gram mixture, versus lime content, after 28 days moist curing at room temperature. The amounts shown were corrected for the estimated amount of soluble silica and alumina in the waste lime; from the chemical analysis shown in Table 1, it was assumed that all the 1.1% insolubles in the lime were silica which would dissolve in dilute HCl, and 63% of the 1.6% R_2O_3 was soluble alumina.

Figure 4 shows a net gain of cementitious reaction products with the addition of waste lime to soils. It is interesting to note that more silicates than aluminates were formed in soil-waste lime mixtures, and the rate of formation of silicates with increased lime content coincides with the rate of strength gains (Figs. 2 and 3). This suggests that silicates are primarily

responsible for the strength gains in soil-lime mixtures. Friable loess and plastic loess gave about the same amounts of silicates at a specific lime content after 28 days curing. The higher strengths produced in friable loess mixtures (Figs. 2 and 3) are therefore attributed to a better structure of the coarser loess through better particle interlocking.

Inasmuch as carbide waste lime contains essentially Ca(OH)_2 and very little MgO and impurities, it is reasonable to believe that the mechanisms in stabilizing soil with waste lime are the same as with high-calcium hydrated lime. The above results show that the effectiveness of carbide waste lime for soil stabilization is comparable in every respect to a commercial high-calcium lime.

High-Calcium vs. Dolomitic Lime

Soft-burned dolomitic monohydrate lime containing both Ca(OH)_2 and active MgO often produces higher early strength than does high-calcium hydrated lime. This is attributed to the hydration of MgO to Mg(OH)_2 , which is cementitious in nature and reacts relatively rapidly in comparison with pozzolanic reaction between Ca(OH)_2 and clay (9). Although this advantage of dolomitic lime may be important in late-season construction, comparable strengths may be eventually obtained with high-calcium lime so long as there is sufficient montmorillonitic clay to react.

Slurry vs. Powder

Construction of stabilized roads with powdered lime has been hampered somewhat by control and health problems created by lime dust, especially during hot, windy weather. An alternate method for safer use and better control of lime lies in its application in the form of a slurry. An early

study found that lime is equally effective whether it is used as powder or as slurry (1), and lime slurries have been successfully applied through spray bars on many occasions. Since carbide waste is usually processed and shipped in slurry form, it offers this advantage.

A disadvantage of slurry application is in stabilization of wet soils which must be dried before compaction. That is, in order to add 4% lime, the 40% solid concentration would also mean adding 6% water. Ordinarily water must be added anyway, but this could be a factor on some jobs.

Economy

Carbide waste lime is produced in most major cities as a by-product from the acetylene industry. In its slurry form, it is normally sold on a delivered, dry solid basis. The amount delivered is determined by weighing the calibrated tankwagon, measuring the specific gravity, and deriving the exact percentage of solids from a lime conversion table.

With trucking an important part of the costs, it is necessary to know the distance from source in order to quote a delivered price. However, since results have shown that waste lime is comparable in effectiveness to high-calcium hydrated lime on a pound-for-pound dry solid basis, and the price of commercial lime is of the order of \$20 per ton, the maximum economically competitive haul of waste lime slurry is estimated as about 60 miles radius from the sources located at Omaha and Davenport. The by-product lime thus should be considered in any soil-lime construction within reasonable distance from these points.

REFERENCES

1. Davidson, D. T., Noguera, G., and Sheeler, J. B. Powder versus slurry application of lime for soil stabilization. American Society for Testing and Materials, Special Technical Publication 245: 244-253. 1960.
2. Diamond, S., and Kinter, E. B. Mechanisms of soil-lime stabilization; an interpretive review. Highway Research Record 92: 83-102. 1965.
3. Glenn, G. R. X-ray studies of lime-bentonite reaction products. Paper presented at 66th Annual Meeting of the American Ceramic Society, Chicago, Illinois. 1964.
4. Ho, Clara and Handy, R. L. Characteristics of lime retention by montmorillonitic clays. Highway Research Record 29: 55-69. 1963.
5. _____, Electrokinetic properties of lime-treated bentonites. Paper presented at 12th National Conference on Clays and Clay Minerals, Atlanta, Ga., Oct., 1963.
6. Ruff, C. G., and Ho, Clara. Time-temperature-strength-reaction product relationships in lime-bentonite-water mixtures. Paper presented at 45th Annual Meeting of the Highway Research Board, Washington, D. C. Jan., 1966.
7. Wang, J. W. H., Davidson, D. T., Rosauer, E. A., and Mateos, M. Comparison of various commercial limes for soil stabilization. Highway Research Bulletin 335: 64-79. 1962.
8. _____, Mateos, M., and Davidson, D. T. Comparative effects of hydraulic, calcitic, and dolomitic limes and cement in soil-lime stabilization. Highway Research Record 29: 31-39. 1963.
9. _____, and Handy, R. L. Role of MgO in soil-lime stabilization. Paper presented at the 44th Annual Meeting of the Highway Research Board, Washington, D. C. Jan., 1965.

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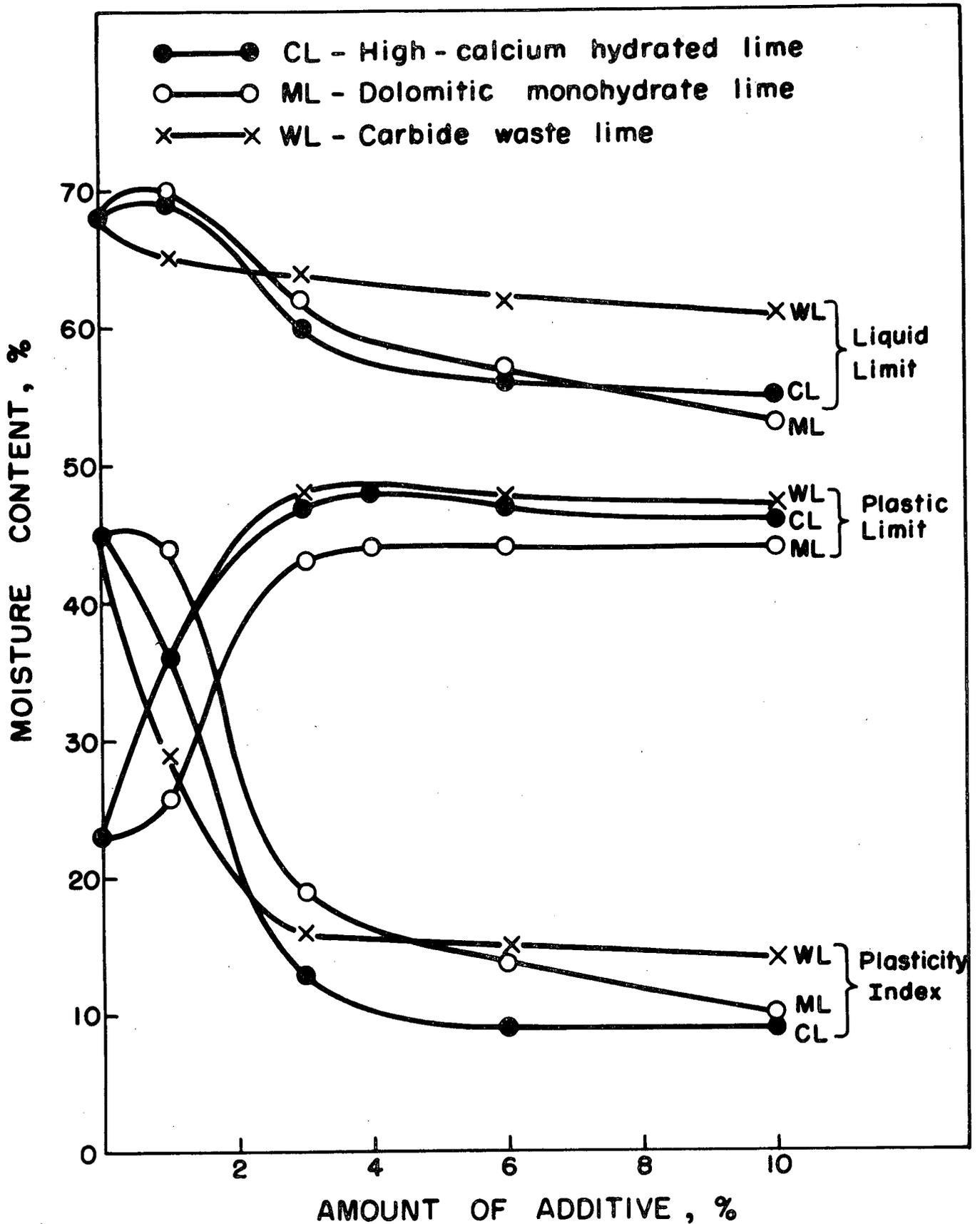


Figure 1. Effect of limes on the Atterberg limits of gumbotil.

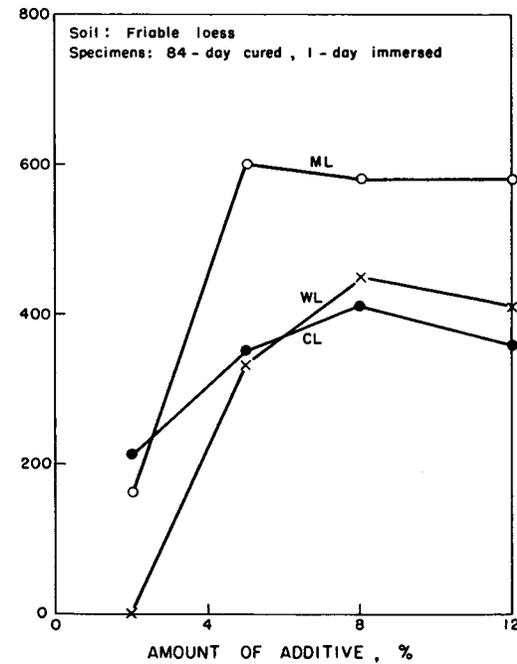
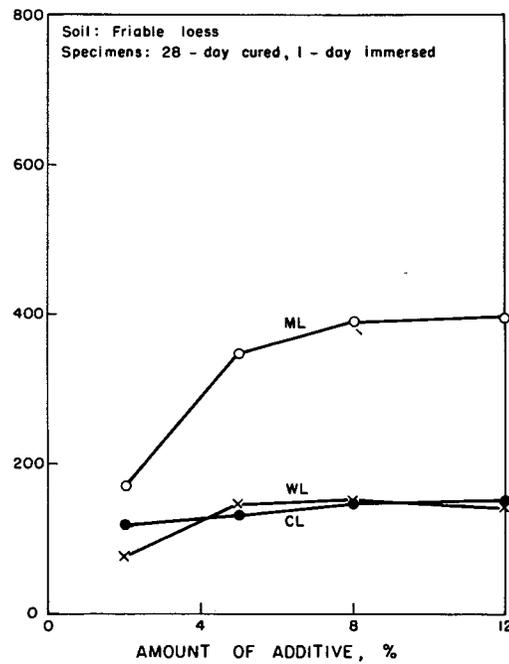
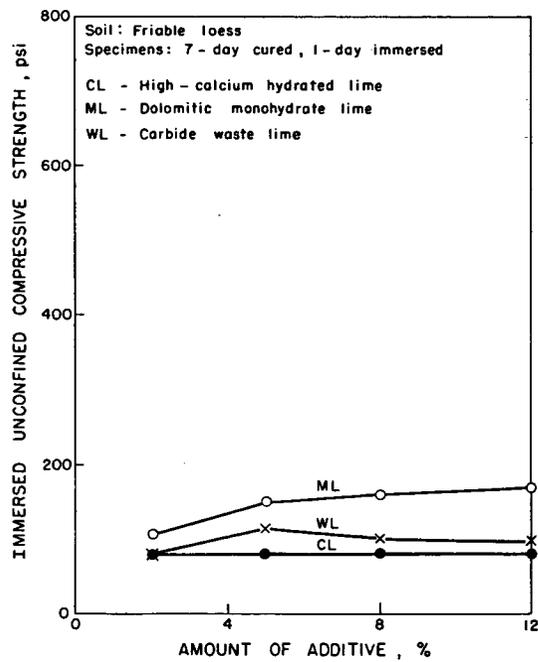


Figure 2. Effect of lime on the immersed unconfined compressive strength of friable loess.

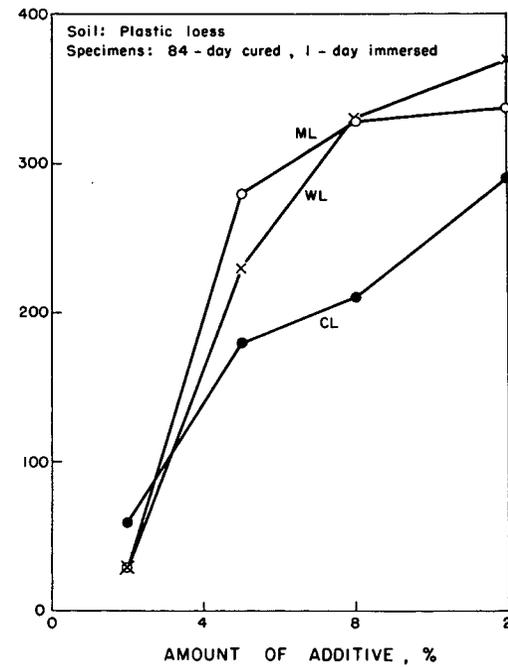
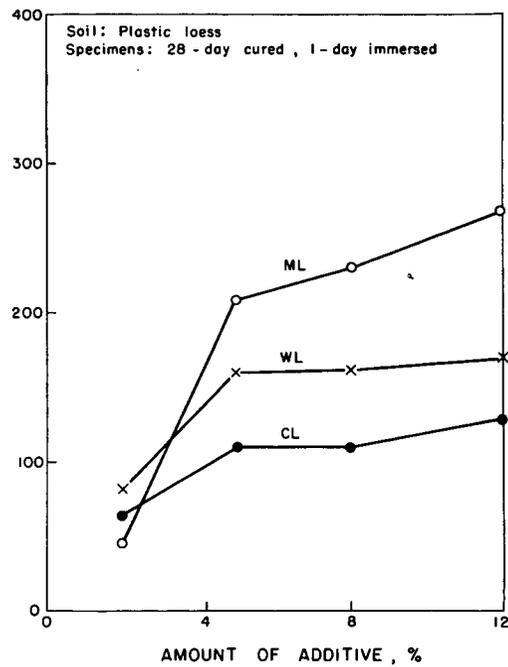
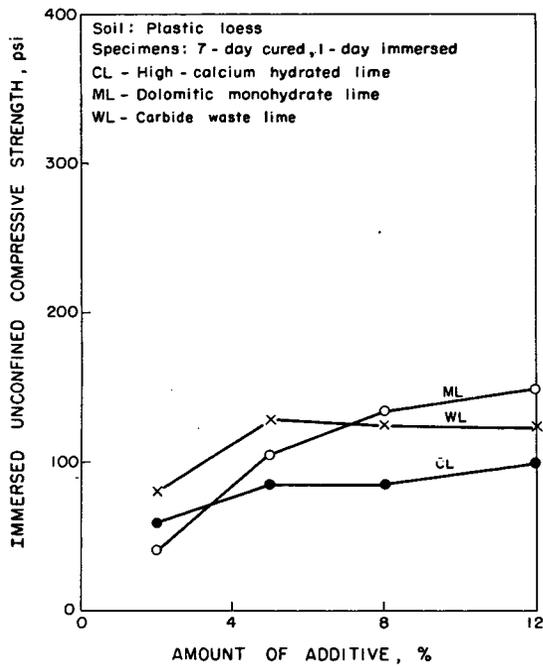


Figure 3. Effect of lime on immersed unconfined compressive strengths of plastic loess.

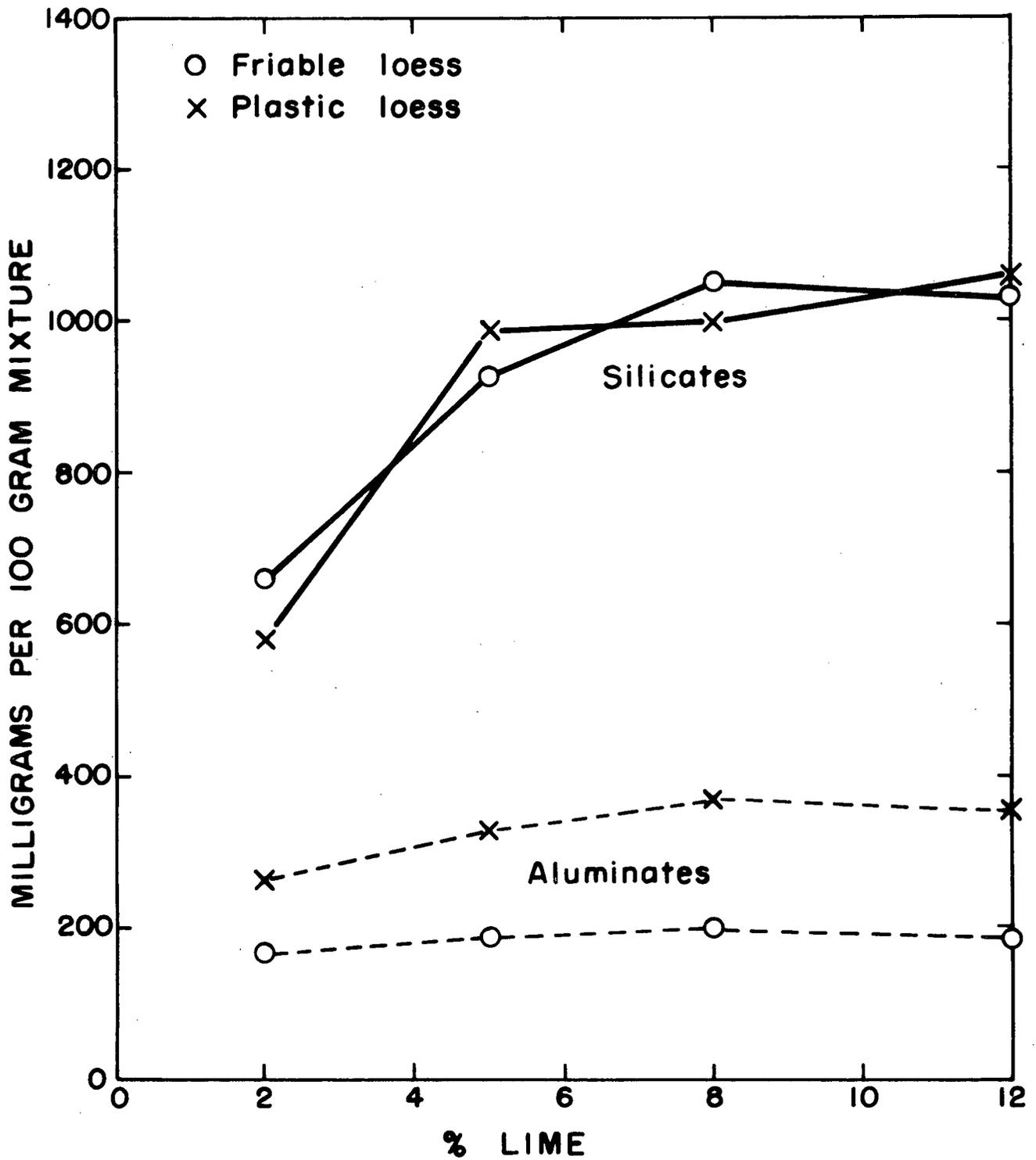


Figure 4. Reaction products formed in soil-waste lime mixtures cured for 28 days.