Evaluation of Soil-Lime Stabilization Mixtures

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As the use of lime for stabilization of both fine-grained and granular soil materials continues to increase each year, so do the requests for lime content recommendations. This information is not readily available. Members of our profession customarily turn to whatever means of testing that is available to seek answers. This report comments on ways and means of analyzing soil-lime mixtures from the following standpoints:

1. Strength and P.I. tests on cores taken from old roads;
2. The cracking problem for lime-stabilized base courses;
3. Deflection tests;
4. Relation of strength to percent of lime with emphasis on effect of curing time;
5. The rehealing properties of some mixtures; and
6. The effect of moisture, lime content, purity of lime, and fineness of lime on early loss of cohesion in raw soil.

The report indicates that core strengths are two and one-half to three times as great as would be obtained under normal room temperature curing periods. The report also concludes that for equal percentages of the four types of limes studied, the finer and purer the lime the greater the loss in the cohesion of the raw gumbo soil tested. This loss of cohesion is believed to be one of the key factors influencing efficient and economical mixing in the field. On the basis of testing road cores, both short- and long-time cured laboratory specimens and early effects on cohesion of soil, a chart for recommended lime contents is presented. The chart includes the plasticity index, and the percent minus No. 40 mesh, and is based on the use of a fairly pure fine-hydrated lime.

•SEEKING information on the evaluation of soil stabilization mixtures, we obtained undisturbed cores from old roads of known behavior (Figs. 1 and 2). This is not new, but perhaps our attempts to relate our preliminary laboratory strengths to those obtained from cores may be new to some. The cores taken from a $10\frac{1}{2}$-yr old lime-treated clay project located between Houston and Beaumont are approximately three times stronger than would have been predicted from ordinary preliminary laboratory tests (Fig. 3). During trimming, excess portions were retained for soil constants. The numbers opposite plotting points represent the plasticity index. There was no relation between strength and P.I., and there was no noticeable difference in strength for the two percentages of quick lime used. The cores containing 8 percent treatment of lime gained less in P.I. with age than the mixtures containing $4\frac{1}{2}$ percent (Fig. 4). Although the data are not included in this report, the average soil binder content (although variable) produced by drying and slaking was 17 percent less for the 8 percent mixtures. Figure 5 shows results of tests on raw gravel and cores from lime-treated gravel (Fig. 2). It appears that maximum strengths for this mixture were reached somewhere

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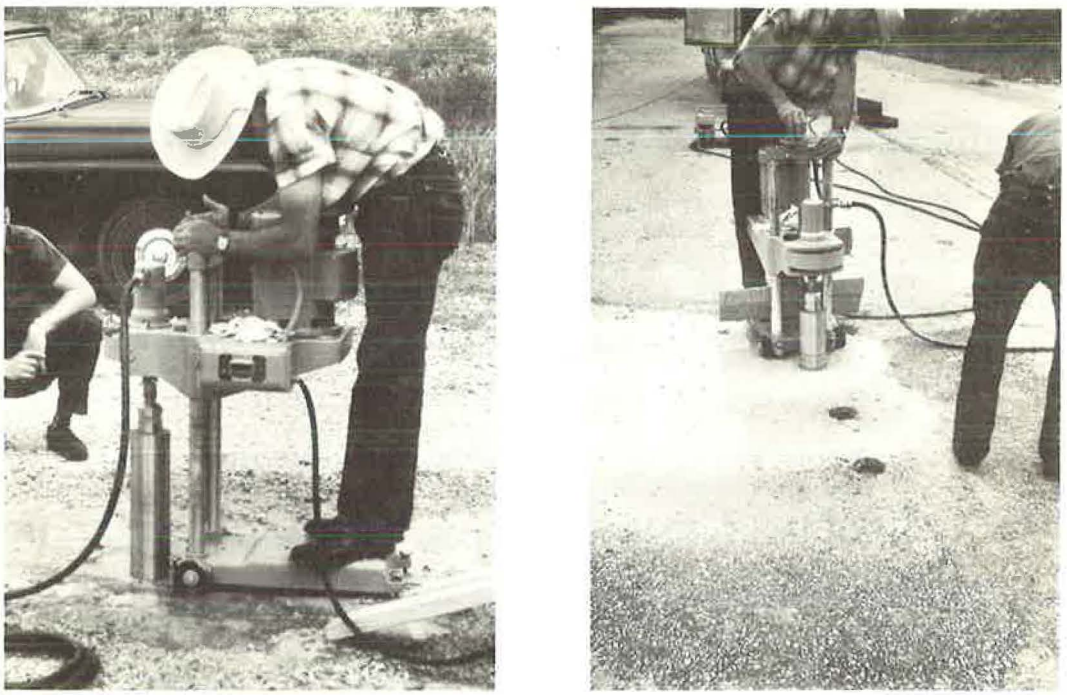


Figure 1. Removal of undisturbed cores from old roads of known behavior.

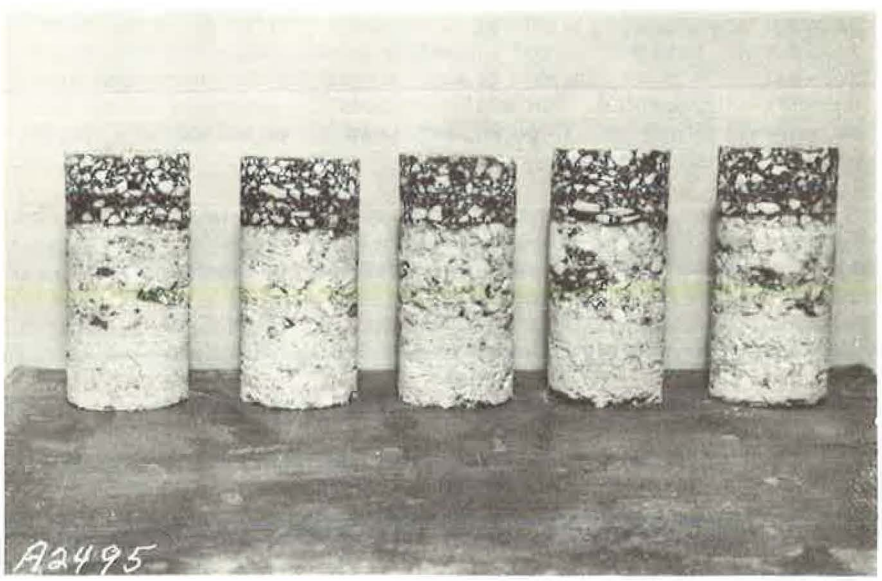


Figure 2. Cores from old roads of known behavior.

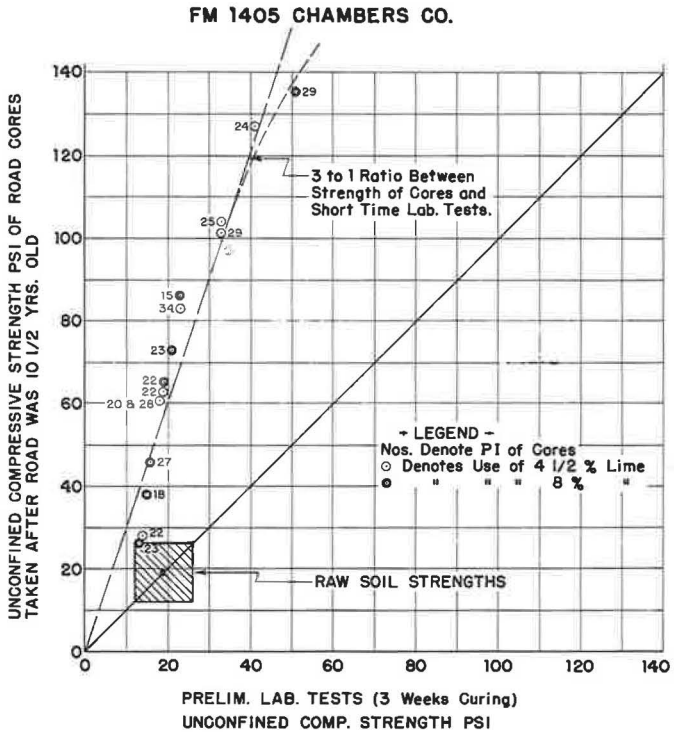


Figure 3. Relation of compressive strengths of clay-lime field cores to preliminary laboratory (short-time) results.

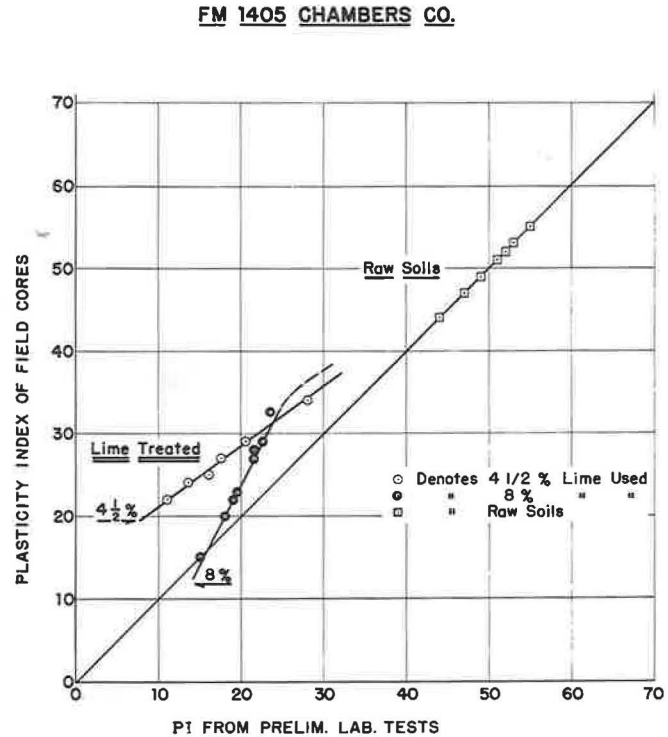


Figure 4. Relation of P.I. of clay-lime field cores to those obtained from short-time tests.

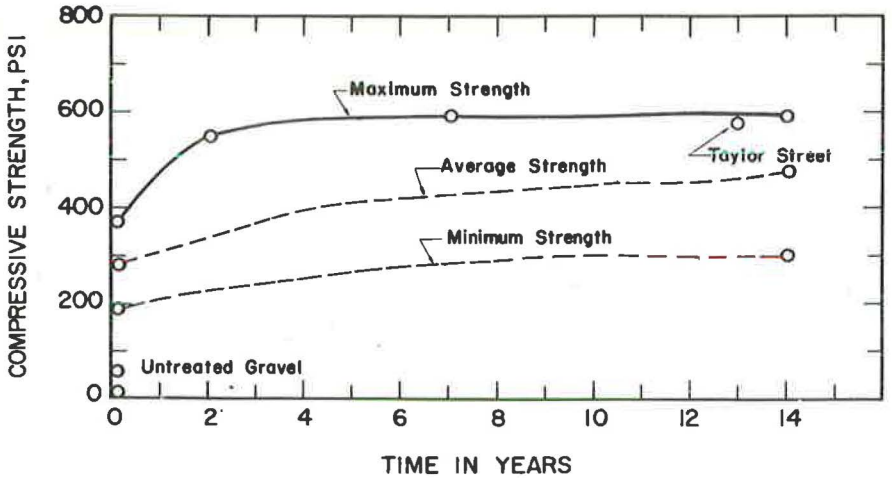


Figure 5. Unconfined compressive strengths.

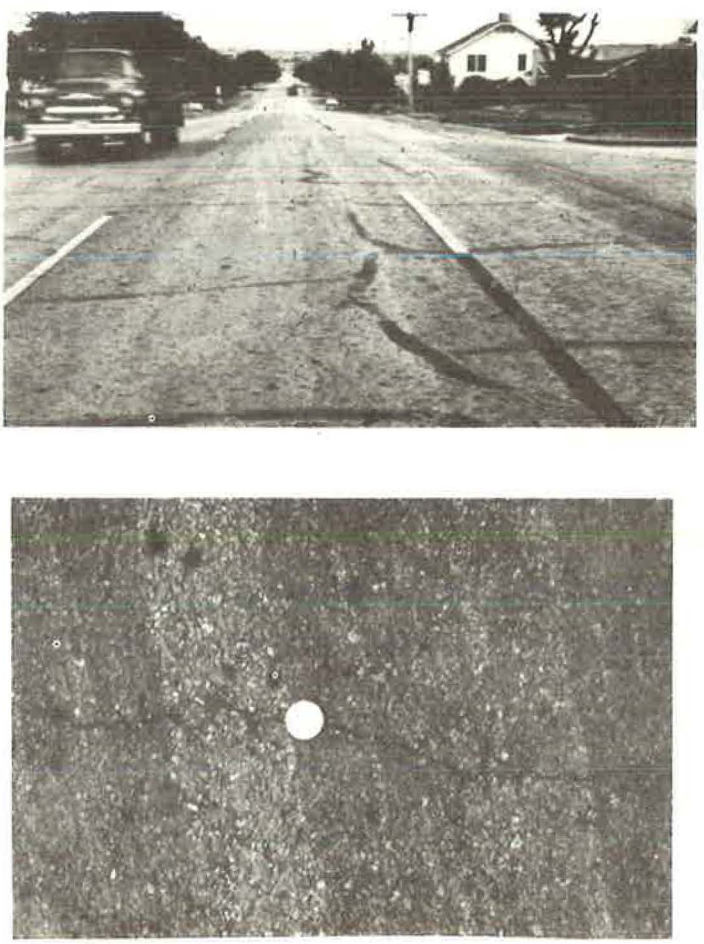


Figure 6. Shrinkage cracking in streets of Llano.

Figure 7. Benkelman beam deflection test.

between 1 and 24 mo. Other long-time tests, not included in this report, indicate soils containing much greater amounts of lime may still gain in strength after 10 yr (1). It is possible that the strength results in Figure 3 for the 8 percent lime might have gained

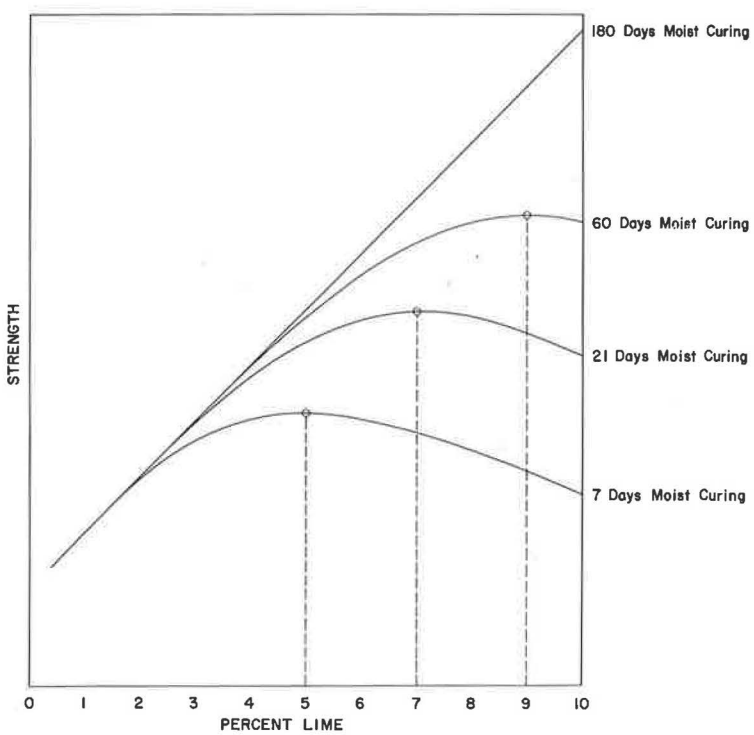


Figure 8. Optimum percent lime.

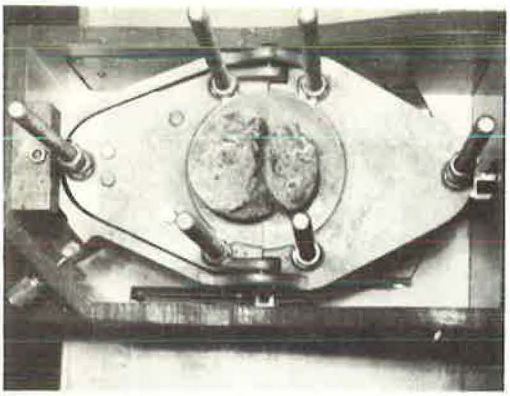


Figure 9. Cohesiometer specimen after breaking first time.

Figure 10. Rehealed cohesiometer specimen after 18 mo curing in moist room; specimen supported 1,500-gm load.

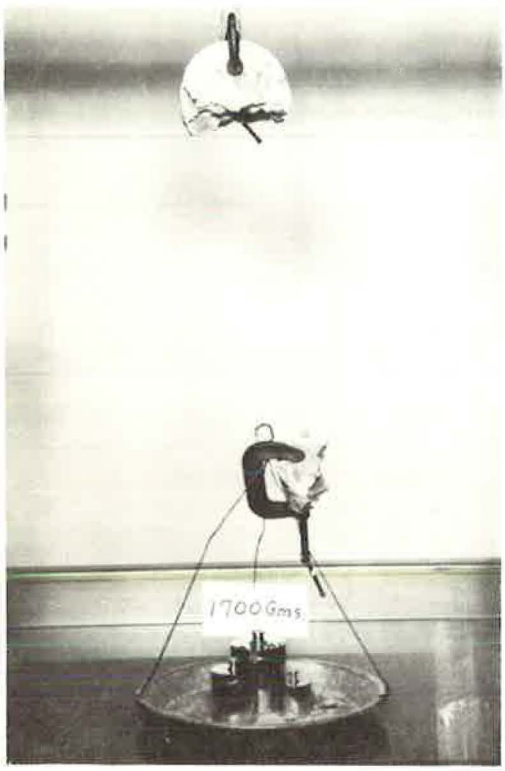


Figure 11. Same specimen as in Figures 9 and 10 breaks along old shear plane when 1,700-gm load is applied.

a great deal with time, but the road was abandoned for the sake of a new location shortly after the cores were taken.

Another method of analysis used for evaluation of treated base courses concerns cracking such as is shown in Figure 6. This problem is complicated by the fact that cracking can be caused by many factors other than shrinkage and other characteristics of the material itself; these causes include overloading when mixture is critically tender, volume change of subgrade, and inadequate depth design. We have nothing new to offer on this subject except to say that we are working on it largely from the standpoint of materials analysis.

Considerable progress in the use of deflection tests (2) to bring out increased beam strength with age has been accomplished by use of the Benkelman beam (Fig. 7).

Despite accomplishments in testing of cores, road cracking, or road deflections, we still have to tie mix design for all future work to some preliminary laboratory test which can be accomplished in a reasonably short time. Unfortunately, when confronted with an admixture design problem, we probably obtain results for only one of the curves given in Figure 8. Seldom do engineers realize that they have obtained only one of the elusive optimum lime contents that time of curing could change.

Another interesting aspect of evaluating lime stabilization mixtures involves autogenous healing. A core cut from a 12-yr old gravel stabilized with 3 percent lime was tested in a cohesiometer (Fig. 9), then placed in a moist room for approximately 18 mo, during which rehealing took place. A load of between 1,500 and 1,700 gm was required to pull the specimen apart again (Figs. 10 and 11).

MIXABILITY

In the stabilization of highly plastic clays with lime, it is believed that fairly good mixing is essential to successful results, and that efficient mixing is affected by the purity and fineness of the lime perhaps as much as by weather, moisture content, and equipment. It is further believed that for clay soils the cohesion of the soil is its greatest deterrent to pulverization. Figure 12 shows how the cohesiometer was used to evaluate cohesion of a soil having a P.I. of 42. The upper curve shows the effect of moisture content of the raw soil. In this case, 2- by 6-in. diameter specimens were compacted with 50 blows of a 10-lb rammer dropped 18 in. Specimens were held overnight without moisture content change so that moisture films could adjust before testing. A peak occurred in the curve at about optimum moisture for heavy compaction. In the case of soil-lime mixtures, the overnight delay before testing was deleted because we wanted to know the short-time condition of the mix, as in the case of passing it through a mixer. Total time used in molding and testing soil-lime mixtures was approximately 20 min. One percent lime reduced cohesion of the raw soil materially, but as the lime content was increased to 2, 3, 5, 6½ and 8 percent, cohesion was decreased further, perhaps with not much distinction between mixes containing 5, 6½ and 8 percent. These data from the peaks of these curves, expressed as percentages, are shown as the lower curve in Figure 13; data obtained in the same manner for three other limes varying in purity and fineness are shown in the lower right hand corner. To compare the relative effects of the four limes tested, horizontal lines on pertinent percent cohesiometer values were drawn and percentages of lime selected which produced equal effects on cohesion of the raw soil (for 50 percent cohesion, see Fig. 13). Percentages in Figure 14 were obtained in this manner. The data indicate that purity and fineness have an important influence on the lime contents required to produce equal cohesional properties in the soil tested. No procedure for this particular cohesiometer test is presented, inasmuch as a choice of details of the procedure is being studied. Soil materials of low cohesional characteristics probably would not be affected similarly, but most lime sold to treat soils is used for treating clayey soil materials where there is a mixing problem. Pure lime is enhanced for stabilization of clays as its degree of fineness is increased. The benefits of finely ground limes are most noticeable during pulverization and mixing. It is commonly assumed that fairly good mixing is an important quality in road-building mixtures. Also important is the contractors' ability to achieve such a mixture rapidly, in the most economical manner. It is believed that the finer the lime used, the more clay contracts and reactions there will be to ameliorate the soil in a reduced period of time.

SELECTION OF LIME CONTENT

Because there are so many variables in construction, we doubt that there is a strictly representative strength test method available for determining lime content for soil stabilization purposes which can be performed within a reasonable length of time. It is believed that Figure 15 offers the best method available for selecting lime contents for stabilization of soils; however, some form of strength test to check the lime's reaction with soils is necessary. We use a minimum unconfined compression value of 50 psi for subgrade or subbase and 100 psi for base materials which must carry a surfacing. In the preparation of Figure 15 the following factors were taken into consideration:

1. construction delays during mixing due to change of weather;
2. purity and fineness of lime;
3. imperfect mixing and compacting;
4. imperfect sealing and curing;

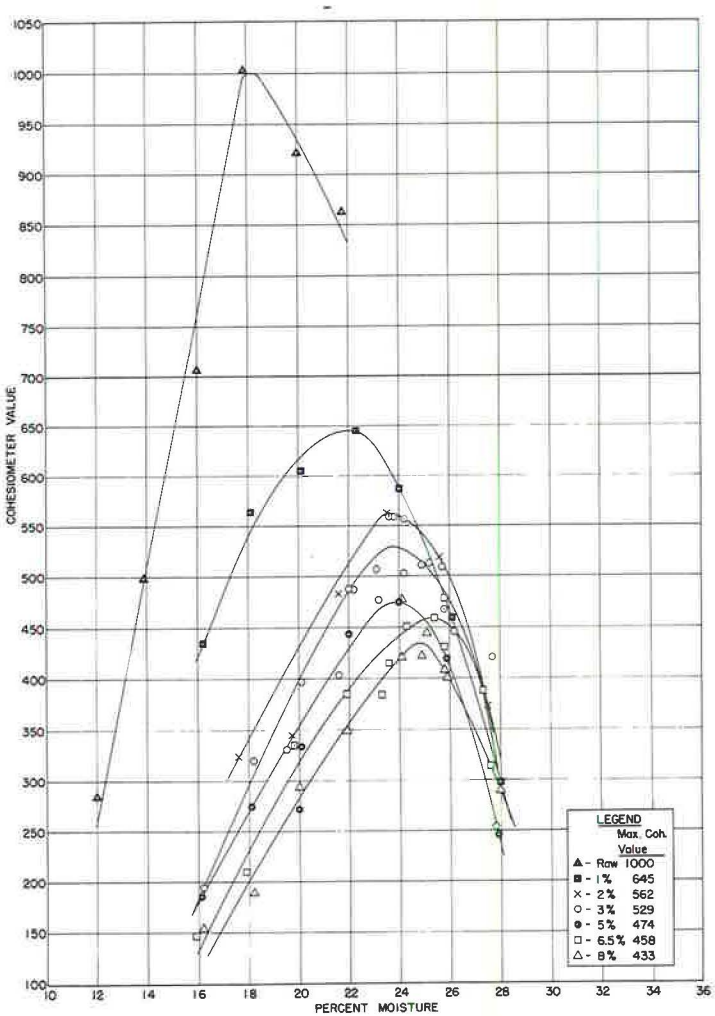


Figure 12. Relation of cohesiometer value to percent moisture for black gumbo manor clay soil containing various percentages of a fine pure lime.

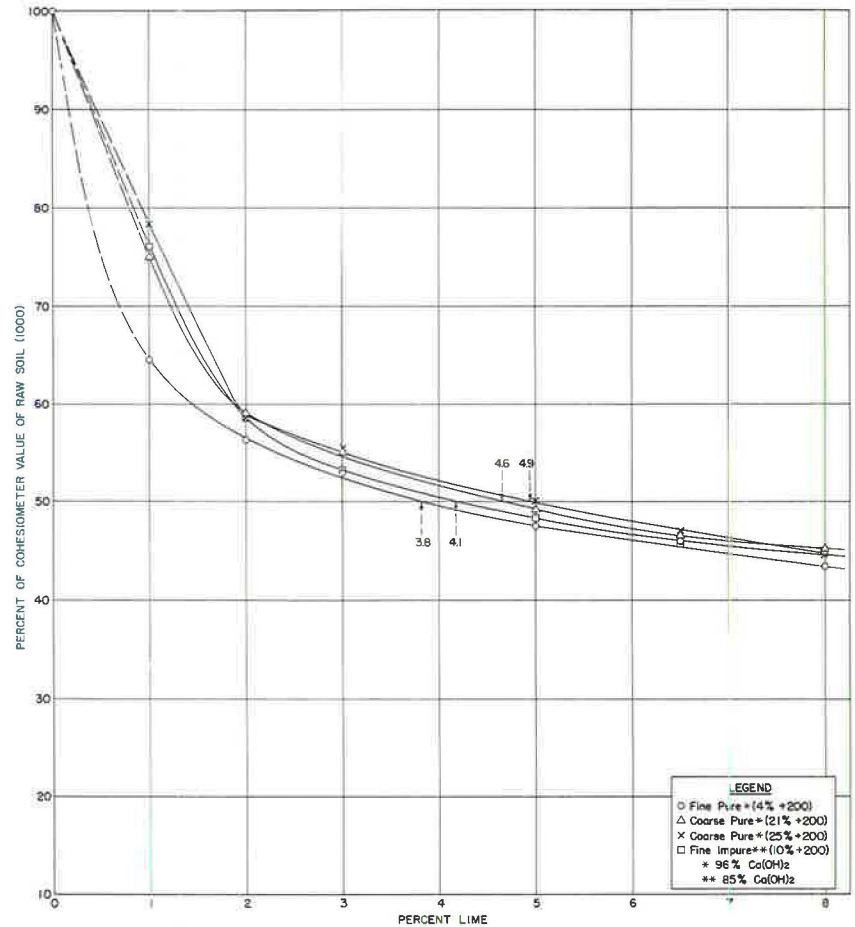
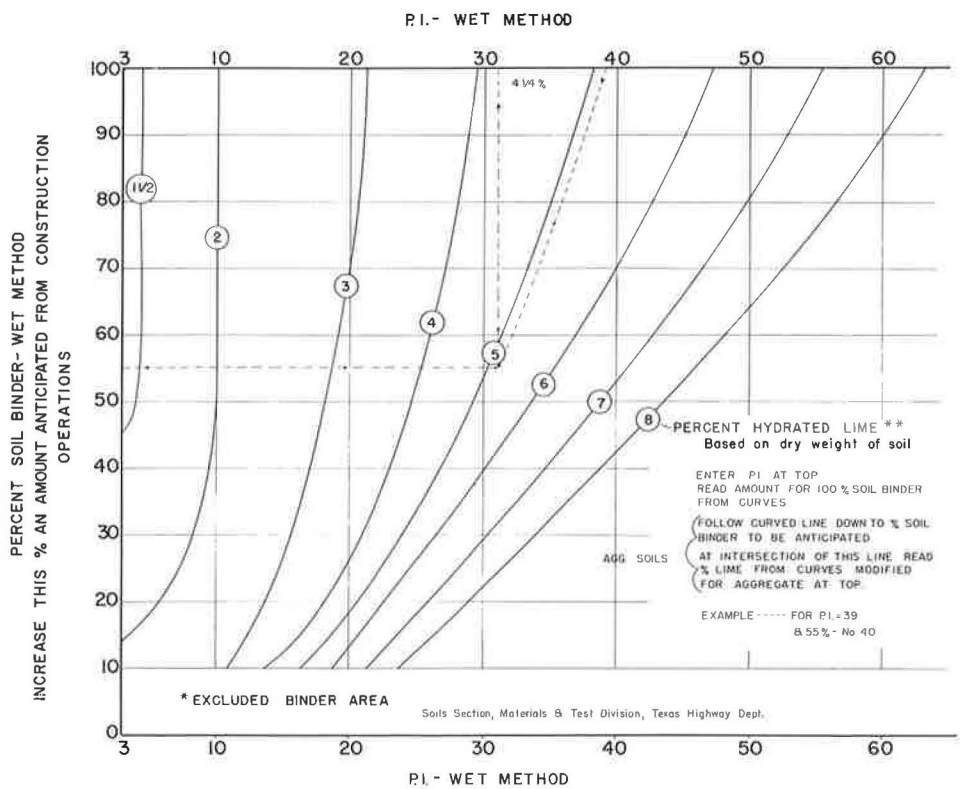


Figure 13. Effect of various types of limes on optimum cohesiometer values of manor clay.

Cohesiometer Values in % of Raw Soil	Percent Lime Req'd. to Produce Equiv. Cohesiometer Values			
	Fine Pure* 4% + 200	Coarse Pure* (A) 25%+200	Coarse Pure* (B) 21%+200	Fine Impure** 10% + 200
100	0.0	0.0	0.0	0.0
75	0.5	1.2	1.0	1.1
70	0.7	1.4	1.2	1.3
65	1.0	1.6	1.5	1.5
60	1.4	1.9	1.9	1.9
55	2.3	3.0	2.9	2.5
50	3.8	4.9	4.6	4.1
45	6.7	7.8	8.2	7.4

* 96% $Ca(OH)_2$
** 85% $Ca(OH)_2$

Figure 14. Percentages of various types of limes required to produce equivalent cohesiometer values.



* Exclude use of chart for materials with less than 10% - No. 40 and cohesionless materials (P.I. less than 3)

** Percent of relatively pure lime usually 90% or more of Ca and/or Mg hydroxides and 85% or more of which pass the No 200 sieve. Percentages shown are for stabilizing subgrades and base courses where lasting effects are desired. Satisfactory temporary results are sometimes obtained by the use of as little as 1/2 of above percentages. Reference to cementing strength is implied when such terms as "Lasting Effects" and "Temporary Results" are used

Figure 15. Recommended amounts of lime for stabilization of subgrades and bases.

5. strengths from long-time curing tests;
6. permanence of effects desired from treatment; and
7. plasticity of soil and durability of portion retained on No. 40 sieve.

The percentages shown (Fig. 15) are for long-time cementing effects in which the layer involved becomes a part of the layer system of the pavement. As little as one-half of these amounts may be used if only temporary working table effects are desired. In this case, where the layer is treated with a small amount of lime, it should not be counted as part of the pavement system. The use of such low percentages in the treatment of some "gumbo" soils has made it very difficult to meet the specification requirement for pulverization (60 percent passing the No. 4 sieve). The chart is applicable to all soils except for a few which have a P.I. below 3 and contain less than 10 percent passing the No. 40 sieve. Ordinarily these types of soils are not treated with lime but occasionally this might be necessary. In such cases, a special investigation should be made encompassing a great deal more than mere use of the chart.

CONCLUSIONS

1. A study of cores from old roads can be helpful in the evaluation of soil-lime stabilization mixtures; the data indicate that (a) strengths of cores from properly constructed old roads can generally be expected to be from two and one-half to three times as great as those obtained under normal room-temperature curing periods; (b) the P.I. of the soil-lime mixtures has no relation to strength; and (c) 8 percent lime had less tendency for P.I. to increase with age than 4½ percent mixtures. (Portions slaked for soil binder showed that the 8 percent mixtures produced less soil binder than the 4½ percent mixtures.)
2. A study of cracking, rehealing and load deflections of existing jobs can also contribute to evaluation of lime stabilization mixtures.
3. Short-time strength tests probably will not identify optimum lime contents for most construction, but it is essential that they be made to check against use of soils which are nonreactive when treated with lime. Long-time tests would do a better job of identifying optimum lime contents, but are impractical from the standpoint of time and might not suggest the use of enough lime due to the ideal conditions under which they are run.
4. The use of pure fine limes decreases the cohesion of heavy clay soils more effectively than coarse pure or fine impure limes; therefore, difficulty of mixing should be decreased when the purest and finest limes available are used. Each agency will have to determine practical limits for purity and fineness. In our area it is believed that limes should be at least 90 percent hydrated lime and contain a minimum of 85 percent passing the No. 200 sieve when wet washed.
5. A chart based on the interrelationship of percent of relatively pure fine lime, plasticity index, and percent soil binder is presented and recommended for use. This chart is believed to meet most of the rigorous requirements of the state of the art at this time.

ACKNOWLEDGMENTS

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