Curing Lime-Stabilized Soils

M. C. ANDAY, Highway Research Engineer, Virginia Council of Highway Investigation and Research, Charlottesville

The study investigated the possibility of establishing a correlation between the strengths of field-cured specimens of lime-stabilized soils and those of laboratory-cured specimens. Several sets of specimens of each soil were subjected to field curing during different parts of the spring, summer, and fall of 1961, and only the temperature variable was investigated. The data were analyzed on a strength vs maturity basis. The results obtained indicate that a strength prediction based on 2 days at 120 F laboratory curing can be made with reasonable accuracy. Temperature data recorded throughout the study suggested seasonal limits for lime stabilization.

•ONE PROBLEM in highway construction today is the scarcity of suitable base or subbase materials. A solution offered to the highway engineer is the stabilization of soils otherwise classified as "below specification" or "unsuitable." A major field in stabilization is the use of cement as an additive. Soil-cement and cement-modified soils are successfully used as parts of flexible pavements or as a firm bed under rigid pavements. However, it has been observed that cement cannot be used as successfully with cohesive soils as with more granular soils.

Supported by a great amount of laboratory and field data, most researchers agree that hydrated lime or quicklime should be used to stabilize cohesive soils. However, though the results of laboratory and field research on lime stabilization provide the highway engineer with useful knowledge, it is often difficult to compare the work of different researchers because of the wide range of curing temperatures, temperature levels, and periods of time used to cure soil-lime mixtures.

It is agreed that especially for any kind of strength tests, soil-lime specimens should receive a certain amount of curing before being tested. Further, standardizing this curing period would be a major step toward better understanding and generalization of all future testing and research.

It is fairly common knowledge that the use of lime is severely restricted by climatic conditions; this explains why lime is used more in southern States than in northern regions. Virginia, having a moderate climate, shows great possibilities for lime stabilization. However, where lime is used, the construction season should be limited to summer months and a quick method of evaluating the properties of the stabilized mixtures, together with an acclerated curing period, is needed.

PREVIOUS EXPERIENCE

In 1960 a study (1) was initiated to correlate the gain of strength of lime-stabilized soil specimens cured under two conditions: (a) simulated field curing, and (b) accelerated laboratory oven curing. It was thought that specimens of lime-stabilized soil buried under an artificial pavement, at proper depth, would cure in a manner similar to that of a stabilized soil in regular construction.

Two soils were chosen for study. One showed possibilities as a stabilized base, the other as a stabilized subbase. A typical pavement was chosen for the design of the simulated road. Unconfined compressive strength specimens and California Bearing

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Ratio specimens of each soil were buried at average base and subbase depths of the chosen typical pavement. These specimens were removed from the simulated road at random and tested at 15-day intervals. The values obtained from the unconfined compressive strength specimens were compared with those of similarly molded specimens oven cured at 120 and 140 F. The values obtained from the field-cured CBR's were compared to the values obtained from specimens cured in the moist room.

The conclusions derived from the study (3, 4) indicated the following:

1. There could be a correlation between field-cured and oven-cured unconfined compressive strength specimens.
2. The 120 F oven curing proved to be a more realistic procedure than did the 140 F curing.
3. The results of CBR tests were widely dispersed and no conclusions were derived from them.

On the basis of these conclusions the study was continued on a larger scale to permit generalization of the findings. However, several changes were made:

1. The CBR specimens were omitted.
2. Only 120 F oven curing was used as laboratory accelerated curing.
3. A two-pen temperature recorder was installed at the simulated road and temperatures at assumed base and subbase levels were recorded.

PURPOSE AND SCOPE

It was the purpose of the present study to develop an accelerated curing method under standardized conditions. This, in turn, was to be the basis for a quick laboratory method of determining the suitability of a soil for lime stabilization. The kind of test for the laboratory method of evaluation will be the subject of a separate study (2). This paper reports only the attempts made to find a correlation between an accelerated laboratory curing and simulated field curing.

The study was limited to soils chosen as representative of most Virigina soils under consideration for lime stabilization. Most of the soils sampled were from experimental lime stabilization projects previously installed in Virginia. All soils were stabilized with 5 percent lime. However, to determine if the findings with 5 percent lime were true for another percentage, one soil was stabilized with 3 percent and 5 percent lime and another soil with 5 percent and 8 percent lime.

The study did not consider such variables as movement of moisture or repetition and magnitude of loads, but was concerned with the effect of maturity (temperature × time) on gain of strength.

PROPERTIES OF SOILS TESTED

The physical properties of the six soils chosen for study are given in Table 1, and a location map is shown in Figure 1.

Soil A is a clayey sand common in the northeastern part of the State of Virginia. Pilot tests showed that the soil reacts very well with lime and produces fairly high unconfined compressive strength and resists freeze-thaw and wet-dry tests satisfactorily (5). The pit contains from 30 to 60 percent plus No. 4 material; however, due to the small size of the strength specimens used only the portion of the soil passing the No. 4 screen was sampled. It is believed that when stabilized with lime and covered with adequate surfacing this soil could be used as an alternate to the locally available crushed aggregate. The streets of several residential subdivisions in Fairfax County that were accepted into the State secondary system were built with unstabilized material similar to this soil and created great maintenance problems. During the summer of 1961 several of these streets were treated with cement and lime to help reduce the maintenance problem. These partly experimental projects, though far from being research projects because of the oversized particles used and the lack of compaction control, can serve as a guide towards the use of this soil as a stabilized base.

Soil B is a micaceous silt regarded as being a "troublesome" soil in Virginia. The soil was sampled from an experimental lime, lime-fly ash, and cement stabilization section built in 1956 on Project 1770-03, US 58 Patrick County (6), where it was used as a stabilized subbase.

Soil C is a clayey sand. It was sampled from an abandoned pit from which nearly all the soil was used for an experimental lime stabilization project on Route 641, Isle of Wight County in 1957-58 (6). The soil is not representative of that used on the experimental project, being considerably more sandy. However, at the time it was thought beneficial to include a sandy soil in the accelerated curing study because sands are known to react less with lime than finer grained soils do.

Soil D, a silty clay, was sampled from Project 0460-035-101, US 460 in Giles County, where part of the subgrade was stabilized with hydrated lime. The project was constructed in 1961.

Soil E, a heavy clay, was sampled from the experimental lime stabilization project in Rockingham County, Route 276, Project 0276-082-005. The project was built in 1959 (7).

Soil F is a clayey silty shale. It was sampled during the construction on Project 0050-034-101, C 501, US 50, Frederick County. The project was built in 1961 and the in-situ soil was stabilized with lime to serve as subbase.

About 600 lb of each soil were air dried, screened through the No. 4 sieve, mixed thoroughly, and stored in closed containers. The amount of material retained on the No. 4 screen was recorded and discarded. The gradations in Table 1, therefore, reflect the properties of the minus No. 4 soil.

TEST PROCEDURE

Size and Number of Specimens

Previous experience (1, 3) had indicated that at least 11 or more specimens had to be used for each period of field curing and oven curing in order to obtain satisfactory precision at the 95 percent confidence level. For this reason the Harvard Miniature Mold size (1.34-in. diameter and 2.78-in. height) was chosen as the size of the unconfined compression test specimens to keep the amount of soil needed to a minimum and to obtain a homogeneous mixture. The ease of molding specimens of this size permitted use of 15 specimens for each curing period.

Molding

The maximum density and the optimum moisture content of each soil, with 5 percent hydrated lime added, were determined in accordance with AASHO T99-57 Method A.

The Harvard Miniature Mold was used for molding specimens; however, the spring hammer furnished by the manufacturer was replaced with a home made drop hammer. The hammer was constructed to have a 1-lb weight falling 10 in. The diameter of the hammer head was one-half that of the mold.

Using the Harvard Miniature Mold and this hammer it was observed that at optimum moisture content five layers and fifteen blows per layer would produce a density a little above the maximum obtained by AASHO T99-57 Method A.

All specimens were molded close to their optimum moisture content, wrapped with aluminum foil, and coated with a special wax to preserve the molding moisture content during the curing period. The different stages of preparing specimens are shown in Figure 2.

Field Curing

It was estimated that a lime-stabilized pavement will get a curing of about a month or two before it is opened to traffic. A round figure such as 3,000 degree-days was chosen as basis of comparison. At base and subbase levels this maturity can be reached in about 40-45 days during summer months, and of course it will take longer during winter, fall, and spring. However, it is believed that maturities achieved at different levels (or ranges) of temperature might not affect the lime-stabilized specimens simi-

TABLE 1

PHYSICAL PROPERTIES OF SOILS TESTED

Property	Soil					
	A	B	C	D	E	F
HRB classification	A-2-6 (0)	A-4 (1)	A-2-7 (0)	A-7-6 (20)	A-7-6 (20)	A-4 (2)
Description	Clayey sand	Micaceous silt	Clayey sand	Silty clay	Clay	Clayey silty shale
Origin	Coastal Plain	Piedmont	Coastal Plain	Valley and Ridge Province	Valley and Ridge Province	Valley and Ridge Province
Percent passing:						
No. 4	100	100	100	100	100	100
No. 10	86	99	98	89	100	70
No. 20	68	97	89	87	99	57
No. 40	45	89	58	86	98	50
No. 60	31	76	29	84	98	46
No. 80	28	63	20	84	97	44
No. 100	26	55	16	83	97	44
No. 200	25	39	12	82	96	41
Percent silt (0.05-0.005 mm)	3	29	6.6	12.9	10	22
Percent clay (0.005 mm)	21	4	5.5	63.2	84	16
Specific gravity	2.70	2.75	2.67	2.74	2.77	2.72
Liquid limit (%)	35	40	55	63	75	29
Plasticity index (%)	11	N.P.	26	35	48	8
Max. den. with 5% lime (pcf)[a]	117.0	94.8	122.0	87.5	88.0	110.0
Opt. moist. cont. with 5% lime (%)[a]	13.4	24.4	11.0	30.0	29.0	16.0
Considered for	Base	Subbase	Base	Subbase	Subbase	Subbase

[a]AASHO T-99

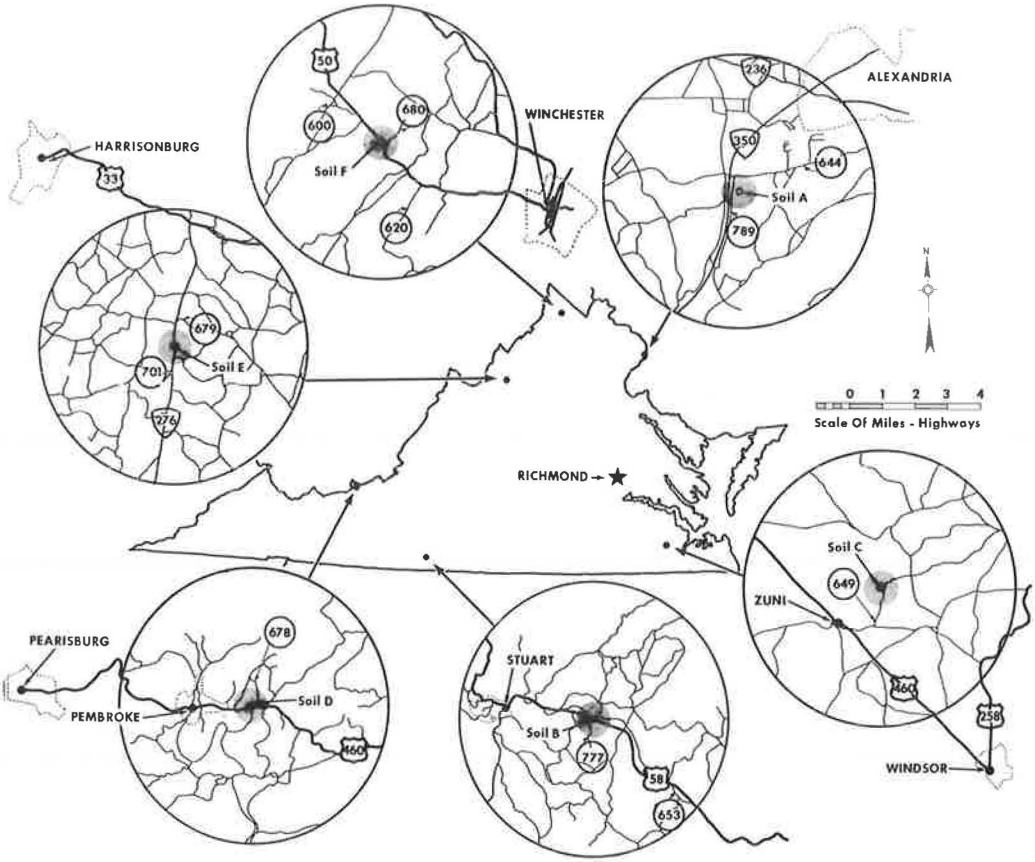
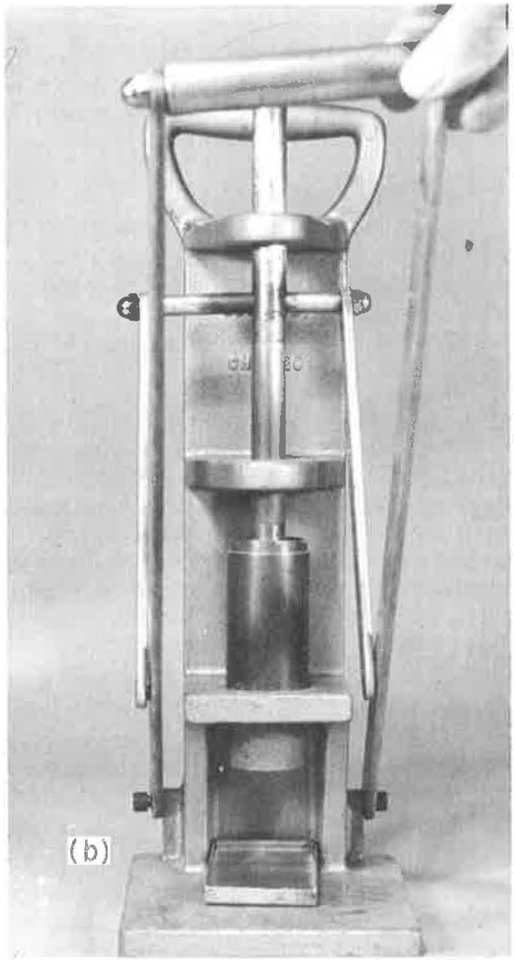


Figure 1. Location of soils investigated.



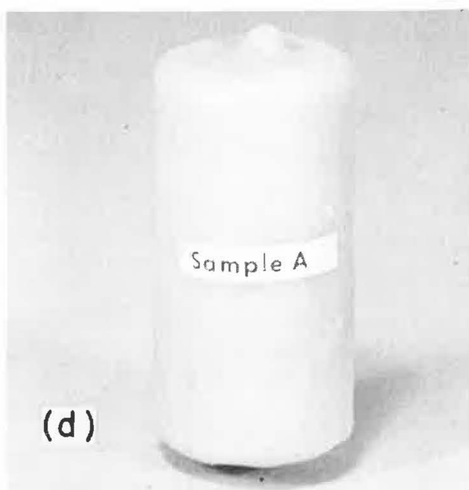


Figure 2. Stages of molding specimens: (a) molding equipment, (b) ejection of specimen, (c) waxing, (d) final specimen.

larly. For this reason temperatures at air and assumed base and subbase level were continuously recorded during the study. This subject is discussed later.

Generally, maturity is defined as the summation of the products of temperatures with their durations. However, for each specific purpose, the datum temperature should be specified. Therefore, unless otherwise specified, maturity will mean 0 F as the datum temperature.

Field-Curing Schedule

The study was started in June 1961. Forty-five unconfined compression test specimens of each soil were molded and subjected to field curing. Figure 3 shows the simulated road and the location of test specimens according to their uses as base or subbase materials.

At periods of 30, 45, and 60 days, 15 randomly selected specimens were tested for unconfined compressive strength. The total of 45 specimens is referred to as Series I. When all specimens of one soil had been tested, another set of 45 specimens (Series II) was molded and subjected to field curing and tested in the manner described.

Series III of each soil was molded during the fall of 1961. Because not much strength development was expected due to low temperatures, only 30 specimens of each soil were made and these were randomly tested in two groups of 15 each at maturities around 2,500 and 3,500 degree-days, respectively. A schematic representation of curing periods for each soil and average temperatures and accumulated maturities for each month are shown in Figure 4.

Laboratory Curing and Testing

Forty-five specimens of each soil were molded and cured in a 120 F oven. At periods of 1, 2, and 3 days, 15 random specimens were tested. The temperatures maintained during laboratory curings were within ± 5 F.

All specimens were tested for unconfined compressive strength at room temperature (70 F ± 5 F) and at a rate of strain of about 0.12 percent per second.

RESULTS

The unconfined compressive strengths of field-cured and laboratory-cured specimens were compared. Figure 5 shows the average unconfined compressive strength and the 95 percent confidence limits are plotted against maturity. From the curves

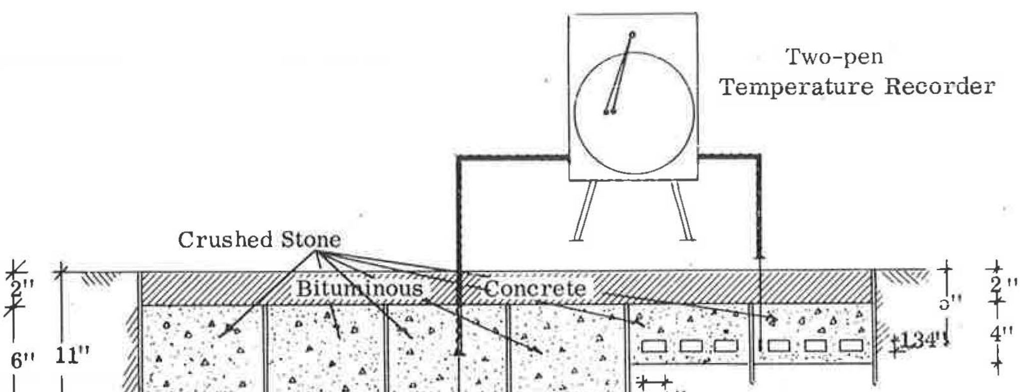
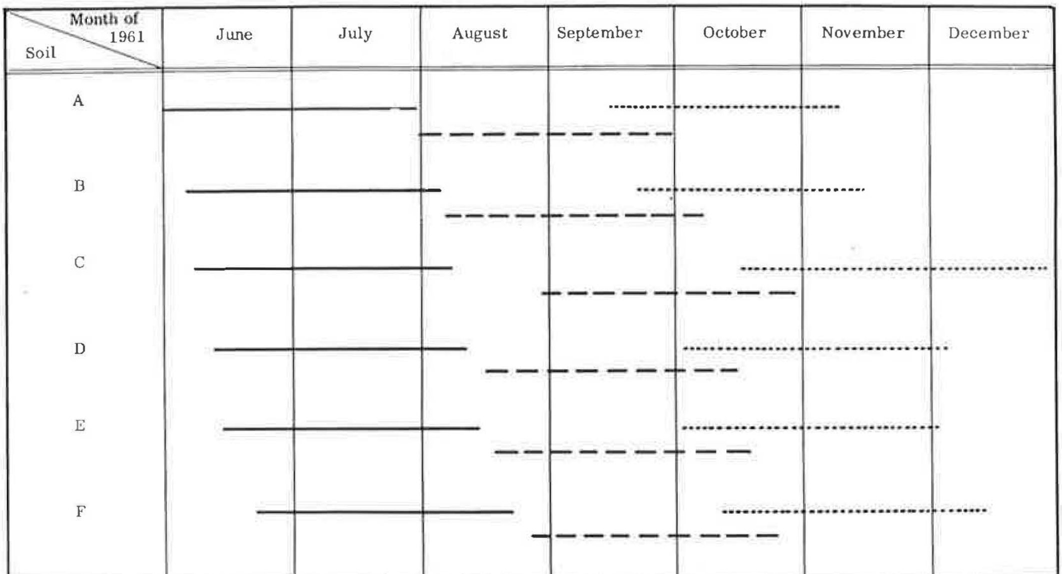


Figure 3. Simulated road and depth of field-cured specimens.



	June			July			August			September			October			November			December		
	Air	Base	Sub-base	Air	Base	Sub-base	Air	Base	Sub-base	Air	Base	Sub-base	Air	Base	Sub-base	Air	Base	Sub-base	Air	Base	Sub-base
Ave. monthly temp., deg. F	72	74	72	76	78	77	76	78	78	73	76	77	60	62	64	51	52	54	36	37	38
Maturity above 0 F, deg. days	2074	2139	2096	2359	2423	2368	2356	2414	2411	2192	2278	2296	1856	1937	1983	1515	1573	1631	1111	1136	1190
Maturity above 50 F, deg. days		689	646		873	838		864	861		778	796		387	433		130	159		0	0
Maturity above 60 F, deg. days		399	356		563	528		554	551		478	496		108	135		21	24		0	0

LEGEND: Series I ——— Series II — — — Series III ....

Figure 4. Field-curing schedule and maturity data.

obtained, the time required for laboratory-cured specimens to reach a strength equivalent to that of field-cured specimens which received 3,000 degree-days of maturity can be determined. The determinations for Series I and Series II are summarized in Table 2.

In Figure 5, the 95 percent confidence limits and the average values of strength achieved with simulated field and laboratory curing were compared. This approach was considered realistic because the confidence limits reflected the variation in each set of 15 specimens. From the figure it might seem that the range of the accelerated curing period for this soil is rather large (0.7 days). However, the strength values are within 16 psi, or a variation of ± 8 psi. For each soil, the range and variation of strength values are shown in the last column of Table 2. Soil E showed the maximum range and variation, 52 psi and ± 26 psi, respectively. This variation seems reasonable in soils work. The coefficient of variation and the confidence limits for strength values for each type and period of curing are given in Table 3.

The values in Table 2 for the mixtures containing 3 and 8 percent lime indicate that the findings for 5 percent lime are also applicable for other percentages.

For practical purposes the average of all accelerated curing periods (last figure in the accelerated curing day column in Table 2) can be used as a standard. It is believed that this average curing period of 2 days at 120 F is realistic. It will predict, within reasonable limits, the unconfined compressive strength that can be developed by a soil at a time when it is needed; i. e., about 40 to 45 days after construction. As a contrast some of the presently used curing periods for lime-stabilized soils, such as

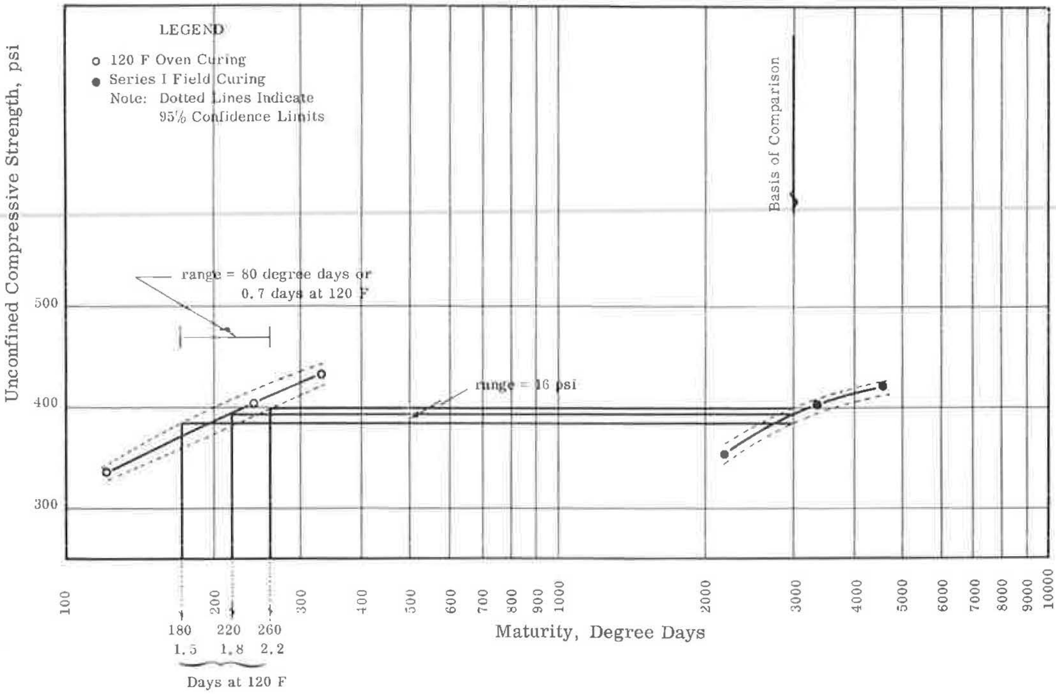


Figure 5. Example of comparison of field and oven curing.

TABLE 2

TIME OF ACCELERATED CURING AT 120 F TO ACHIEVE 3,000 DEGREE-DAYS FIELD STRENGTH

Soil	Lime Content (%)	Series	Accelerated Curing (days)	Unconfined Compressive Strength (psi)	
				Average	Variation
A	5	I	2.5	450	± 20
		II	2.4	433	± 14
B	5	I	1.9	240	± 8
		II	2.1	249	± 5
C	5	I	2.3	45	± 3
		II	1.9	49	± 3
D	5	I	1.8	395	± 8
		II	1.4	361	± 9
E	5	I	2.2	490	± 26
		II	2.4	500	± 7
F	5	I	2.2	304	± 8
		II	1.4	269	± 5
A	8	I	1.5	217	± 20
D	3	I	2.0	202	± 11
Avg.			2.0		

TABLE 3

COEFFICIENT OF VARIATIONS OF ALL UNCONFINED COMPRESSION TESTS

Soil	Series	Coefficient of Variation					
		Simulated Field Curing			120 F Curing		
		30 Days	45 Days	60 Days	1 Day	2 Days	3 Days
A	I	8.6	5.0	6.3			
	II	5.5	6.5	5.9	5.8	4.3	5.7
	III	-	5.3	3.9			
B	I	9.4	5.6	4.4			
	II	2.9	3.6	3.4	8.7	3.5	2.9
	III	-	11.0	14.0			
C	I	10.1	9.8	-			
	II	15.5	14.0	13.4	7.2	7.7	4.1
	III	-	9.8	8.4			
D	I	4.9	2.9	5.4			
	II	4.4	3.5	4.0	3.7	5.6	4.3
	III	-	2.9	5.0			
E	I	10.0	8.7	4.3			
	II	3.5	2.6	3.7	5.6	4.8	13.3
	III	-	5.6	7.2			
F	I	4.0	3.1	3.2			
	II	3.7	2.8	7.2	3.6	3.3	2.6
	III	-	4.1	3.6			

5 or 7 days at 140 F, might reflect unconfined compressive strength attainable at a year or two after the stabilization process. Data from previous experiments, although limited, might illustrate this point (3).

In Figure 6 the unconfined compressive strengths of a stabilized soil, cured in the simulated road and at 140 F in the oven, are plotted against their ages. From the shape of the curve, after 60 days of field curing the soil specimens reached their maximum strength, whereas the curve for the 140 F oven-cured specimens shows little tendency for leveling off. Even if the laboratory curve did level off after a curing of 5 days at 140 F, the strength reached at that time might never be reached with field curing.

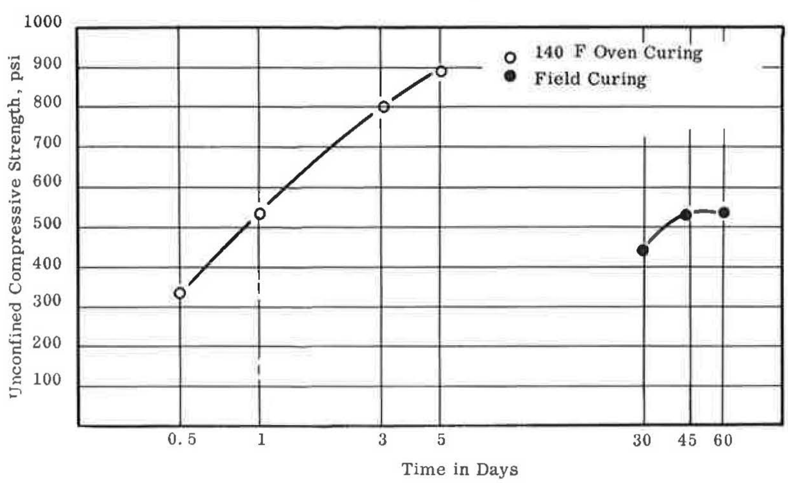


Figure 6. Comparison of field curing and 140 F oven curing.

Season Limits to Lime Stabilization in Virginia

The foregoing portion of the paper deals with the major intention of the study. However, from the temperature and strength data obtained throughout the study, important corollary information was developed. In Figure 7a the strengths of field-cured specimens of a soil are plotted against their maturities. The two curves represent the gain of strength for Series I and III, with Series III of each soil being subjected to field curing after the middle of September 1961 (Fig. 4). From the temperature data, at the lower part of Figure 4, it can be seen that both the average monthly temperatures and maturities are lower for October than for the preceding months, and the same is true for November and December.

In Figure 7a, curves for Series I and Series III are obtained by plotting strength values against their maturities, taking 0 F as datum temperature. With this method the two curves do not follow the same path. However, if a higher datum is taken for calculating maturities (e.g., 50 F) and the strength values are plotted against these maturities, both curves change position and come closer to each other (Fig. 7b). The important point is that the maturities of Series I are decreased by a constant value

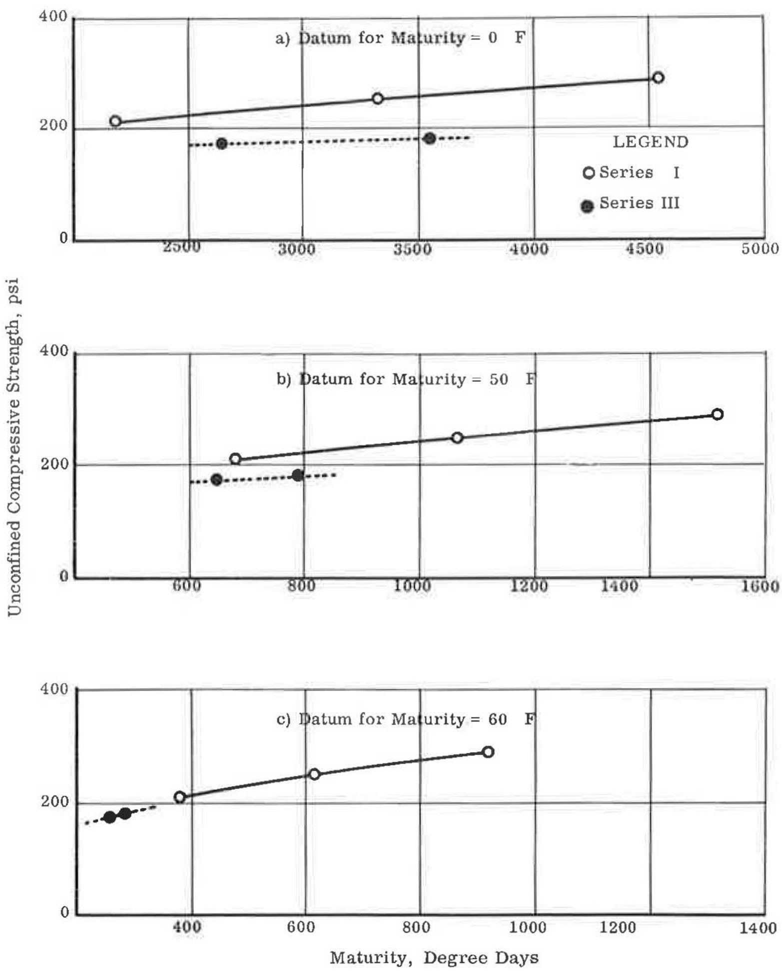


Figure 7. Strength data for Soil B vs maturities with different datum.

TABLE 4

ANALYSIS OF STRENGTH-MATURITY DATA FOR SEASON LIMITS FOR LIME STABILIZATION

Soil	Series	Min. Temp. Required for Lime to React[a] (°F)
A	I	55
	II	55
B	I	60
	II	58
C[b]	I	-
	II	-
D	I	53
	II	49
E	I	49
	II	52
F	I	50
	II	50

[a]Range for soils tested = 49 to 60 F.
[b]Results not conclusive for this sandy soil.

because there were no temperatures below 50 F during its field curing. On the other hand, the curve for Series III is affected more, because its field-curing period did have temperatures below 50 F. Using this method, and taking different datum temperatures for maturity calculations, points for Series I and Series III might be made to lie on the same curve (Fig. 7c).

It is assumed that only one strength-maturity curve exists for each stabilized soil, with the condition that the minimum temperature necessary for lime to react is provided. If this assumption is valid, then the temperature at which the points for Series I and Series III lie on the same curve is the minimum temperature required for lime to react.

The strength-maturity data of each soil and of each series were analyzed by the preceding method. Table 4 summarizes the temperatures for which the points for Series III of each soil will lie on the same curve as those for Series I and Series II. In the table this temperature is referred to as "the minimum temperature required for lime to react."

The data on soils included in this study, with the exception of Soil C which showed very little reaction with lime (Table 2), indicate that not much reaction of lime with soil should be expected at temperatures below 49 or 50 F.

It was mentioned earlier that a curing of 2 days at 120 F would correspond to about 3,000 degree-days, or 40 to 45 days of simulated field curing during summer months. This "3,000 degree-days" refers to a maturity calculated with 0 F as datum temperature. From the preceding discussion it is seen that for limiting the construction season for lime stabilization the datum temperature should be taken as 50 F, if the objective is to obtain a gain of strength. This would mean a reduction of about 2,250 degree-days (45 days × 50 F), leaving about 750 degree-days of maturity calculated with 50 F as datum temperature. Therefore, it is suggested that lime stabilization should not be attempted at a date after which a maturity of 750 degree-days (calculated with 50 F as datum temperature) is not anticipated to accumulate.

Figure 4 shows that in the simulated road, at subbase level, the maturities accumulated during October, November, and December were 433, 159, and 0 degree-days, respectively (50 F as datum temperature). This gives a total of 592 degree-days which, because it is below the needed maturity, indicates that in 1961 lime stabilization should not have been attempted after the middle or end of September.

As a word of caution, it is not intended that lime stabilization be limited to summer months. The hypothesis presented merely urges the construction engineers to be cautious in setting final dates, if any cementation is desired. Local weather forecasts, though applicable only to air temperatures, might be helpful to the highway engineer because temperatures and maturities for air are close to those at the subbase and base levels of the simulated road, as can be seen in Figure 4.

CONCLUSIONS

The data obtained for the six soils investigated and the use of 5 percent hydrated lime of one brand indicate the following:

1. Soil-lime specimens subjected to field curing in a simulated road will show an increase in unconfined compressive strength. However, the amount and rate of gain of strength will depend on the type of soil and climatic effects.

2. At Charlottesville, Va., during the summer of 1961, about 40 to 45 days were required to develop a maturity of 3,000 degree-days if 0 F is taken as datum temperature (or 750 degree-days, if 50 F is taken as datum temperature).

3. The unconfined compressive strength of soil-lime specimens having this maturity could be predicted by an accelerated curing of two days at 120 F.

4. If it is assumed that only one strength-maturity curve exists for each stabilized soil, then not much reaction of lime with soil should be expected at temperatures below 50 F.

ACKNOWLEDGMENTS

The author expresses his gratitude to B. B. Chamblin, G. A. Gatlin, and L. R. Staunton for helping in every phase of the study. Special thanks go to T. E. Shelburne, Director of Research, for his general guidance.

REFERENCES

1. Anday, M. C., "Working Plan, Curing Lime Stabilized Soils." Virginia Council of Highway Investigation and Research (March 1960).
2. Anday, M. C., "Working Plan, A Laboratory Evaluation of Lime Stabilized Soils for Field Performance." Virginia Council of Highway Investigation and Research (April 1962).
3. Anday, M. C., "Progress Report No. 1, Curing Lime Stabilized Soils." Virginia Council of Highway Investigation and Research (Dec. 1960).
4. Anday, M. C., "Accelerated Curing for Lime-Stabilized Soils." HRB Bull. 304, 1-13 (1961).
5. Unpublished reports by the Virginia Council of Highway Investigation and Research.
6. Nichols, F. P., Jr., "Progress Report No. 3, Base and Subgrade Stabilization Experiments." Virginia Council of Highway Investigation and Research (March 1959).
7. Anday, M. C., "Progress Report No. 4, Base and Subgrade Stabilization Experiments." Virginia Council of Highway Investigation and Research (Jan. 1960).

Discussion

MANUEL MATEOS and JERRY W. H. WANG, Soil Research Laboratory, Iowa State University, Ames, Iowa —The author is to be complimented for the effort of correlating the strength of field cured soil-lime specimens with those cured in the laboratory at high temperature.

The writers' studies show that different limes develop strength at different rates depending on the curing temperature (8, 9, 10). An example of this is given in Table 5, where dolomitic monohydrate lime gives much higher strength than high-calcium hydrated lime at 70 F curing temperature, but high-calcium hydrated lime gives slightly higher strength than dolomitic monohydrate lime at 120 F curing temperature. How is the lime variable taken into account in the 2 day 120 F quick method for strength prediction?

Table 6 shows that a soil stabilized with dolomitic monohydrate lime has about twice as much strength as with calcitic hydrated lime at a curing temperature of 50 F. Should this suggest that different seasonal limits be used for different types of lime in soil-lime stabilization works? It may also be of interest to know the type of lime used in the studies presented in the paper.

REFERENCES

8. Davidson, D. T., Mateos, M., and Barnes, H. F., "Improvement of Lime Stabilization of Montmorillonitic Clay Soils with Chemical Additives." HRB Bull. 262, 33-50 (1960).

TABLE 5

COMPARISON OF STRENGTHS OF SOILS TREATED WITH TWO TYPES OF LIME AND CURED AT DIFFERENT TEMPERATURES[a]

Soil	Lime Type	Lime Amount (%)	Cured at 70 F: 7 Days	Cured at 70 F: 28 Days	Cured at 70 F: 84 Days	Cured at 120 F: 2 Days
Plastic loess	High-calcium hydrated	2	60	65	60	130
		5	85	110	180	330
		8	85	110	210	485
		12	100	130	290	440
	Dolomitic monohydrate	2	43	45	30	170
		5	105	210	280	380
		8	135	230	300	400
		12	150	270	340	370
Friable loess	High-calcium hydrated	2	80	120	210	210
		5	80	130	350	400
		8	80	150	410	370
		12	80	150	360	360
	Dolomitic monohydrate	2	105	170	160	160
		5	150	350	600	310
		8	160	390	580	330
		12	170	400	580	320

[a]Analyses of soils and limes given elsewhere (4).

TABLE 6

COMPARISONS OF STRENGTHS OF A KANSAN TILL SOIL TREATED WITH TWO TYPES OF LIME AND CURED AT DIFFERENT TEMPERATURES[a]

Lime Type	Amount (%)	Cured at 50 F: 7 Days	Cured at 50 F: 28 Days	Cured at 70 F: 7 Days	Cured at 70 F: 28 Days	Cured at 100 F: 7 Days	Cured at 100 F: 28 Days
High-calcium hydrated	6	86	125	129	179	358	765
Dolomitic monohydrate	6	150	249	223	321	402	642

[a]Analyses of the soil and limes given elsewhere (1).

9. Mateos, M., and Davidson, D. T., "Physical and Mineralogical Factors in the Stabilization of Iowa Soils with Lime and Fly Ash." Iowa State University Engr. Exp. Sta. Bull. 196, 175-272 (1962).
10. Mateos, M., "Temperature Curing of Sand-Lime-Fly Ash Mixtures." Iowa State University Engr. Exp. Sta. Progress Report (1963).
11. Wang, J. W. H., Mateos, M., and Davidson, D. T., "Comparative Effects of Hydraulic, Calcitic and Dolomitic Limes and Cement in Soil Stabilization." Presented at 42nd Annual Meeting, HRB (1963).

M. C. ANDAY, Closure—Thanks are due Messrs. Mateos and Wang for their discussion. As explained in the paper, the determination of a curing period that will predict field-cured strengths at a time when the treated pavement will be subjected to traffic was the first step of a general study. This study is being continued. The scope of the study is to establish minimum unconfined compressive strength values for laboratory specimens to qualify soils for base or subbase lime stabilization. This will be accomplished by comparing the performance of several lime stabilization projects in Virginia, with the strength of specimens prepared in the laboratory. These specimens will be prepared from soils obtained from these projects, mixed with identical percentages of lime, and cured for 2 days at 120 F. Once the minimum unconfined compressive strength is specified, then it will be a matter of testing to determine how to obtain this strength, if attainable. The type of lime to be used will be a matter of concern when testing shows that the addition of one type of lime will not give the desired strength and that the addition of another type will. For this reason the lime variable was omitted.

Furthermore, experience has shown that even though different types of limes are used for stabilizing a soil, the strength development will be close enough for practical purposes. The author would like to illustrate this by using the discusser's data. However, it should be kept in mind that it is not the intention of the author to generalize the illustration but just to point out a practical aspect of lime stabilization.

Figure 8 shows the strength of the "plastic loess," tested by the discussers, with different percentages of two types of lime. The shaded area between the two curves indicates the practical percentages of lime that are used in field work (3 to 7%). Assuming that (a) the samples were randomized and (b) the results were calculated statistically, the differences between mean strengths are not more than 40 or 50 psi. The author does not consider this significant. The many variables involved in conducting an unconfined compression test on a laboratory prepared and cured soil-lime specimen can justify the preceding statement.

In addition to these reasons, Virginia's problem due to the lime variable is not nearly as severe as that of some other States because nearly all the limestone used in manufacturing lime is from the New Market—Five Oaks Limestone Formation. The product is a high-calcium lime, which was used in the study.

No further comments are made here as to the effect of different limes on the seasonal limits for lime stabilization, because this was not investigated in the study.

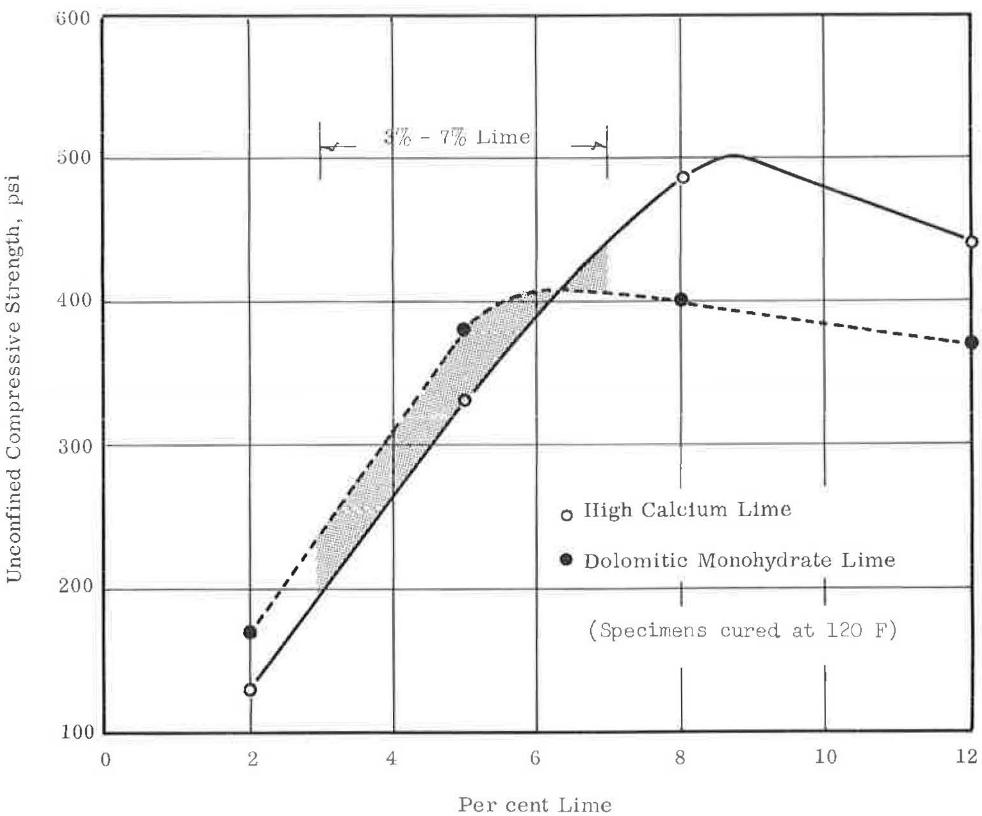


Figure 8. Strength vs percent lime for plastic loess soil.