Chemical Treatments for Surface Hardening of Soil-Cement and Soil-Lime-Flyash

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A bituminous wearing surface is nearly always used on base courses constructed of soil-cement or soil-lime-flyash. A simpler expedient would be to chemically treat the compacted roadbase to increase hardness within the upper surface. Even if the hardened crust were inadequate as a wearing surface, it might alter freeze-thaw susceptibility to allow a reduction in the thickness of bituminous surfacing and give a saving in cost.

Surface treatments investigated in the laboratory were calcium chloride, sodium hydroxide, sodium carbonate, and sodium silicate. Measured amounts of these solutions were sprinkled on the surfaces of molded 2-in. by 2-in. specimens confined in their molds. Solution amount, concentration, and time of application were varied. Other specimens were either moist-cured or sprinkled with distilled water to provide a control. At the end of the treatment and curing period the specimens were tested for bearing capacity by the Iowa Bearing Value, essentially a miniature CBR. Bearing values were measured from plunger penetrations of up to ½ in.

Soil-lime-flyash was benefited most by application of sodium silicate solutions. The sodium silicate penetrates into the soil and probably reacts with calcium and magnesium ions from the lime to produce insoluble calcium and magnesium silicates. A single application of sodium silicate followed by continual moist curing approximately doubled the bearing strength, and sodium silicate treatment followed by daily applications of water increased bearing capacity in the surface layer about four times. The silicate crust also forms an effective seal against entry of surface water. From these results, a field test appears to be the next step. Similar results are to be expected for soil-lime.

Results with soil-cement were less spectacular, but by no means less interesting. Sodium silicate application followed by daily wetting with water again proved to be the best treatment, the improvement being between 20 percent and 90 percent over control strengths,

depending on the soil. A sandy soil was most benefited. Daily wetting was in itself beneficial to the silty soil and this alone increased the bearing strength about 30 percent over that from ordinary moist curing. However, daily sprinkling decreased the bearing strength of the stabilized sandy soil. A sodium silicate soil-cement field test appears warranted, using sandy soil.

● SOIL-CEMENT, and more recently soil-lime-flyash, are becoming important members in the engineer's list of materials for low-cost roads or lots. Unfortunately both materials require a bituminous wearing surface which not uncommonly costs more than the price of the soil stabilization itself. A beneficient alternative for light-traffic uses would be to chemically treat the stabilized soil to increase strength in the upper layer of pavement. This paper reports the search for such treatments.

TEST METHODS

A punch-type bearing test was utilized to give a measure of surface hardness of the treated soil. The Iowa Bearing Value (IBV) test, essentially a miniature CBR, was selected because the small 2-in. diameter by 2-in. high specimen allows a considerable saving in time and labor. Tests were run in triplicate and the average bearing values reported.

Stabilized soil cylinders slightly over 2 in. long were compacted to standard Proctor density inside of 5-in. long brass sleeves by means of a drop-hammer molding apparatus. Each sleeve was then slipped over a 3-in. high pedestal which pushed the soil cylinder into the upper 2 in. of the sleeve. The protruding soil specimen was then struck off level with a straightedge, giving a cut surface similar to that left on a stabilized soil road after trimming by a blade grader. The trimmed soil cylinder was pushed back to the other end of the sleeve so the walls of the sleeve might aid in retaining the curing solution.

Chemicals

Curing solutions of different chemicals were sprinkled on the cut soil surfaces in varying amounts, comparable to those which could be obtained on a road with standard distributor equipment. Control specimens were sprinkled with corresponding amounts of distilled water. Laboratory sprinkling was done from a height of 3 in., from a graduated burrette.

Curing

Starting the day after treatment, most of the treated and control specimens were daily sprinkled with distilled water in the amount of $\frac{1}{2}$ gal per sq yd, and allowed to dry at 80 F ± 5 F in a relative humidity of 40 percent ± 5 percent. As specimens remained in the brass cylinders, only one end was exposed to open air.

For comparison, reference specimens not treated with chemicals were cured by wrapping in thin plastic ("Saran-wrap") and storing at 70 F ± 5 F in a relative humidity of 95 percent ± 5 percent.

Testing

The 5/8-in. diameter IBV plunger rod was pushed into a test specimen

at a constant rate of 0.05 in. per min, and the load in pounds was recorded at every 0.02 in. of strain to 0.20 in., then at every 0.05 in. until the penetration reached 0.50 in. The IBV is the load in pounds when the plunger penetration is 0.08 in., or a little over 1/16 in. (1). (The Iowa Bearing Value is closely correlative with the California Bearing Ratio in the normal range for unstabilized soils. However, these correlations probably are not valid for stabilized soils. As a very rough guide, 0.08-in. IBV's of 1,000, 500, and 100 are approximately equivalent to 0.1-in. unsoaked CBR's of 200, 100, and 10 for unstabilized soils containing 50 percent to 80 percent sand.)

The remainder of this paper is in two parts, the first on treatments for soil-lime-flyash, the second on treatments for soil-cement.

SOIL-LIME-FLYASH

A sample of Detroit Edison Company St. Clair flyash was used in the investigation. This flyash has a specific surface of 2,720 sq cm per gm and a 3.6 percent loss on ignition. Data show 11.3 percent retained on the No. 325 sieve. Except where otherwise specified, samples were molded with 22.5 percent flyash and 2.5 percent monohydrate dolomitic lime, expressed as percents of the dry weight of the mix.

In the initial evaluation two soils were used, both having a fairly high permeability. One, an A-4(8) silt loam, is from the thick, friable loess deposits of western Iowa. The other is a 75:25 mixture of fine alluvial waste sand and medium-textured loess, as used in a stabilized soil base course in primary highway 117 north of Colfax, Iowa (Table 1).

Treatment with Sodium Carbonate

Sodium carbonate has been found to be an effective accelerator for certain soil-lime-flyash mixes, and it was decided to try use of this chemical in a curing solution. It is believed that sodium carbonate reacts with calcium from lime to precipitate calcium carbonate as a cement and simultaneously release sodium hydroxide which acts to accelerate the pozzolanic reaction (2).

Sodium carbonate solutions of 5, 10 and 20 percent concentration were sprinkled to give various weights of chemical per sq yd (Fig. 1). Sprinkling was done after 0, 1, or 2 days preliminary moist curing. Thereafter each succeeding day the specimens were sprinkled with distilled water, and after 7 days they were tested.

The loess was not benefited by the sodium carbonate treatment, and bearing values were below those of the controls sprinkled with distilled water (Fig. 1a, b). General heaving and swelling were noticeable in the tops of specimens, indicating deleterious volume change from excess sodium carbonate. Furthermore, control strengths were below those from continuous moist curing except when daily sprinkling was light, less than 0.4 gal per sq yd (this amount represents control sprinkling with water to equal the amount of solution at a concentration of about 10 percent—in Figure 1 stronger concentrations mean less water), indicating the deleterious effects of excess wetting.

Sprinkling was particularly damaging to the surface of the stabilized sand-loess mixture, and IBV's fell from 650 in moist-cured specimens to an average of about 200 in the controls sprinkled only with water. Sodium

TABLE 1

SOIL PROPERTIES

Material	Friable Loess (No. 20-2V)	75:25 Sand-Loess			Dune Sand (No. S-6-2)	Detroit Clay	Kansan Till (No. 409-12C)
		Sand	Medium Textured Loess				
Location	Harrison Co., Ia.	Jasper Co., Ia.	Jasper Co., Ia.		Benton Co., Ia.	Monroe Co., Mich.	Ringgold Co., Ia.
Soil series	Hamburg	—	Tama		Carrington (?)	—	Burchard
Great soil group	Lithosol	—	Brunizem		Brunizem	—	Brunizem
Sampling depth	80 ft	—	5 ft - 40 ft		1½ ft - 16 ½ ft	—	4½ ft to 10½ ft
Horizon or bed	C, oxidized, calcareous	Washed sand dredged from terrace of Des Moines River	C, oxidized, calcareous		C, oxidized, leached	C, oxidized, calcareous	C, oxidized, calcareous
Liquid limit	34%			18.9%	19%	47%	42%
Plastic limit	28%			16.4%	—	21%	20%
Plasticity index	6			2.5	N.P.	26	22
Gravel (>2 mm)	0%			0%	0%	0%	0%
Sand (2-0.074 mm)	0.3%			57.7	94.4	10.5	31.9
Silt (74 - 5μ)	82.7			30.2	1.6	14.1	28.9
Clay (<5μ)	17.0			12.1	4.0	75.4	39.2
Colloids (<1μ)	12.3			—	3.5	70.5	—
Textural classification	Silt loam			Sandy loam	Sand	Clay	Clay
AASHO classification	A-4(8)			A-4(1)	A-3(0)	A-7-6(15)	A-7-6(12)
Clay minerals	Montmorillonite and illite			Montmorillonite and illite	Montmorillonite and illite	Chlorite and illite	Montmorillonite and illite
Cation exchange cap., me/100 gm	13.4			11.0	—	19.0	29.5
Carbonate content	10.2%			11.6%	0%	0.9%	2.1%
pH	8.7			8.0	6.5	7.6	8.25
Organic matter content	0.17%			0.16%	0.04%	1.1%	0.17%
ASTM Cement requirement, by weight	9%			8%	—	—	—
OMC for soil-cement	17%			9.8%	—	—	—
Std. Proctor density	105 pcf			129 pcf	—	—	—
OMC for soil + 24% 1:7 lime-flyash	20%			11%			
Std. Proctor density	98 pcf			120 pcf			

Lime - Fly Ash Stabilized Soils

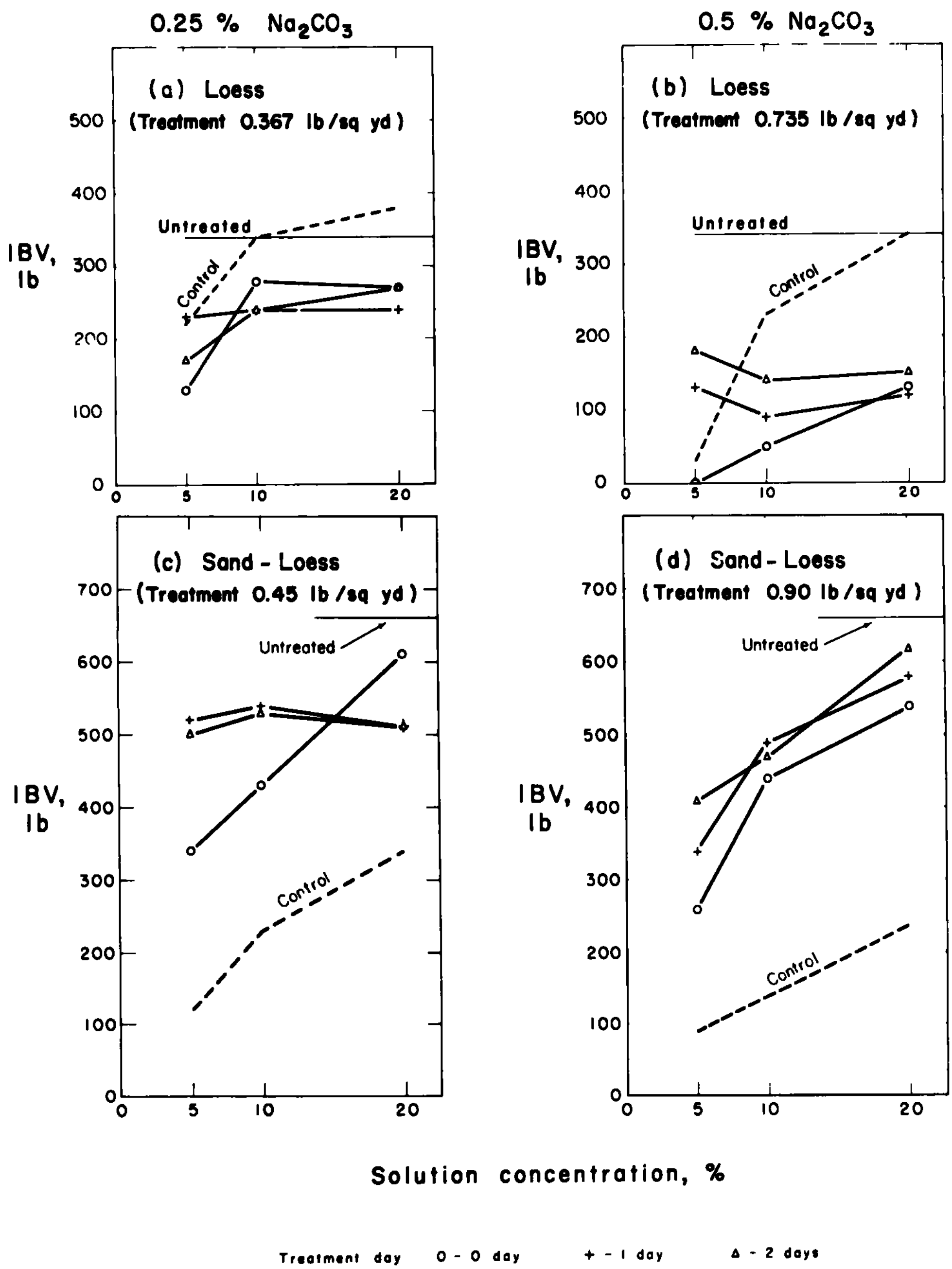

Figure 1. Effects of sodium carbonate solutions on 7-day Iowa Bearing Values of soil-lime-flyash. Control specimens were sprinkled with distilled water; untreated specimens were simply moist-cured. The 0.25 percent and 0.5 percent Na_2CO_3 figures refer to weight of the chemical compared to total dry weight of the specimen.

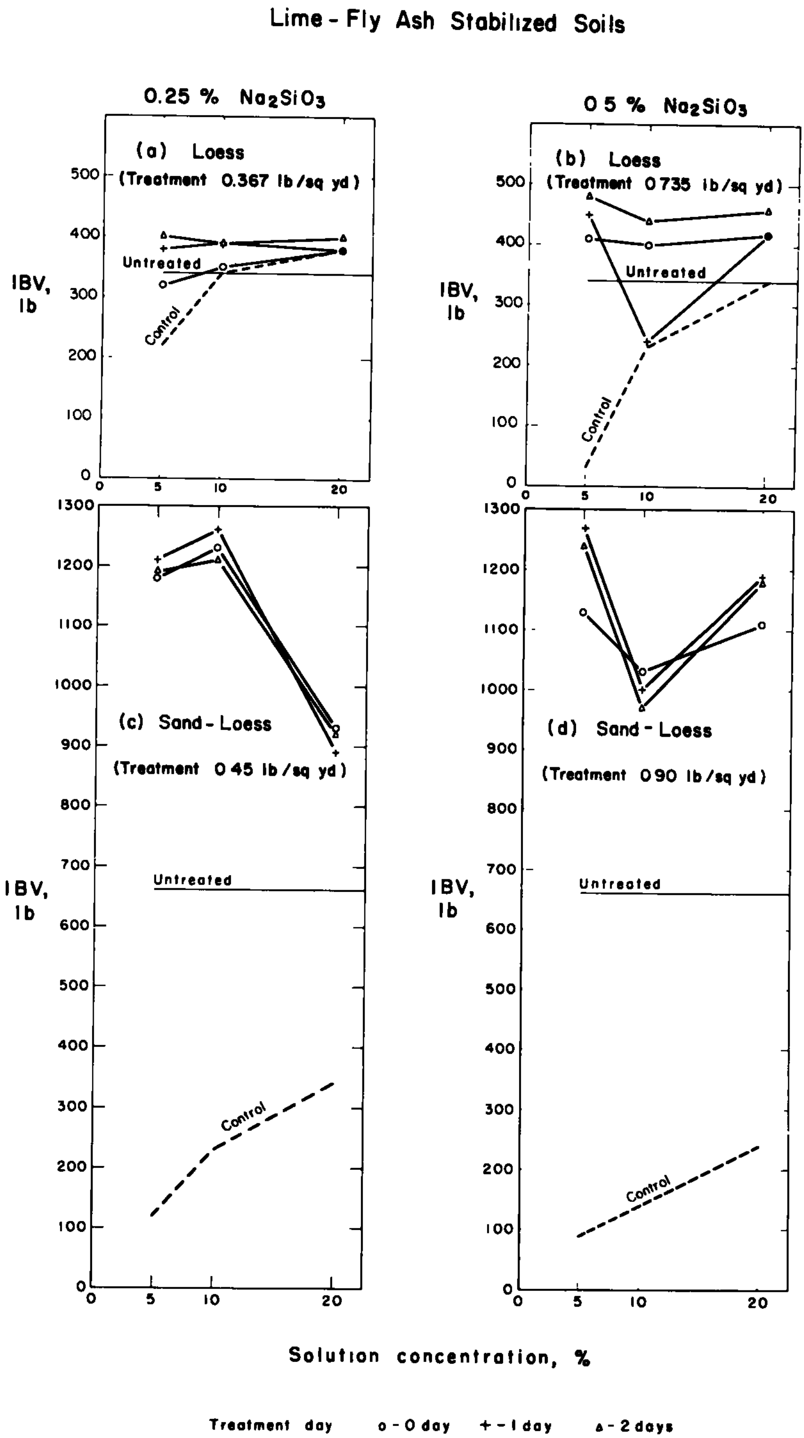

Figure 2. Effects of sodium silicate solutions on 7-day IBV's of soil-lime-flyash. Results are particularly good with the sandy soil. A low solution concentration means more water is used to get the same application of chemical.

carbonate was beneficial, particularly when the chemical was added in high concentration; i.e., without much water (Fig. 1c, d), but bearing values still were not so high as with ordinary moist curing. It is concluded that while sodium carbonate contributes to bearing strength of sand-loess, the gain is often cancelled by the deleterious effect of wetting. Testing with this chemical was discontinued.

Treatment with Sodium Silicate

The second chemical tried reacts somewhat similarly to the action of sodium carbonate; that is, sodium silicate reacts with lime to precipitate calcium silicate and release sodium hydroxide. Tests were conducted similarly to those with sodium carbonate, and results were more encouraging. The IBV for stabilized loess was raised from 325 only to about 450, but for stabilized sand-loess it was raised from 650 to between 1,000 and 1,250 (Fig. 2c, d). The day of treatment was found to be not critical. Therefore in this and later investigations the curing solution was added immediately after molding as the time representing the greatest field convenience. Specimens were then sprinkled with water the second through the sixth days. This wet-dry treatment was found to give somewhat better strengths than continuous moist curing after treatment.

Next, two kinds of sodium silicate were evaluated, one the metasilicate, Na_2SiO_3, having an $Na_2O:SiO_2$ molar ratio of 1:1, and the other having a molar ratio of 1:3.25. Both amount and concentration of solution were varied. The loess soil 20-2V was used, because this previously gave poorest results. As seen in Figure 3, bearing values go as high as 700, or approximately double, as more sodium silicate is used. The 1:3.25 silicate gave slightly higher strengths.

Age and Penetration. An important phase of the work was to discover the effects of sodium silicate at different depths and after longer curing times. A 20 percent solution of 1:3.25 silicate was sprinkled on the surface of stabilized sand-loess immediately after molding. This treatment was followed by 6 days of wet-dry treatment as before, then continuous air drying, as would be expected in the field.

TABLE 2

EFFECT OF 1 GAL PER SQ YD OF 20 PERCENT SODIUM SILICATE (1:3.25) ON IBV OF LOESS-LIME-FLYASH

Penetration Depth, in.	Iowa Bearing Value, lb: 7-Day Control	7-Day Treated	14-Day Control	14-Day Treated	28-Day Control	28-Day Treated
0.08	180	1,570	300	2,010	730	2,860
0.20	650	2,490	1,260	3,250	3,020	4,570
0.50	1,560	4,650	4,580	5,950	7,010	8,270

Bearing values at different depths and ages are shown in Table 2. Results are particularly striking at 7 days, when the bearing value is triple even after a penetration of 0.50 in. At 0.08 in., the 7-day bearing value is increased eight-fold. After 28 days the effect is still strong at 0.08-in. and 0.02-in. penetration, but less marked at 0.50 in.

Lime-Fly Ash Stabilized Loess

Sodium Silicate, wet-dry cure

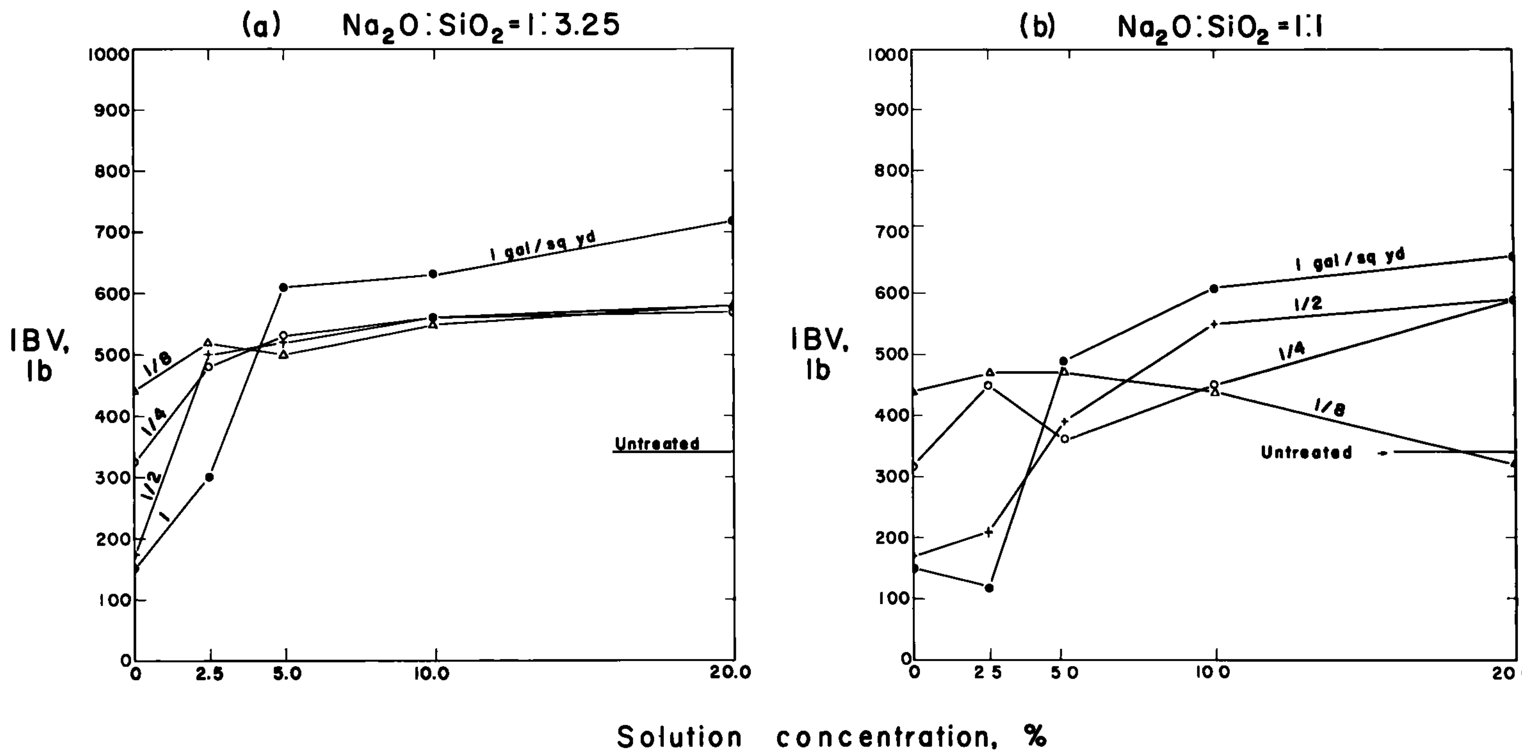

Figure 3. Seven-day IBV's for loess-lime-flyash treated with two different kinds of sodium silicate solution. In (b) note the deleterious effect of too much wetting with low concentration of chemical.

TABLE 3

EFFECT OF 1 GAL PER SQ YD OF 20 PERCENT SODIUM SILICATE (1:1 and 1:3.25) ON IBV OF FOUR SOILS

Soil	Lime + Flyash, %	Lime:Flyash Ratio	Penetration Depth, in.	7-Day IBV, lb*		
					Treated	
				Control	1:1	1:3.25
75:25 Sand-loess (A-4(1))	25	1:9	0.08	180	1,930	1,570
			0.20	650	2,940	2,490
			0.50	1,560	4,980	4,650
Dune sand (A-3)	25	1:5	0.08	290	1,640	1,970
			0.20	—	2,760	3,050
			0.50	—	4,690	5,010
Detroit clay (A-7-6(15))	20	1:4	0.08	370	380	360
			0.20	630	540	540
			0.50	1,020	830	890
Kansan till (A-7-6(12))	6 lime 0 flyash	—	0.08	540	530	540
			0.20	850	750	—
			0.50	1,400	1,050	—

*Definite shear failures indicated by dash.

Soils. So far the testing has intentionally been with relatively permeable soils. Results with four different soils are shown in Table 3. Both 1:1 and 1:3.25 silicates were used; the 1:1 is less viscous and should penetrate more. However, results with clayey soils were consistently poor, probably due to poor penetration. The choice of silicate ratio made little difference.

Lime. Different chemical classes of lime have proved satisfactory for soil stabilization, so there was a question which would react best with sodium silicate. Results with the two types of sodium silicate are shown in Table 4. With this soil the 1:1 $Na_2O:SiO_2$ appears best. Bearing

TABLE 4

EFFECT OF 1 GAL PER SQ YD OF 20 PERCENT SODIUM SILICATE (1:1 and 1:3.25) ON IBV OF SAND-LOESS STABILIZED WITH FLYASH AND TWO DIFFERENT KINDS OF LIME

Type of Lime	Penetration, Depth, in.	7-Day IBV, lb		
			Treated	
		Control	1:1	1:3.25
Dolomitic monohydrate ($Ca(OH)_2$ + MgO)	0.08	180	1,930	1,570
	0.20	650	2,940	2,490
	0.50	1,560	4,980	4,650
Calcitic hydrate ($Ca(OH)_2$)	0.08	140	1,370	680
	0.20	540	2,080	1,260
	0.50	1,760	3,420	2,640

values are about 50 percent higher for dolomitic monohydrate, $Ca(OH)_2$ + MgO. By contrast the control samples show little difference in strengths with the two types of lime.

Lime-Flyash Ratio. Theory suggests that because sodium silicate reacts with lime, the reaction might be benefited by a higher ratio of lime to flyash. Dune sand stabilized with 25 percent lime-flyash in two ratios, 1:2 and 1:5 was treated with two types of sodium silicate.

Results in Table 5 show that contrary to this theory, the 1:5 lime-flyash ratio gave best results. However, shear failures of control specimens make the results difficult to evaluate. Insofar as sodium silicate surface treatment is concerned, lime-flyash ratio is not critical.

TABLE 5

EFFECT OF 1 GAL PER SQ YD OF 20 PERCENT SODIUM SILICATE (1:1 and 1:3.25) ON IBV OF DUNE SAND STABILIZED WITH TWO RATIOS OF LIME-FLYASH

Lime:Flyash Ratio (Total Amount: 25% by Weight)	Penetration Depth, in.	7-Day IBV, lb*		
		Control	Treated	
			1:1	1:3.25
1:2	0.08	460	1,380	1,280
	0.20	810	2,200	1,910
	0.50	2,200	3,860	—
1:5	0.08	290	1,640	1,970
	0.20	—	2,760	3,050
	0.50	—	4,690	5,010

*Definite shear failures indicated by dash.

TABLE 6

MOISTURE CONTENTS OF SOIL-LIME-FLYASH AFTER 7 DAYS CURING WITH AND WITHOUT 1 GAL PER SQ YD 20 PERCENT SOLUTION SODIUM SILICATE TREATMENT. ALL SPECIMENS RECEIVED A DAILY WETTING

Soil	Moisture Content, %		
	Control (Water Treatment)	Sodium Silicate	
		1:1	1:3.25
Loess	17.5	22.1	21.1
75:25 Sand-loess	9.0	12.6	10.6
Dune sand	9.3	11.3	11.7

Surface Seal. Sodium silicate treatment gave all appearances of sealing the soil-lime-flyash surface against further entry of water. In some cases $\frac{1}{4}$ gal of water per sq yd failed to soak in during 24 hr. Equally as important, moisture retention within the specimens is improved (Table 6), undoubtedly benefiting strength. A bituminous film would of course do likewise.

Cost. The current cost of sodium silicate is about 2 to 3 cents per

lb. The cost of a 20 percent solution is thus in the neighborhood of 5 cents per gallon. The heaviest application investigated would therefore cost about 5 cents per sq yd. In comparison, this is approximately equal to the cost of the asphalt in a single spray coat (0.3 gal per sq yd), to which must be added the cost of stone chips and rolling. Two asphaltic coats are usually used.

Summary—Soil-Lime-Flyash. Of two types of curing solutions investigated for compacted soil-lime-flyash, sodium silicate appears best. Ratio of Na_2O to SiO_2 and ratio of lime to flyash are not critical, and the treatment is only modestly sensitive to kind of lime. Good results are obtained only with permeable soils, in this case friable loess and a mixture of loess and sand. Laboratory data indicate that a satisfactory treatment may be 1 gal of 20 percent solution per sq yd of road surface, which gives a three- to eight-fold increase in bearing strength. Field tests would appear to be justified.

SOIL-CEMENT

For the investigation of surface treatments for soil-cement, two soil samples, the friable loess and the 75:25 mixture of fine sand and medium-textured loess, were stabilized with required amounts of Type I portland cement (Table 1), and then treated with various curing solutions, cured, and tested as before. For comparison, untreated samples were moist-cured the same periods, and untreated control specimens were given a daily sprinkle with distilled water.

Treatment with Sodium Hydroxide

Previous investigators have reported soil-cement strength benefits from sodium hydroxide, either as an additive (3) or in a curing solution (4).

The present investigation (Fig. 4) shows that surface treatment with sodium hydroxide solutions immediately after compaction usually gives best results, and this procedure was adopted. Data in Figure 4 show that sodium hydroxide treatment followed by 7 days of moist curing only slightly benefited the 75:25 sand-loess, but the loess soil-cement shows a maximum gain from IBV 820 to an IBV near 1,250 (Fig. 4a, b). This soil was selected for further study.

Further results (Fig. 5) show that when treatment is followed by moist curing the best treatment is a 5 or 10 percent NaOH solution sprayed at the rate of $\frac{1}{2}$ gal per sq yd. Treatment followed by daily wetting and drying gives better bearing strengths, the optimum treatment being about the same. Particularly interesting in this case is that wetting and drying with no sodium hydroxide treatment (0 percent concentration) was just as beneficial to the stabilized loess as wetting and drying after a treatment. From the standpoint of surface hardness, wetting and drying with no chemical thus appears to be the best and certainly the most economical method for curing friable loess soil-cement, and may give an increase in bearing strength in the neighborhood of 20 percent.

The previously measured high IBV of 1,250 for loess soil-cement was not repeated. Investigation revealed that the higher IBV was for an earlier loess sample, 20-2(IV), having a measurable pozzolanic activity (4). Furthermore, the later sampling for 20-2V was actually in error, and 20-2V is not truly representative of friable loess of western Iowa. However,

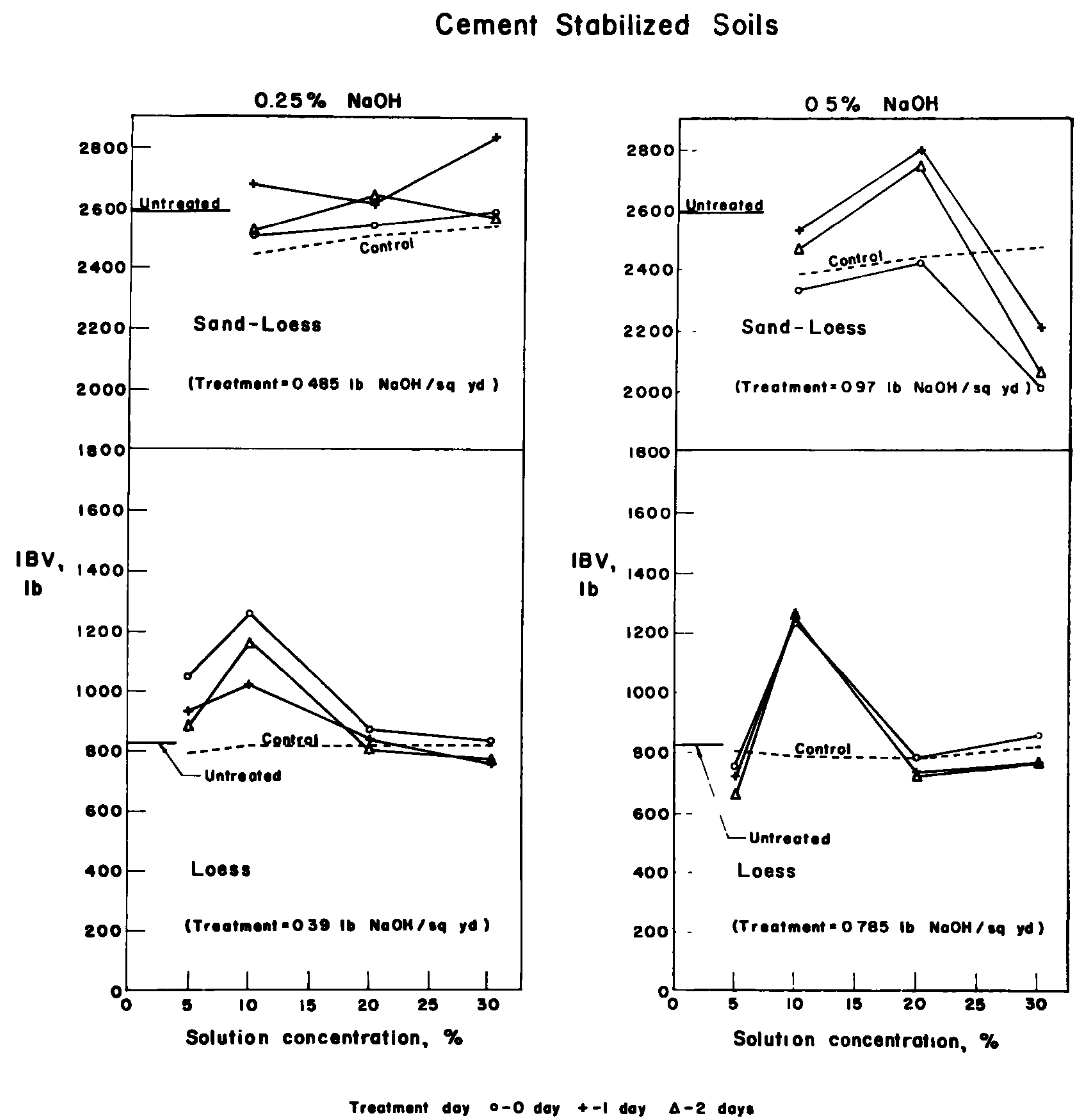

Figure 4. Effects of sodium hydroxide solutions on 7-day IBV of two kinds of soil-cement.

this may be, the poorer results do establish that sodium hydroxide treatment is particularly sensitive to soil mineral composition.

The conclusion is that spraying on a 10 percent solution of sodium hydroxide at the rate of about ½ gal per sq yd will boost the surface hardness of loess soil-cement as much as 50 percent, but this depends on the pozzolanic activity of the loess soil. With a poorly reacting soil—and most would be poorly reacting—the benefit is less and may be equalled by merely wetting and drying every day for 7 days. Testing with this chemical was not continued.

Cement - Stabilized Loess

NaOH Treatment

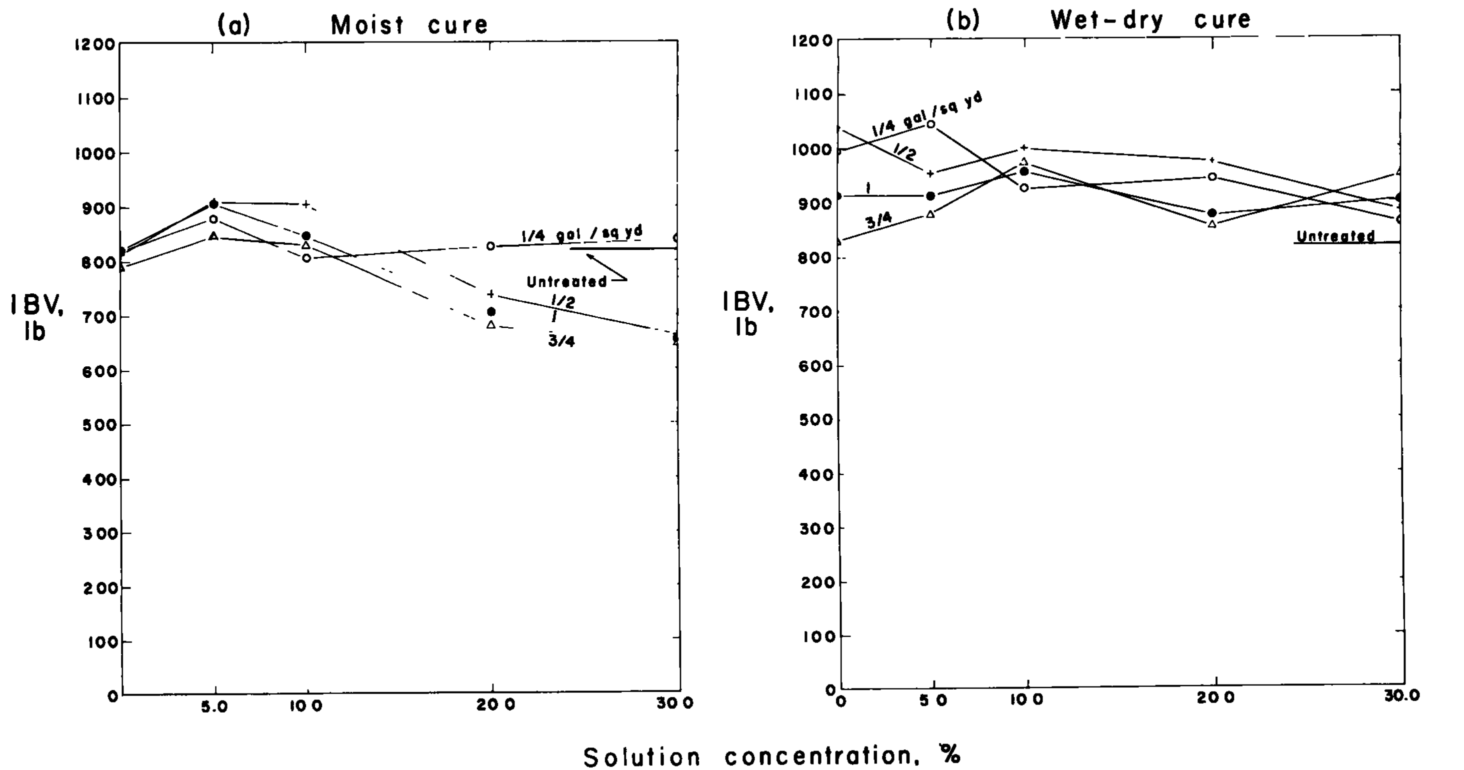

Figure 5. Seven-day IBV's for loess soil-cement treated with solutions of sodium hydroxide and either moist-cured or wetted with water every succeeding day. From previous tests a 10 percent solution applied in the same amounts (0.425 and 0.85 gal per sq yd) should have given an IBV of 1,250 (Fig. 4). Inconsistency is explained in the text.

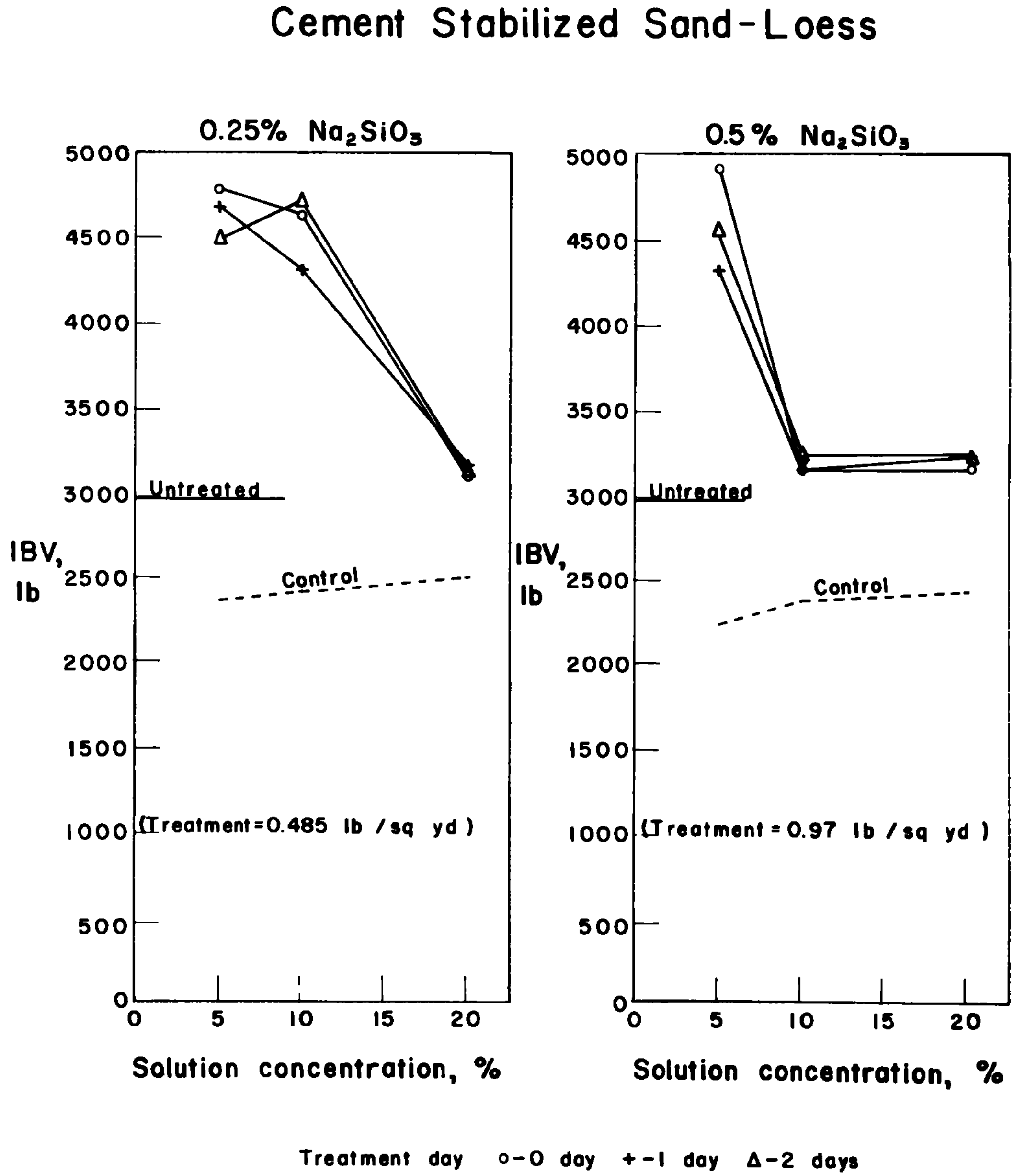

Figure 6. Effects of sodium metasilicate solutions on 7-day IBV of sand-loess soil-cement. Control strengths after daily wetting with water are lower than strengths of untreated, moist-cured specimens.

Treatment with Sodium Metasilicate

The next chemical tried was sodium metasilicate. Cement-stabilized 75:25 sand-loess was considerably benefited by this treatment, the IBV's being increased from 3,000 to a maximum near 4,900 (Fig. 6). Treatment with 5 percent solutions, immediately after compaction, proved best. With sandy soil, wetting and drying with plain water proved harmful, as shown by the low control IBV's. Bearing values at different depths are shown

Cement-Stabilized Loess

Na_2SiO_3 Treatment

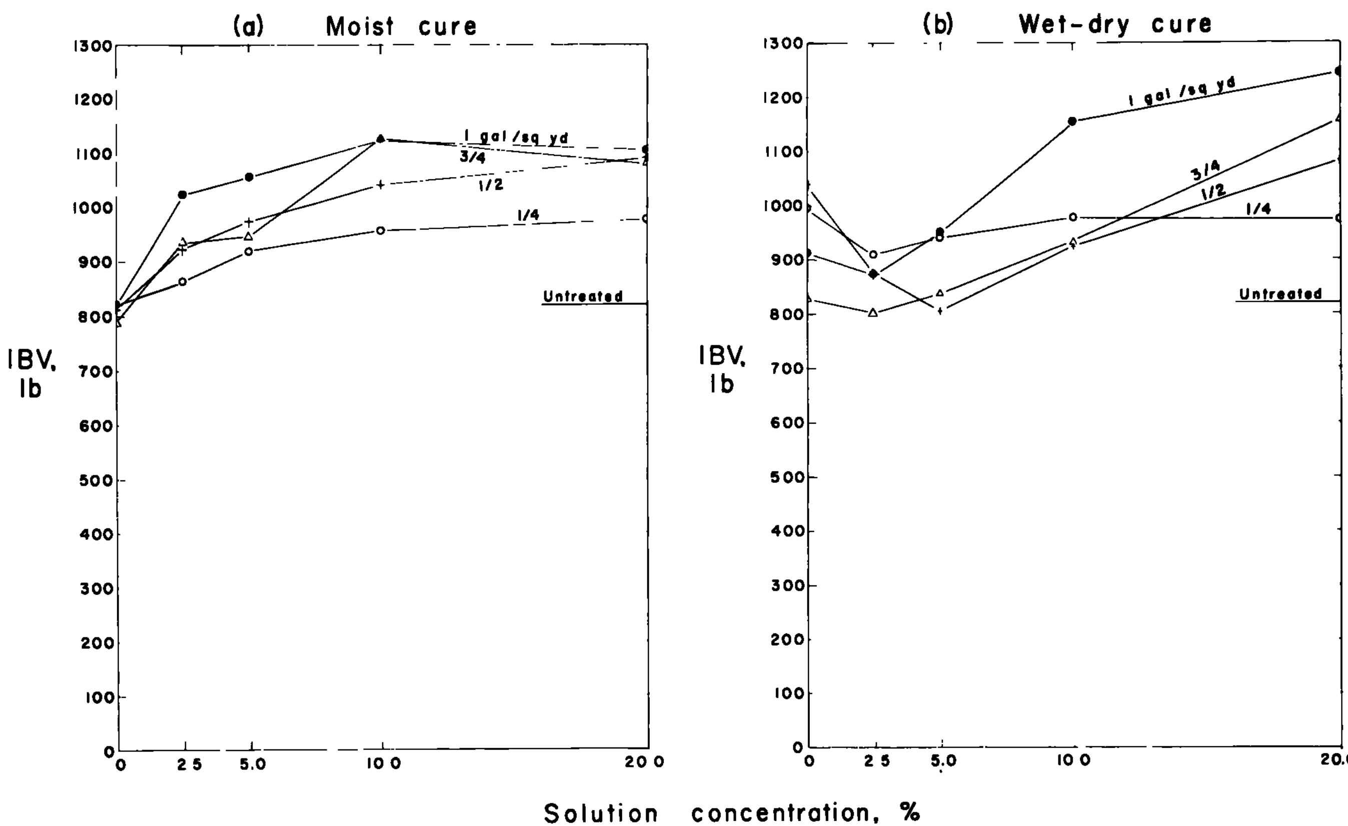

Figure 7. Seven-day IBV's for loess soil-cement treated with solutions of sodium metasilicate and either moist-cured or wetted each succeeding day with ½ gal per sq yd plain water.

in Table 7; note the gain is still strong at a penetration depth of 0.5 in.

TABLE 7

EFFECTS OF 5 PERCENT SODIUM METASILICATE SOLUTIONS ON 7-DAY IBV OF MOIST-CURED CEMENT-STABILIZED SAND-LOESS

Penetration Depth, in.	Iowa Bearing Value, lb			
	Na_2SiO_3 Content			
	0% (control)[a]	0.25%[b]	0% (control)[a]	0.5%[b]
0.08	2,400	4,787	2,260	4,927
0.20	4,000	7,553	3,810	7,827
0.50	7,630	11,973	7,210	12,107

[a]Treated immediately after compaction with equal amount of distilled water.

[b]Percent of dry weight of specimen. 0.25 percent = 0.390 lb per sq yd for loess, or 0.485 lb per sq yd for sand-loess. 0.5 percent chemical is double these figures.

Detailed studies with sodium metasilicate were conducted with loess soil-cement. Results in Figure 7b indicate that stabilized loess is benefited by wetting without any chemical, the IBV increasing from 820 to over 1,000. However, if initial application of water exceeds ½ gal per sq yd, bearing strengths are lowered. It will be recalled that after the first day the control specimens all received ½ gal of water per sq yd. If moist curing is used, 3/4 to 1 gal of 10 percent sodium silicate solution per sq yd will increase the IBV to over 1,100. If wetting and drying are used, 1 gal of 20 percent solution per sq yd raises the IBV to over 1,200, but this is not too much over that from spraying the road every day with the ½ gal per sq yd plain water.

Treatment with Calcium Chloride or Sodium Carbonate

Of the other chemicals tried, calcium chloride solutions give only a slight increase in the IBV of loess or sand-loess soil-cement (Table 8). Solutions are best applied immediately after compaction, as application after one or two days was in some instances deleterious. The mechanism may be one of accelerating the set.

Sodium carbonate solutions were erratically beneficial to loess soil-cement if applied immediately after compaction (Table 9). Crystal growth probably has a deleterious effect, particularly if it takes place after the soil-cement has time to set (5).

Testing with these chemicals was not continued.

Summary—Soil-Cement. Comparison of treated to untreated wet-dry and moist-cure control specimens shows that a good way to cure cement-stabilized friable loess (silt) soil is by wetting every day with ½ gal of water per sq yd. Early sprinkling in excess of this should be avoided. One gal per sq yd 20 percent sodium silicate raises the IBV about 35 to 50 percent.

With a permeable sand-loess soil, wet-dry treatments are somewhat deleterious to soil-cement surface hardness and decrease bearing strength 5

TABLE 8

EFFECT OF CALCIUM CHLORIDE SOLUTIONS ON 7-DAY IBV OF MOIST-CURED SOIL-CEMENT

Soil	Solution Concentration, %	0.08-in. Iowa Bearing Value, lb			
		$CaCl_2$ Content			
		0% (Control)[a]	0.25%[b]	0% (Control)[a]	0.5%[b]
Friable loess	10	820	867	790	965
	20	820	833	820	753
	30	820	785	820	747
75:25 sand: loess	10	2,443	2,837	2,390	2,840
	20	2,500	3,113	2,442	2,833
	30	2,535	2,747	2,483	2,693

[a]Treated immediately after compaction with equal amount of distilled water.
[b]Percent of dry weight of specimen. 0.25 percent = o.390 lb per sq yd for loess, or 0.485 lb per sq yd for sand-loess. 0.5 percent chemical is double these figures.

TABLE 9

EFFECT OF SODIUM CARBONATE SOLUTIONS ON 7-DAY IBV OF MOIST-CURED LOESS SOIL-CEMENT

Solution, Concentration, %	0.08-in. Iowa Bearing Value, lb			
	Na_2CO_3 Content			
	0% (Control)[a]	0.25%[b]	0% (Control)[a]	0.5%[b]
5	795	903	800	797
10	820	875	787	840
20	820	847	820	842

[a]Treated immediately after compaction with equal amount of distilled water.
[b]Percent of dry weight of specimen. 0.25 percent = 0.390 lb per sq yd for loess, or 0.485 lb per sq yd for sand-loess. 0.5 percent chemical is double these figures.

to 10 percent, or roughly in proportion to the amount of water sprayed on. However, only a 5 percent solution of sodium metasilicate applied in the amount of $\frac{1}{2}$ gal per sq yd will approximately double the bearing strength. A field test seems warranted.

Calcium chloride or sodium carbonate solutions are not particularly effective surface hardeners for soil-cement.

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