

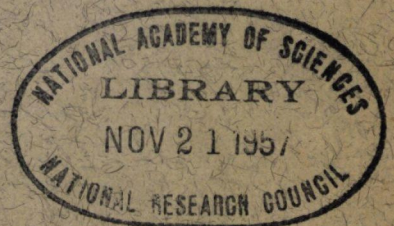
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BULLETIN No. 1

SILICATE OF SODA

AS A

SOIL STABILIZING AGENT



1946

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**SILICATE OF SODA  
AS A  
SOIL STABILIZING AGENT**

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**HIGHWAY RESEARCH BOARD  
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH  
NATIONAL RESEARCH COUNCIL**

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## FOREWORD

This report has been reviewed by members of the Department of Soils and found to contain fundamental information of general interest to highway engineers, on a soil stabilizing agent on which there has been practically no published reports. It is upon their recommendation that this report is being published as a bulletin.

The statements made or opinions expressed in the report are those of the authors and are not to be considered as expressing the official attitude of the Board.

## SILICATE OF SODA AS A SOIL STABILIZING AGENT<sup>/1</sup>

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There is very little work published with reference to the use of silicate of soda in soils work except as it has been used as a dispersing agent in making mechanical analyses. However, there are a few references which indicate that silicate of soda might be used as a soil stabilizing agent where soils are used in structures such as highway fills, earthen dams, etc. Silicate of soda was applied to a section of test road in Guernsey County, Ohio (1)<sup>/2</sup> with favorable results. Sullens and Van Dyke (2) and Baker and Garrison (3) have shown that heaving shales can be drilled by the addition of silicate of soda to the drilling muds, which suggests it might also act favorably if applied to surface soils. The investigation reported herein was not an attempt toward immediate development of a commercially feasible system of soil stabilization with silicate of soda, but rather an attempt to obtain fundamental information on which such a system might subsequently be based.

The particles found in soils are usually grouped into four size classes: fine gravel, sand, silt, and clay. Of these the clay, or colloidal fraction, constitutes nearly all of the active inorganic material within the soils and the chemical and physical properties of soil are almost entirely dependent upon the amount and nature of the colloidal material present. The silt fraction may contain some active material, but the effect of the three larger fractions is largely mechanical. The stability observed in natural soils

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<sup>/1</sup> - This research was supported by a grant from the Sodium Silicate Manufacturer's Institute through the Ohio State University Research Foundation.

<sup>/2</sup> - Numbers in parentheses refer to the list of references at the end of the paper.



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results from the forces acting between particles in the colloidal range. Accordingly, the present study was concerned largely with particles within the colloidal range, and their response to additions of silicate of soda.

The report is in two parts: experiments with clay minerals and experiments with soils.

## EXPERIMENTS WITH CLAY MINERALS

### Materials

#### Clay Minerals

Since the colloidal fraction of soils is made up largely of three types of clay minerals, viz. the kaolinitic type, the illitic type, and the montmorillonitic type, plus in some instances, varying amounts of amorphous material, attention was focused largely upon pure clay mineral specimens representative of each of the crystalline colloidal materials found in soils. With the exception of the illite samples, the minerals studied were purchased from Wards Natural Science Establishment, Inc., Rochester, New York, and consisted of a bentonite from Rock River, Wyoming, a montmorillonite from Yavapai County, Arizona; kaolinite from McNamee mine, near Langley, South Carolina; and halloysite from near Bedford, Indiana. The two illite samples were supplied by Dr. R. E. Grim of the Illinois State Geological Survey. The illite was extracted from underclay from Fithian, Illinois, and the grundyite from a clay from Goose Lake, Illinois.

#### Silicates of Soda

The silicates of soda used were designated for convenience: Silicate A, a liquid silicate with  $\text{Na}_2\text{O}:\text{SiO}_2$  per cent ratio of 1:3.2; Silicate B, a liquid silicate with  $\text{Na}_2\text{O}:\text{SiO}_2$  per cent ratio of 1:1.6. Six additional silicates were used in the preliminary parts of this investigation. They were four liquid silicates having  $\text{Na}_2\text{O}:\text{SiO}_2$  per cent ratios of 1:2.00, 1:2.4, 1:2.9, and



1:3.9, and two crystalline silicates having  $\text{Na}_2\text{O}:\text{SiO}_2$  mol. ratios of 1:1 and 3:2. These six silicates were not studied farther because results with some were not promising and others would be impractical to use.

### Procedure

Preliminary studies indicated that both the grade and concentration of silicate used would affect the properties of clay-silicate mixtures. Accordingly, the clay-silicate mixtures were prepared by adding the desired amount of a 20 per cent silicate solution to a known amount of clay mineral (all silicate concentrations throughout this paper refer to per cent of anhydrous silicate to air dried soil or clay). Sufficient distilled water was then added to bring the mixture to proper consistency for molding into briquettes.

The clay-silicate mixtures were molded into cubes one centimeter in each dimension by pressing the mixture firmly into a brass mold with the hands, trimming off the excess clay and pushing the briquettes from the mold with a small rubber plunger.

The briquettes were thoroughly air dried at laboratory temperatures, weighed, measured, and tested for resistance to crushing and slaking action of water. The slaking action of water was determined by wet sieving two briquettes for one half hour and weighing the material retained on each sieve. The method used was similar to the Yoder (4) method of aggregate analyses except that an automatic siphon was used which allowed the water to rise slowly to the top of the nest of sieves and then be siphoned rapidly away. The water in the top sieve was stirred mechanically during the analysis.

In order to determine the effects of moist aging upon the reaction between silicate of soda and the clay mineral, part of each batch of clay-silicate mix was aged in evacuated desiccators over water for 15 days before molding. One representative from each mineral type was also treated with

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various amounts of calcium chloride before treating with silicate of soda in order to determine the interaction that might take place between these two chemicals if both were used in a soil stabilization program.

### Discussion

The data obtained in the study of the clay minerals are voluminous and are of interest only in that certain generalities can be derived which serve as a guide to study the reaction between silicate of soda and soils. For this reason, and because it has been summarized in detail elsewhere (5), only a very limited amount of data on clay minerals will be presented.

#### The Kaolinitic Minerals

The kaolinitic minerals are 1:1 lattice type minerals and show very little tendency toward swelling when wetted. They have low affinity for water, low exchange power, and low surface activity.

Kaolinite - The resistance to crushing of kaolinite briquettes increased with increasing silicate concentration. This increase was a straight line function. The only exception to this generalization was found when kaolinite mixed with excess calcium chloride was treated with silicate of soda, in which case there was no increase in crushing resistance with increasing silicate concentration. Instead, the crushing resistance remained constant. Apparently the excess calcium precipitates the silica as insoluble calcium silicate before it reacts with the mineral.

The percentage of water stable aggregates increased with increasing silicate concentration (Figure 1), except for the mixture containing excess calcium chloride.

Halloysite - The resistance to crushing of the halloysite briquettes first increased and then decreased with increasing silicate concentration. This increase to a maximum followed by a decrease suggests some type of

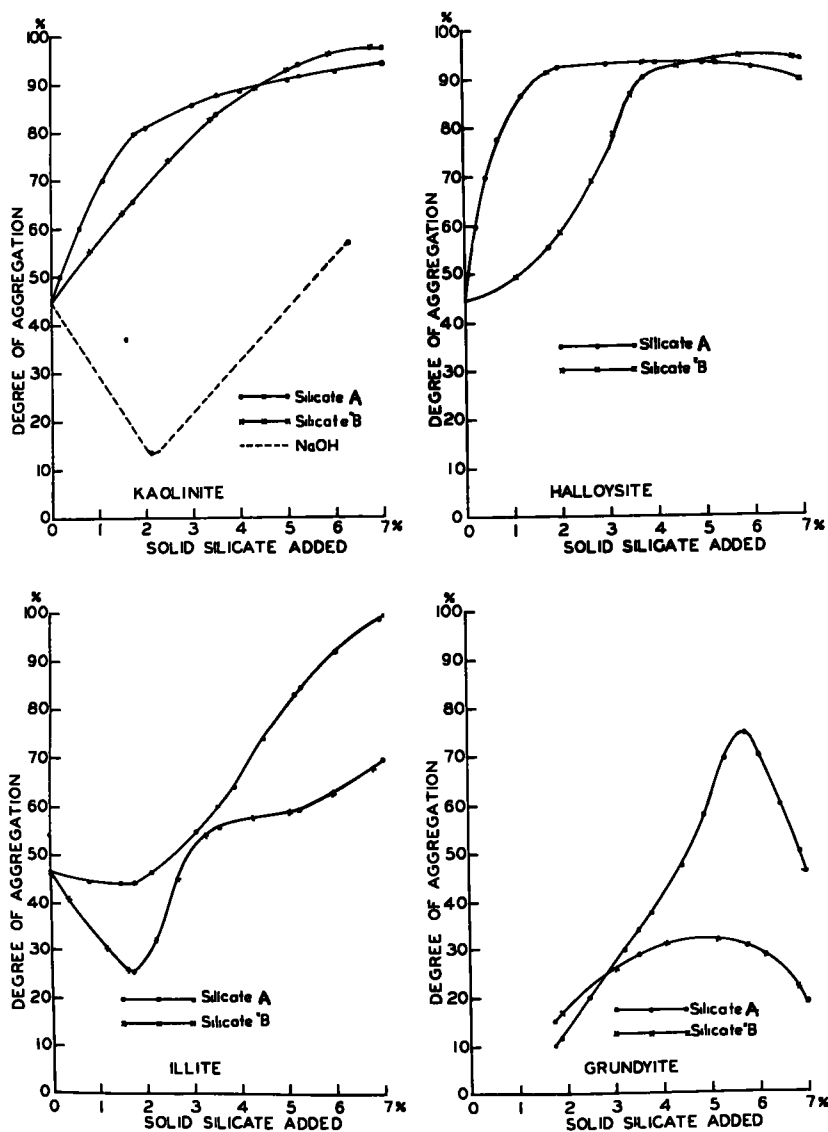


Figure 1. The Effects of Silicate of Soda Concentration on Degree of Aggregation of Clay Mineral Briquettes

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chemical reaction between the halloysite and silicate of soda. The water stability of halloysite briquettes, as measured by total water stable aggregates, (Figure 1) increased with increasing silicate concentration.

#### The Illitic Minerals

The illites are 2:1 lattice type minerals, but do not show the variable spacing exhibited by the montmorillonitic minerals. They have little tendency to swell and are intermediate in properties between the kaolinitic minerals and the montmorillonitic minerals.

Grundyite - The resistance to crushing of the grundyite-silicate briquettes increased with increasing silicate concentration. Although there were some discrepancies, the reasons for these discrepancies are not known. In general the resistance to crushing of grundyite-silicate briquettes increased when the mixture was aged in a saturated atmosphere before molding into briquettes. When grundyite was mixed with dry calcium chloride and also when it was calcium saturated before treating with silicate of soda, the results for resistance to crushing were too variable to permit generalizations. If there was any stabilizing effect, as measured by crushing resistance, the silicate appears to be at least equal to calcium chloride.

Grundyite briquettes prepared with water alone did not disintegrate in water. Instead they became soft and gelatinous with no evidence of aggregate formation. All silicates caused aggregation of the grundyite, and the percent of water stable aggregates increased with all silicates up to a concentration of 5.25 per cent anhydrous solid silicate of soda (Figure 1). No aggregates were formed when grundyite was treated with sodium hydroxide indicating that the  $\text{SiO}_2$  group is important from the standpoint of water stability of the briquettes. The data for water stability of briquettes prepared from calcium saturated grundyite and grundyite mixed with dry calcium chloride were too variable to permit generalizations.

Illite - The resistance to crushing of illite briquettes first increased to a maximum and then decreased with increasing silicate concentration. Aging moist tended to increase the resistance to crushing of briquettes prepared from the illite silicate mixtures. The silicates used increased the water stability of the illite briquettes only at concentrations above 3.5 per cent anhydrous silicate of soda (Figure 1).

#### The Montmorillonitic Minerals

The montmorillonitic minerals have 2:1 type lattices which exhibit variation in one dimension with change in water content. They are characterized by very high surface activity and exchange power. They have a high affinity for water and swell to a very marked degree.

Bentonite\* - The crushing resistance of bentonite briquettes prepared with different silicates in various concentration was extremely variable and no generalizations can be made. There was no apparent difference between the response of calcium saturated bentonite and bentonite in its natural state. When excess calcium chloride was present it apparently reacted with the silicate as discussed in the case of kaolinite.

It was impossible to measure water stability of bentonite-silicate briquettes because they did not disintegrate when placed in water but instead swelled and became gelatinous. It was observed that with high silicate concentrations the bentonite briquettes would swell to a greater degree and in less time than that required to reach the final volume with low concentrations. In most cases the final volume of the silicate treated briquettes was several times the original size of the briquettes while the untreated bentonite briquettes reached only their original size.

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\*Note: Bentonite is a rock composed mostly of the mineral montmorillonite.

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Montmorillonite - In general the crushing resistance of the montmorillonite-silicate briquettes decreased with increasing silicate concentrations. Aging the clay-silicate mix in a moist atmosphere before molding greatly increased the crushing resistance of the montmorillonite briquettes. This was especially true for those silicates of high alkali ratio. It was also impossible to measure the water stability of the montmorillonite briquettes, because all of them, regardless of silicate concentrations, completely disintegrated in a matter of seconds when placed in water.

### Conclusions

In general, aging dry in the laboratory for periods of 30 days and 5½ months did not alter the crushing resistance of any of the clay-silicate briquettes. This indicates that any reaction between the clay minerals and silicate of soda takes place in a moist condition. This conclusion is further borne out by the fact that aging in a moist atmosphere usually improved the properties of the clay-silicate mixtures.

The generalizations made from the study of clay minerals suggest that: (1) beneficial results could be expected from treating kaolinitic soils with silicate of soda, (2) favorable reactions might result from treating soils with colloidal complex of illitic material with silicate of soda, and (3) if the colloidal complex of a soil is composed largely of montmorillonitic material treatment with silicate of soda will most likely be detrimental to the stability of such a soil.

### EXPERIMENTS WITH SOILS

#### Soil Types

The soils studied are representative of several soil types. Included were a Clermont silt loam from the experiment farm at Clermont County, Ohio;

a Wooster silt loam from the Ohio Agricultural Experiment Station at Wooster, Ohio; a Wauseon very fine sandy loam from Fulton County, Ohio; a Brookston silty clay loam, from the experiment farm at Holgate, Ohio; and Cecil clay, B horizon from Raleigh, North Carolina.

### Procedure

Each soil was treated with various concentrations of liquid silicate ( $\text{Na}_2\text{O}:\text{SiO}_2$  1:3.2 per cent ratio) and enough water to bring it to the proper molding consistency. The total amount of water used was 10 per cent less than the amount which would have been required to wet the soil to the lower plastic limit, so that the soil was in the friable range when molded. They were then molded into cylindrical briquettes 1-3/4 in. in diameter and 1 1/4 in. high, in brass cylinders under a pressure of 100 pounds per sq. in. The briquettes were thoroughly air dried and the weight, volume, and crushing resistance in pounds per briquette determined. After the briquettes had been crushed they were further crushed in a mortar to pass a 2 mm. sieve (No. 10) and were then subjected to the tests discussed later in this paper.

### Discussion

Most of the tests made are standard tests for highway engineering departments. Eno (1) concluded that "the three necessary tests are: the hydrometer test extended for one hour, and the Atterberg tests for the lower liquid and lower plastic limits." In addition to these three "necessary tests" the degree of aggregation, which is a measure of the slaking action of water, was also determined. The exchange capacity of the soils was determined to indicate whether there had been a chemical reaction between the silicate of soda and the soil colloid.

Before discussing the results obtained for the individual soils it seems advisable to point out a few of the implications that can be made from these tests.



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### Significance of the Tests

**Degree of Aggregation** - The most stable structures found in soils are those in which the fine primary particles are held together in stable aggregates. The stability of the structure depends upon the resistance of soil aggregates to disintegration by water or mechanical manipulation, and no matter how well aggregated a soil appears to be, if the aggregate disintegrate when subjected to continued wetting the soil will be subject to either puddling or erosion or both.

A subgrade of well aggregated soil will contain numerous channels or large pores through which internal drainage can take place. If, however, the soil aggregates break down to primary particles when subjected to long continued wetting these primary particles will clog the larger pore spaces, seal up the soil and make internal drainage impossible or very slow. Any treatment that increases the degree of aggregation and the water stability of the soil aggregates would be very beneficial in stabilizing a soil, since there would be much less tendency to break down into mud when wet. The increased internal drainage would be helpful by keeping the surface drier thus lessening the chance of injury through frost action. The aggregate analysis was made by the Yoder (4) method on parts of the briquettes that had not been crushed. The degree of aggregation given in the tables is the summation of the per cent of particles smaller than 0.25 mm. which were aggregated into effective particles larger than 0.25 mm.

**Lower plastic and lower liquid limits** - The liquid limit is defined as the lowest moisture content, expressed as a percentage of the weight of the oven-dry soil, at which the soil will just barely flow as a viscous liquid. The liquid limit (LL.) was determined by standard procedures (6, 7). The lower plastic limit (LPL) is defined as the lowest moisture content, express-

ed as a percentage of the weight of oven dry soil, at which the soil just begins to break into pieces when rolled into threads  $1/8$  in. in diameter.

The significance of the LPL and LL in highway construction has been pointed out by Eno (1). He has shown, after analyzing 840 Ohio soils, that the volumetric change decreases with decreasing plastic index. A decrease in volume change would be very significant in an earthen structure. Thus any treatment which would decrease the plastic index\* of a soil would be beneficial from the standpoint of a subgrade construction.

**Volume Shrinkage** - The volume shrinkage was determined as follows: soil samples were wetted to the lower liquid limit and pressed firmly into glazed porcelain crucibles of known volume, dried over night in the laboratory and then oven dried. The volume was determined by immersing the soil in mercury and weighing the mercury displaced. The change in volume which a soil makes upon wetting or drying is a factor which greatly affects the life and service of hard surfaced roads. The swelling and shrinking that takes place in a soil are directly related to the amount and the type of colloid material present and this in turn is affected by the cations absorbed on the surface of the colloidal micelles. Any treatment which materially decreases the amount of swelling and shrinking of the soil should be very beneficial in highway construction.

**Crushing Resistance** - The resistance of soil briquettes to crushing is considered to be a measure of the cohesion of the soil. Since there should be a close relationship between cohesion and wearing quality of a surface, it is probable that a high crushing resistance might be indicative of good wearing quality.

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\*The plastic index expresses the range of moisture content over which the soil is plastic. It is defined as the moisture content at the liquid limit minus the moisture content at the lower plastic limit.

**The Exchange Capacity** - It was found in the study of clay minerals that each gram of  $\text{SiO}_2$  added to quartz sand had an exchange capacity of 0.5 m.e. of ammonia. If the silicate of soda added to a soil is not chemically combined with the constituents of the soil, but is acting only as a cementing agent it would be expected to increase the exchange capacity of that soil by 0.5 m.e. or less for each gram of  $\text{SiO}_2$  added. If the increase in exchange capacity was significantly greater than this expected amount, it was considered as evidence that a chemical reaction had taken place between the silicate and clay mineral of the soil. However time did not permit a detailed study of the nature or possible mechanism of this assumed reaction.

**Colloidal Content** - The colloid content was determined by the hydrometer method (8). No dispersing agent was used except in the case of the untreated sample to which enough sodium carbonate was added to make the  $\text{Na}_2\text{O}$  present equivalent to the  $\text{Na}_2\text{O}$  present in the sample treated with 2.3 per cent solid silicate of soda.

#### The Effects of Silicate of Soda on the Properties of Soils

**Cecil Clay** - The Cecil clay, which is representative of a large group of soils in the southeastern United States, was included in the investigation because the colloidal fraction has been identified by soil workers as kaolinitic in nature and the kaolinitic clays showed greatest response to treatment with silicate of soda. The data in Table 1 and Figures 2 and 3 show that the degree of aggregation increases while the lower plastic limit, lower liquid limit, plastic index volume shrinkage and colloids (which is a measure of ease of dispersion or rate of breakdown of the aggregates formed) decrease with increasing silicate concentration. The decrease in plastic index and volume together is in agreement with the work of Eno (1) and indicates the relationships which he developed for natural soils would probably hold for

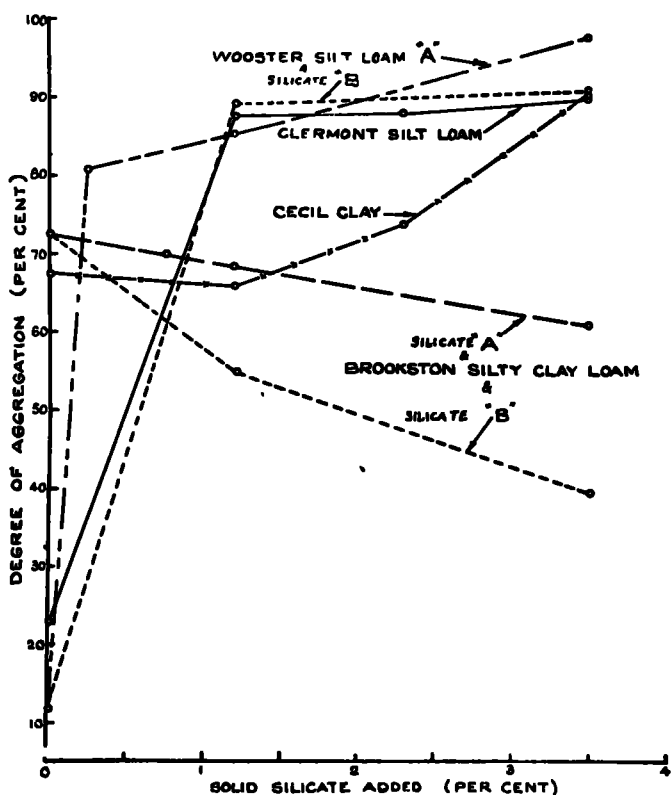


Figure 2. The Effect of Silicate "A" on the Degree of Aggregation of Soil Briquettes

chemically treated soils. The crushing resistance of the briquettes (Figure 4) treated with silicate of soda also increased up to concentrations of 3.5 per cent solid silicate of soda. It should be noted that these responses are all in the proper direction to indicate that such soils would be benefited for engineering application by addition of silicate.

Table 1

The Effects of Silicate of Soda (a) on the Properties of Cecil Clay

Silicate Conc.	Degree of Aggregation	Plastic Limit	Liquid Limit	Volume Shrinkage	Colloids	Exchange Capacity
per cent	per cent	per cent	per cent	per cent	per cent	ml/100 g
0.0	67.3	48.1	74.0	46.0	63.5	10.2
1.2	66.2	34.8	55.2	36.2	67.5	12.4
2.3	74.2	35.3	44.9	33.0	53.5	13.5
3.5	90.4	35.6	43.7	21.0	43.5	14.5
7.0	95.3	40.6	44.1	12.9	24.4	16.5

(a) Silicate A (Ratio 1:3.2).



Figure 3. The Effects of Silicate of Soda on the Size-Distribution of Aggregates of Soil-Silicate Briquettes

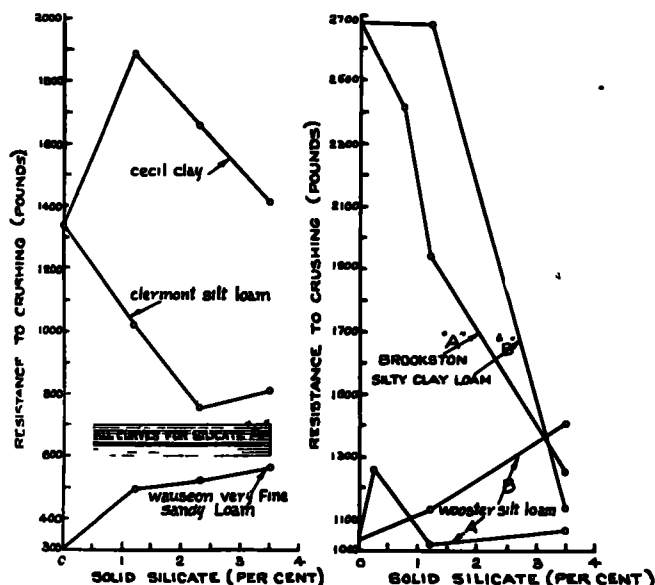


Figure 4. The Effects of Silicate on Crushing Resistance of Soil Briquettes

The increase in exchange capacity is greater than would be expected from mere addition of silicate alone. The expected values are 10.2, 10.8, 11.3, 12.9 and 13.6 as compared with 10.2, 12.4, 13.5, 14.5 and 16.5 which are the values obtained. Thus the increase was about twice that expected,

indicating that some chemical reaction between clay and silicate probably occurs.

It seems apparent that treatment of Cecil clay with 1 to 2 per cent silicate of soda on an anhydrous base would greatly increase its stability and that this improvement would not be due to cementing action alone but to a chemical reaction between the soil minerals and the silicate of soda.

**Clermont Silt Loam** - The data in Table 2 show that with exception of the degree of aggregation the treatment with silicate of soda did not appreciably affect the properties of the Clermont silt loam. The remarkable increase in the amount of water stable aggregates (Figures 2 and 3) which occurred when Clermont silt loam was treated with 1.2 per cent silicate of soda suggests that the stability of this soil in a structure could be greatly improved by such treatment.

Table 2

## The Effects of Silicate of Soda (a) on the Properties of Clermont Silt Loam

Silicate Conc.	Degree of Aggregation	Plastic Limit	Liquid Limit	Volume Shrinkage	Colloids	Exchange Capacity
per cent	per cent	per cent	per cent	per cent	per cent	ml/100 g.
0.0	22.7	20.6	27.15	31.3	31.1	9.2
1.2	88.2	20.0		30.1	30.1	10.4
2.3	88.2	22.2		22.1	28.1	10.8
3.5	90.0	21.9	27.30	26.1	27.1	11.2

## (a) Silicate A. (Ratio 1:3.2)

The increase in exchange capacity was greater than could be expected as shown by comparing the expected values of 9.2, 9.8, 10.3, and 10.9 with 9.2, 10.4, 10.8, and 11.2 which are the values obtained. This suggests a chemical reaction between the clay mineral of Clermont silt loam and the silicate of soda added.

Wauseon Very Fine Sandy Loam - The silicate of soda increased the lower plastic limit and crushing resistance of the Wauseon very fine sandy loam but did not appreciably affect the colloids as measured by the hydrometer (Table 3). The briquettes did not break down during the aggregate analysis; silicate of soda did not aggregate this soil but solidified it. This is borne out by the fact that there was no great increase in the exchange capacity due to treatment with silicate of soda. The expected values were 9.3, 9.9, 10.4 and 11.0 while those obtained were 9.3, 10.3, 10.3 and 10.4. Apparently the only effect of silicate of soda on Wauseon very fine sandy loam was cementation, which was to be expected since this soil contained very little clay to react with silicate.



Table 3

The Effects of Silicate of Soda (a) on the Properties of  
Wauseon Very Fine Sandy Loam

Silicate Conc.	Degree of Aggrega- tion	Plastic Limit	Liquid Limit	Colloids	Exchange Capacity
per cent	per cent	per cent	per cent	per cent	ml/100 g.
0.0	14.9	19.7	21.1	11.1	9.3
1.2	97.6*	21.2	—	10.1	10.3
2.3	98.4*	24.9	—	10.1	10.3
3.5	97.8*	23.5	24.2	11.1	10.4

(a) Silicate A (Ratio 1:3.2).

\* Not aggregation but cementation. The entire sample was on the top sieve of the nest of sieves.

Brookston Silty Clay Loam - Treatment with silicate of soda slightly decreased the volume shrinkage of Brookston silty clay loam as it was measured in the volumetric change test (Table 4). The degree of aggregation and the crushing resistance of Brookston silty clay loam decrease with increased silicate concentration (Figures 2, 3, and 4). The colloids, as determined by the hydrometer method, also decreased slightly with increased silicate concentration which indicates that the silicate of soda slightly increased the stability of finer aggregates.

The variation in the exchange capacity of Brookston silty clay loam due to treatment with silicate of soda cannot be explained without further investigation. It does not seem to indicate a chemical reaction between the clay mineral and silicate but rather may be due to a physical relationship between the amount of silicate present and the active surface of the clay. In light of the present data it is doubtful that there would be any advantage in treating soils such as the Brookston silty clay loam with silicate of soda.

Table 4

The Effects of Silicate of Soda on the Properties of  
Brookston Silty Clay Loam

Silicate Conc.	Degree of Aggrega- tion	Plastic Limit	Liquid Limit	Volume Shrinkage	Colloids	Exchange Capacity
per cent	per cent	per cent	per cent	per cent	per cent	ml/100 g
0.0(a)	72.5	29.8	46.5	39.2	54.8	30.25
0.75(a)	69.8	30.5	—	37.9	51.7	33.3
1.20(a)	69.4	29.0	—	36.2	49.5	31.0
3.50(a)	61.0	31.1	44.8	37.1	47.4	29.7
1.2(b)	55.3	29.6	—	—	52.4	—
3.5(b)	39.6	31.8	—	—	45.0	—

(a) Silicate A. (Ratio 1:3.2). (b) Silicate B. (Ratio 1:1.6).

Wooster Silt Loam - The outstanding effect of silicate of soda on the Wooster silt loam was the remarkable increase in degree of aggregation when only 0.25 per cent of silicate was added (Table 5 and Figures 2 and 3). The increase was from 12 per cent for untreated soil to 80 per cent when 0.25 per cent of silicate of soda was added. The volume shrinkage was also affected considerably by treatment with silicate of soda. The increase in exchange capacity was very close to the expected increase as can be seen by comparing the expected values of 9.1, 9.7, 10.2, and 10.8 with the obtained values of 9.1, 9.6, 10.2, and 9.8. This suggests that the effects of silicate of soda upon Wooster silt loam may be due to a physical rather than a chemical reaction between the silicate and the soil. This is a point that should be studied in greater detail because any treatment which will increase the water stable aggregates of a soil like the Wooster silt loam from 12 to 80 per cent merits further investigation from an agronomic as well as an engineering standpoint.

Table 5

The Effects of Silicate of Soda on the Properties of  
Wooster Silt Loam

Silicate Conc.	Degree of Aggrega- tion	Plastic Limit	Liquid Limit	Volume Shrinkage	Colloids	Exchange Capacity
per cent	per cent	per cent	per cent	per cent	per cent	ml/100 g.
0.0	12.1	22.9	27.6	27.9	28.1	9.1
0.25(a)	80.1	22.3	—	19.9	25.5	9.6
1.2(a)	85.5	22.1	—	19.5	25.9	10.2
3.5(a)	97.8	24.6	29.6	16.1	24.5	9.8
1.2(b)	89.5	22.3	—	—	26.5	—
3.5(b)	90.1	21.4	28.6	—	27.5	—

(a) Silicate A. (Ratio 1:3.2). (b) Silicate B. (Ratio 1:1.6).

#### Conclusions

The response of the Cecil clay to silicate of soda was very similar to that of kaolinite and halloysite. This was expected since the colloidal fraction of Cecil clay has been identified by soil scientists as kaolinitic in nature. It also suggests that a thorough knowledge of all the reactions that take place between silicate of soda and clay minerals should make possible fairly accurate predictions of the response of various soils to silicate treatment if the mineral composition of the colloidal complex is known.

Time did not permit the identification of the clay minerals which make up the colloidal fraction of the other soils studied. However, the Brookston silty clay loam would be the most likely of all the soils studied to be montmorillonitic in nature. The response of the Brookston silty clay loam to silicate of soda was very similar to the response of montmorillonite and bentonite.

The response of Wooster and Clermont silt loams to small additions of silicate of soda suggest that the mechanical make up of the soil, i.e. the proportions of sand, silt and clay that make up the soil might also be an important factor in determining the response of the soil to treatment with silicate.

It was observed that concentration of silicate of soda of one per cent or more dissolved the organic matter of the soil and with alternate wetting and drying this organic matter moves to the surface and scales off. Thus if silicate of soda were to be used to stabilize the surface of secondary roads it would probably have to be used in concentrations of less than one per cent solid material by weight, or the surface of the road might ravel and have very poor wearing qualities. If used in subgrades where the soil did not dry out this effect on the organic matter of the soil might not be a serious handicap.

All the data, both with soil and clay minerals, show that the silicate of high  $\text{SiO}_2$  low  $\text{Na}_2\text{O}$  content gave the most favorable results.

One important conclusion to be drawn from the data is that it will not be possible to apply silicate of soda indiscriminately to all soil types and get favorable results. In fact in many cases such a procedure would produce very unfavorable results. With other soils, however, it appears that silicate has great promise as a soil stabilizing agent both for engineering and agronomic applications. Treatment should be applied only where soils have been adequately studied and evaluated, since some soils actually showed negative response.

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