Sodium Chloride Stabilized Roads in Iowa

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Sodium chloride has been used as a secondary road stabilizer for a number of years and the performance of salt-stabilized roads has been reported periodically. These reports have differed widely as to success, costs, maintenance methods, riding qualities, and other items. The Iowa Engineering Experiment Station has undertaken a project to clarify and better understand the use and mechanism of sodium chloride stabilization.

The counties in Iowa which have existing salt-stabilized roads were contacted and each county engineer was interviewed. This paper reports a summation of these interviews and gives the composition and dimensions of the salt-estabilized roads, as well as maintenance practices, present physical conditions of surfaces, effects of winter, and comments of county engineers.

● SODIUM CHLORIDE has been used in varying degrees as secondary road wearing surface stabilizers for a number of years. The successes or failures of this stabilizing agent have been reported periodically but these reports differ widely as to degree of success, maintenance requirements, costs, riding qualities, and other items. County engineers in Iowa have discussed sodium chloride stabilization pro and con without reaching any general agreement as to effectiveness or economic value. However, each county engineer has proceeded according to his own convictions which are generally based on experience and opinion. As a consequence, some counties use large amounts of NaCl and others use none.

The Iowa Engineering Experiment Station has undertaken a project designed to clarify and better understand the use and mechanism of chemical stabilization in this state. The purpose of the project is to study the physical and chemical characteristics of chemically treated roadway surfaces, particularly those which have been treated either with sodium chloride or calcium chloride, or both, in the original construction of the roadway. The main objectives are (1) the determination of the reasons for differences in results from a given method of treatment for a series of aggregate and soil mixtures and for different aggregates and soils, and (2) the evaluation of the benefits derived from chemical treatment of any given mixture of aggregate and soil and for different aggregates and soils.

This paper presents the initial phase of the study in which counties using salt treatment of secondary roads were located and the respective county engineer was interviewed. The results of the interviews follow and are presented under the various headings. Counties using salt stabilization are shown in Figure 1.

SODIUM CHLORIDE

Composition and Dimensions

Fourteen counties using salt for chemical stabilization were found to have a total of 524 mi of salt-stabilized roads. Jones county has the least mileage with only 4 mi of salt-stabilized roads, and Franklin and Linn counties are high with 106 mi. Some salt-stabilized roads have been blacktopped and are included in total mileage.

Table 1 shows counties using salt and gives information pertinent to the material

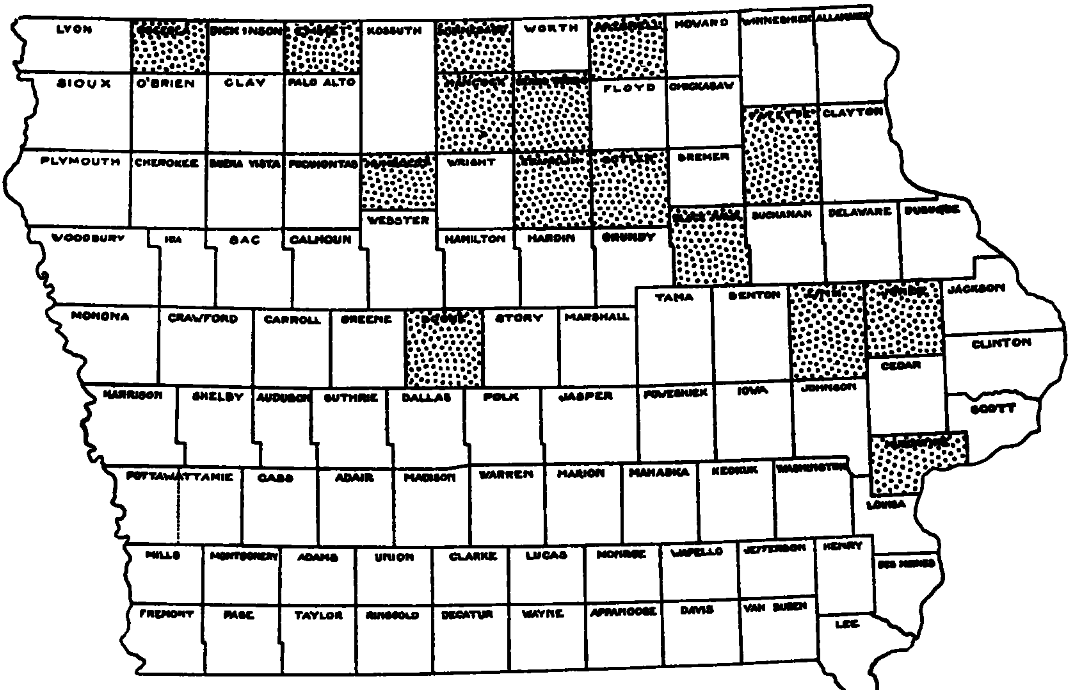

Figure 1. Counties using NaCl stabilization.

content of stabilized roads. Nearly all stabilized wearing courses are deep in the middle and feathered to the edge. The average depth of stabilized material varies from 2 to 4 in., the width varies from 22 ft to 28 ft. Nine counties use soil-aggregate-salt mix, and four counties use salt and aggregate only. The amount of salt used is generally expressed on a ton per mile basis and varies from 5 to 20 tons per mile. Some engineers express salt contents as pounds of salt per ton of soil material, the amounts quoted on this basis varied from 8 to 12 lb per ton. The quotations in Table 1 are expressed on a ton per mile basis by estimating the soil material used per mile and the density of the in-place material. Estimates comparable with 8 to 12 lb per ton are 12 to 19 tons per mile. Aggregates used were either pit run gravel or crushed stone. Glacial clay was used in all soil-aggregate roads. Seven counties include a surface application of about 5 tons of calcium chloride per mile per season to aid in surface moisture retention and dust palliation.

Mitchell County uses a mixture of 75 percent salt and 25 percent calcium chloride, initially applied at a rate of 4½ tons per mile. Subsequent applications bring the total chemical application up as high as 17 tons per mile. The primary purpose of chemical stabilization is to hold the material in place prior to blacktopping.

Construction Procedure and Costs

Most roads are constructed from materials mixed in the field either by blade or by a Seaman Pulvimixer. In general, the gravel and soil materials are windrowed and bladed several times, salt is distributed and bladed in, water is added, the material is uniformly spread and compacted to 90 or 95 percent standard Proctor density. The clay is either pulverized before spreading or pulverized on the road bed before blading. A few counties use plant mixed materials exclusively and some use plant mixed material occasionally. The plant mix method is preferred by many although it is considered somewhat more expensive. One man thought the plant mix was cheaper than a road mix. The general belief is that increased road quality compensates for any added expense.

Cost data proved to be rather scarce. Reports varied from $2,500 to $4,000 per

TABLE 1

COUNTIES USING SODIUM CHLORIDE STABILIZATION AND DATA RELATIVE TO SURFACE COURSE COMPOSITION

County	Miles of NaCl Stabilized Roads	Amount of Original Chemical Treatment (T/mi)	Annual Additional Treatment with $CaCl_2$	Average Thickness (in.)	Width (ft)	Aggregate	Binder
Black Hawk	38	6-10	–	2	22	Class A crushed limestone	Glacial till
Boone	4	20	4 T/mi	4	24	¾ in. pit run	Glacial till
Butler	88	10	Some	3	24	1,320 T ⅝ in. gravel 600 T ⅝ in. rock	300 yd glacial clay
Cerro Gordo	25	5-9	–	3	24	Rock and gravel	Glacial clay
Fayette	16	16-20[b]	Some	3-5	26	2,200 T ¾ in.	About 1 in. from old surface
Franklin	106	9-10	Some	4	26	Gravel	Glacial till
Hancock	50	16[b]	2 lb/sq yd	–	27	Pit run	18-20 percent glacial till
Humboldt	25	13[b]	–	4	26	¾ in. pit run	20 percent glacial clay
Jones	4	20[b]	5 T/mi	–	28	¾ in. crushed rock 40 percent dust	None
Linn	106	–	–	–	–	¾ in. crushed rock	None
Muscatine[a]	1	–	–	–	–	–	–
Mitchell	32	4½	–	–	–	¾ in. crushed rock	None
Osceola	11	9	–	3	26	Pit run	None
Winnebago	19	15	2-3 times a year	4	27	Pit run	12-16 percent glacial clay

[a]Experimental.
[b]Estimated from width, depth and assumed density. Originally expressed in pounds salt per ton of material.

mile of completed road. One engineer reported a cost of $2.00 per ton of laid material, and another reported a cost of $450 per mile for materials alone (gravel, clay and chemical).

Maintenance Practice

Blade maintenance following a rain was the common denominator in all counties, with most engineers expressing the opinion that a shallow cut is essential to good performance. A deep cut destroys the crust that has formed on the immediate wearing surface and allows undue traffic abrasion until a new crust is formed. The formation of a new crust may come too late or not at all, and in either case the road is destined to short life.

All county engineers seem to have a problem in educating the blade men. Most maintenance men have developed the idea that the purpose has not been accomplished unless a large roll of material is carried in front of the blade. Local citizens are also guilty of this misconception and voice such an opinion in no uncertain terms to the blademen. Such harassing can cause improper blading, because maintenance men are prone to slide back into old ways under pressure.

Many of the counties use supplemental applications of calcium chloride for dust palliation and retention of the binding surficial clay and dust. Potholes are hand patched in some counties with mixtures of clay, gravel and calcium chloride. This seems to produce better results than filling the potholes with bladed material and depending on traffic compaction for stability. The latter method is evidently only a temporary measure at best because the bladed material usually does not contain a sufficient amount of binder.

Most engineers using this type of road agree that maintenance attention is needed to insure a good riding surface. Surprisingly, attention to maintaining crowns was mentioned very little. Only one engineer said that it is necessary to rebuild the crown every spring.

Present Physical Condition of Surfaces

County engineers reported everything from smooth to rough when asked to describe the present riding qualities of their salt-stabilized roads. These descriptions have little meaning because they depend on the type of surface with which the salt road is compared. However, every county reports that salt roads exhibit a decided tendency to pit. The amount of pitting appears to depend on the traffic volume, maintenance methods, and the amount of moisture in the road. The moisture content depends mostly on rainfall inasmuch as salt is not deliquescent.

Engineers were asked to describe the dust conditions on the salt roads as either dust free, slightly dusty, dusty, or very dusty. None of the roads were described as dust free or very dusty, and in most cases they were called slightly dusty. Sodium chloride thus appears to have some value as a dust palliative.

Every engineer agreed that salt-stabilized roads exhibit excellent aggregate retention. This is especially a favorable recommendation because traffic on these roads ranges up to 450 cars per day, with an average of about 200 cars per day.

Effects of Winter

Comments on the effects of winter freezing were favorable to salt roads. Most engineers said that treated roads have less tendency to form frost boils than untreated roads, and several county engineers have noticed a few adverse effects due to freezing. Butler and Franklin County engineers have noticed that treated roads do not soften during the usual spring break-up period.

A very interesting and unusual phenomenon was reported in Fayette County where both salt stabilization and calcium chloride stabilization are used. Calcium chloride roads were observed to ice over during winter, but salt roads either do not or have less tendency to ice over.

As previously mentioned, Mitchell County uses a mixture of salt and calcium chloride for stabilization of soil aggregate material. The county engineer has found that the calcium chloride content must be held down to minimize the effects of freezing and thawing.

Comments

Many interesting comments conerning salt-stabilized roads resulted during casual conversations and are listed by county, as follows:

Black Hawk. — Most everyone concerned with salt-stabilized roads is well satisfied with the performance of these roads. This stabilization method conserves gravel.

Boone. — The salt road gets very hard during dry weather and was slippery during wet weather because of too much clay. The slipperiness was corrected by the addition of pea gravel. Some pits developed but were easily repaired. The road was top dressed and rolled with a steel roller before blacktopping.

Butler. — Three-quarters of the clay mixed with the gravel is effective and one-quarter is lost during construction. We formerly added lime dust as a maintenance measure but found that this created a layer of different texture. This layer tended to scale so the practice has been discontinued. Some of the road beds have been tested during the spring and were found to be hard and relatively dry. However, the material was easily broken up with a pick. Salt stabilization saves about 250 tons of aggregate per mile per year on a heavily traveled road. A new road is constructed after an old road is worn out, usually every five years.

Cerro Gordo. — Salt-stabilized roads were constructed in 1954 and 1957. These roads have performed satisfactorily although no additional maintenance material, either salt or calcium chloride, has been applied since construction.

Fayette. — Most of our trouble develops on heavily traveled roads. Surface applications of calcium chloride to the mid 16 ft helps to hold the gravel. This type of stabilization works best on roads carrying about 125 cars per day. Salt stabilization is responsible for large savings of both maintenance and gravel.

Franklin. — Salt roads hold moisture longer than untreated roads. Salt roads also develop a surface crust and stay hard through the spring. Roads do not hold up too well when traffic exceeds 150 cars per day, they tend to be ground up. Stabilized roads are in better all-around condition than untreated roads and therefore save gravel on adjacent roads by drawing traffic.

Hancock. — Salt stabilized roads are used in a 2 to 3 stage blacktop construction. Bad spots appear and are corrected before blacktopping. Roads are in service two or four years before the blacktop is applied. We find a plant mix cheaper than a road mix.

Humboldt. — A sheepsfoot is not as satisfactory for compaction of salt treated roads as a rubber tire roller. We tried to apply the chemical in solution but had spraybar trouble. Salt stabilization costs less to keep aggregate over a period of time and conserves aggregate. Gravel requirements on all roads appear to be reduced due to better surfacing of blacktop over chemically stabilized material.

Jones. — (Trial road) An old road was covered by 1,500 tons of aggregate per mile prior to chemical stabilization. Moisture was added at the quarry and supplemented by a water wagon on the road. The road was constructed in one lift and seems to be performing quite satisfactorily.

Linn. — Road work is contracted and salt is pug mill mixed at quarry. Costs vary from 2.19 to 2.98 dollars per ton of in-place material.

Economics

O.W. Zack maintains records of roads in Butler County which indicate that an untreated gravel road initially requires 1,250 tons of soil-aggregate per mile, followed by 250 tons of aggregate per mile per year for maintenance and that such a road lasts about 4 years. Little or no gravel remains after the 4-yr life of the road so the road must be entirely rebuilt with new material.

Zack's records also indicate that salt-treated roads constructed with 2,200 tons of soil-aggregate-salt per mile last 5 to 7 years before they require rebuilding. Layers of 1 to 2 in. of material remain at this time but the material is rather loose and lacking in binder. The road must then be rebuilt but only a fraction of the original material requirement is needed.

These data have been used to compute cumulative road investments of money and aggregate for an economic comparison of both types of road construction in Butler County. The cumulative cost of each type of road is a stepwise function; yearly for the untreated road and every 5 to 7 years for the treated roads. The average cost per year has been used in both cases to give a continuous rather than a stepwise function. Costs for the treated road have been computed for a 5-year life and for both 1 and 2 in. of remaining material.

Figure 2a shows a comparison of the cumulative investment for both types of road. The initial cost of a salt-stabilized road is almost twice that of an untreated road but the cost rate of an untreated road is higher than that for a treated road. The net result is that after a period of 3½ to 7¼ years (depending on material retention in the treated roads) the same amount of money has been spent to have either type of road. Henceforth the treated road becomes considerably cheaper to maintain. The same trend in the amount of aggregate used is shown in Figure 2B.

Figures 2c and 2d show the amount of saving in dollars and ton of aggregate, respectively, as a function of time. The negative values indicate that an untreated road is cheaper and requires less aggregate than a treated road during the first few years. A little arithmetic shows that if 500 miles of county roads were constructed with salt-stabilized soil-aggregate (1½-in. retention) rather than untreated soil-aggregate the county would save about $2,400,000 and a little more than 2 million tons of aggregate over a period of about 20 years.

The savings in dollars over this 20-yr period is of considerable importance to a county treasury and to each individual taxpayer. Perhaps of more importance is the savings in natural gravel resources which is equivalent to a block of solid stone which would cover a 160-acre farm to a depth of 4 ft.

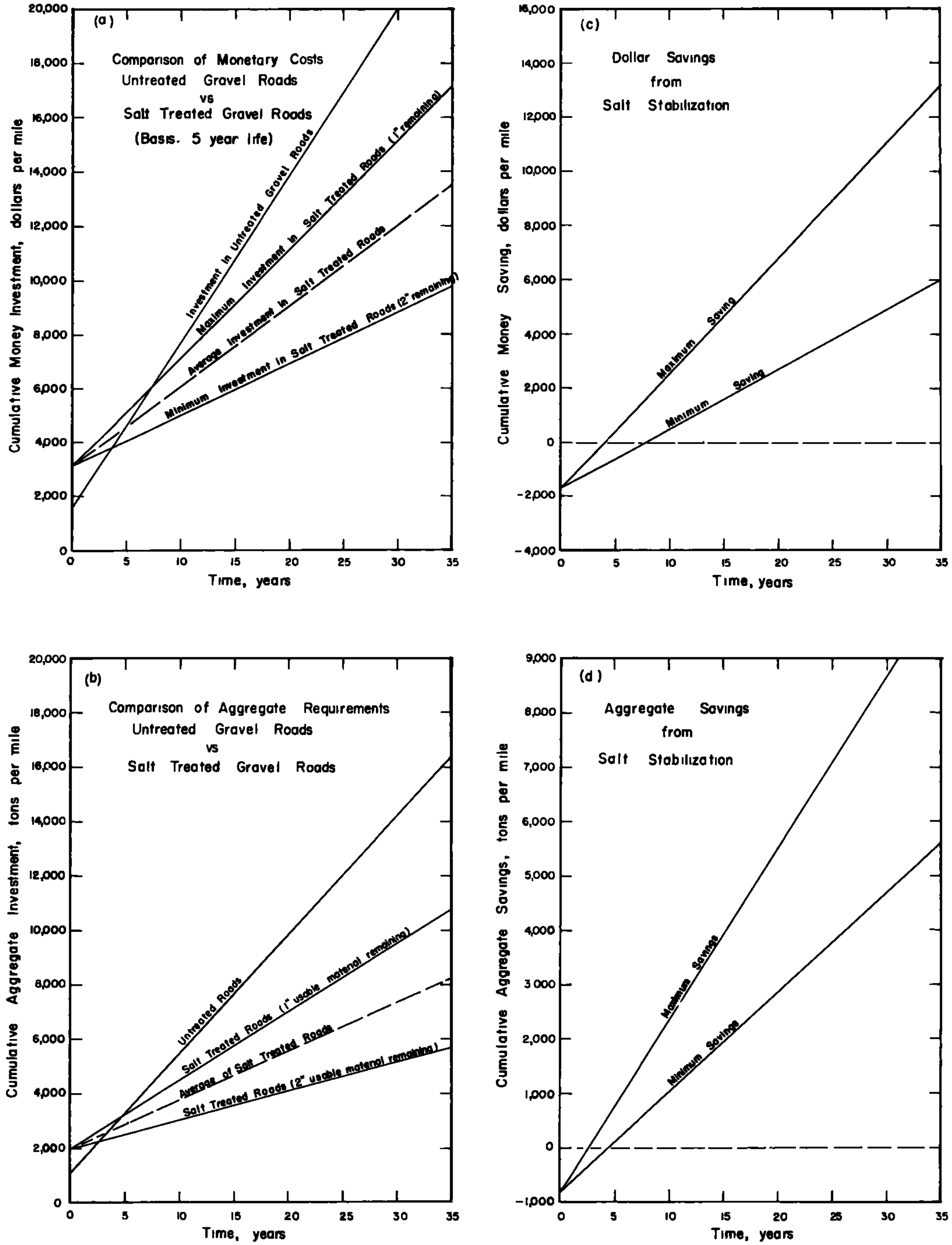

Figure 2. Comparison of cumulative monetary and aggregate investments required to maintain untreated and salt-treated secondary soil-aggregate roads in Butler County, Iowa.

Discussion

The summarized testimony of the county engineers interviewed shows general agreement that salt treatment improves the performance of soil-aggregate roads in several ways. The most important being the long-range conservation of natural resources and reduction in road investments. Iowa's deposits of gravel and stone are being rapidly depleted and are entirely gone in some areas. Should aggregate consumption continue at the present rate the cost of secondary roads will rise still higher because extinction of gravel pits and stone quarries will necessitate long hauls in addition to high prices at the sources of supply. Taylor County in southern Iowa is now faced with this situation. Gravel must be trucked in from outside the county and costs are over $2.00 a ton at the pit.

Salt roads further improve the over-all secondary road picture by presenting a smoother and less dusty riding surface than non-treated roads. Such surfaces attract traffic from adjacent roads and are thus responsible for still more savings in gravel and money by reducing the wear on these adjacent roads. Salt roads also retain a good riding surface longer than untreated roads and therefore require less blade work. Salt roads also show better resistance to winter and spring break-up.

Why do salt roads have all these advantages over non-treated soil-aggregate roads? The improvement has been partially and sometimes completely attributed to a number of reasons, none of which have been completely proved or disproved. A listing of reasons includes high density, low permeability due to clay expansion following leaching, moisture retention, lowered freezing point of water, recrystallization of salt, increased solubility of calcium carbonate, gel formation, flocculation and increased cohesiveness of clay due to sodium ions.

The Iowa Engineering Experiment Station now has a project underway which plans investigation of the physico-chemical phenomena of salt-treated soil-aggregate road material and the effects of these phenomena on the performance of roads constructed of such material. The project is sponsored by the Iowa Highway Research Board and supported by funds from the Iowa State Highway Commission.