Screenings
from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
IOWA STATE UNIVERSITY of Science and Technology
AMES, IOWA

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CHLORIDE ROADS

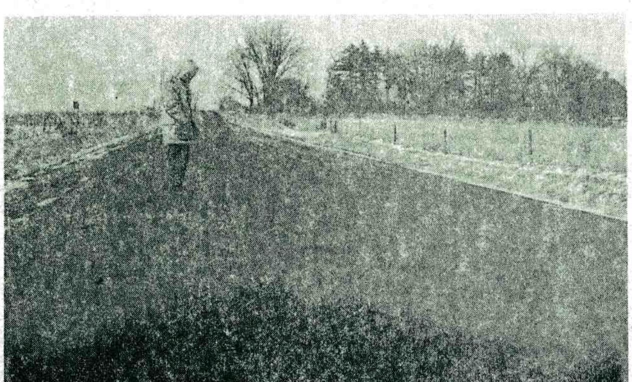
Lo, The Dusty Road!

Man's first notable landmark scribed into the face of the globe was the dusty wagon track, which later developed and flourished into the common dusty road. This is one of our most persistent and bothersome contrivances, being almost in a class with relatives, which just happened along.

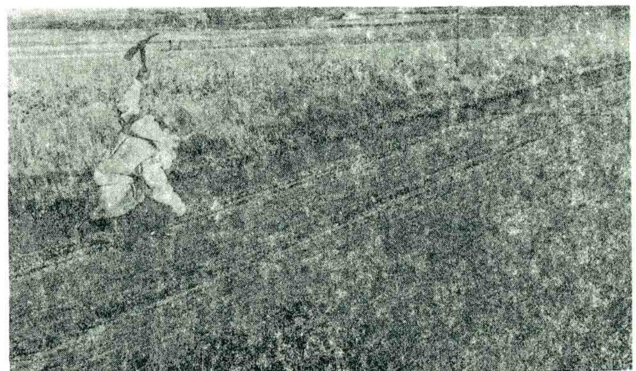
But dust thou art, to dust returnest, so if we want to get new blood and resurrect some of the old we had best keep things stirred up. Therefore drive the dusty road, and be sure to inhale. The next sneeze you breathe may be Napoleon; the next clod you kick may be King Arthur. And it's nice to get an occasional snootful of Beethoven, Aristotle, Moby Dick, or Robin Hood. We have such a wealth of available ancestry in our dusty roads. Particularly when roads run by a cemetery.

Now with Seasoning

Unfortunately for those who like to keep in touch, the billowing ancestral baths are coming to an end; more roads are being surfaced, and more of the remaining roads are being treated with chlorides to help bind particles and hold down dust.



Visiting Eskimo finds firm understanding. This recently completed sodium chloride treated road is covered with a thin asphaltic double chip coat. It should last a number of years. Boone County, Iowa.



Visiting Cossack delves in. This calcium chloride treated road is now 7 years old. Maintenance is by light blading and a yearly surface application of more chloride. Dallas County, Iowa.

Now in use are two chemical kissing cousins, sodium chloride and calcium chloride. The former, common table salt, once had such scarcity and high value that certain crafty primitives would gladly trade their wives to get it. No such useful arrangement exists today. (Actually, even then salt was very cheap, and the wives found out.)

La, the Undusty Road!

An ample application of chlorides will convert the meanest gravel or rock byway into a delightful, hard-surfaced thoroughfare with plenty of fortitude for light traffic and at a cost to salve the wounded taxpayer.

Maintenance is required or the road will go to pot, but maintenance costs are usually much less than for the original gravel or rock road. Maintenance is by occasional light blading or patching, plus a light surface application of chlorides every year or two. An alternative is to preserve the road under thin blacktop.

STRENGTH FROM WITHIN

Chlorides are not good cements; all they do is hold water and tighten the road by a variety of mechanisms discussed later. The road must have some interlocking, granular stability by itself. Chlorides on a clay road would do little good.

Return to Table of Contents

Not only must the road contain some coarse particles to interlock and give strength, it should be dense enough to deflect rain if the salts are to stay put.

The way to a dense mix is through grading. This means gravel or crushed rock for strength, plus small amounts of sand, silt, and clay to fill in the voids. Unfortunately such roads slowly disappear in a cloud of dust.

Putting the damper on

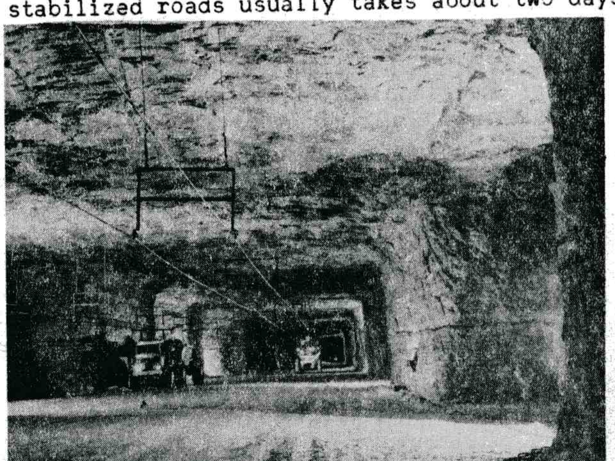
Now for the chlorides. One specification is 1/2 lb of sodium or calcium chloride per sq yd per inch of road thickness: for a 4-inch road 21 ft roadway, this comes to 12 1/3 ton per mile. Actual practice varies.

Chlorides are added either dry or in solution, either to material on the road or at a batch plant for later hauling to the road. If added on the road, a special road mixer is used, or the mix can be tumbled back and forth with blade graders. Mixed materials are spread and compacted.

During compaction the technique is to splatter on enough water to hold the moisture content high enough to gain density. This also helps to draw some fine materials up into the surface, giving a better seal against rain.

The Dry Cure

Once the road is completed it is allowed to dry out or "cure," implying a previous illness. If salt is used, crystals now form in the surface zone and help knit the road. If calcium chloride is used, no crystals form, but the whole road shrinks and becomes harder. Curing of salt-stabilized roads usually takes about two days; curing of calcium chloride roads takes 2 to 10 days, depending on the weather. Light traffic in this period does no harm.



Salt mines in America are nice places to work, no matter what your politics. This view shows the underside of Detroit. Salt layers were deposited when ancient seas dried up.

MECHANISMO

We know you're just dying to know what it is that chlorides do in roads, besides making them taste sour and salty. For one thing the chlorides keep grass from growing, not too much of a problem, actually, except when traffic is light. In Iowa, of course, our problem is corn; the soil is so rich that overnight the corn will----never mind, you wouldn't believe us, though our eyes are weak and our breath is strong, and our hearts as pure as driven golf balls.

Added Slick-Slipperiness

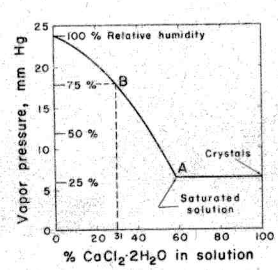
The first benefit from chlorides is to aid in compaction. Calcium chloride solutions are effective lubricants, and sodium chloride lubricates by dispersing the clay binder. Anyway, compacted density is usually up 1 to 7% with the same compactive effort, or the same density may be obtained with fewer roller passes. In some rather spectacular examples the number of roller passes is reduced as much as two-thirds.

Extra Slop-Slopperiness

Anybody who has tried to salt his french fries in wet weather knows about hygroscopicity. Plainly, salt absorbs water.

Not only do chlorides absorb water in wet weather, they retard evaporation when the day is dry. These phenomena are related to an obscure vitality called <u>vapor pressure</u>. Salts lower the vapor pressure of water, which at 77° F comes to 23.8 mm of mercury. For example, calcium chloride can lower the vapor pressure to 7 mm, reducing evaporation from a free surface more than three times.

Vapor pressure of water in air is proportional to relative humidity, or general dampness. Thus if the humidity is low enough, vapor pressure



Vapor pressure of calcium chloride solutions. Temperature, 77°F.

Example: Relative humidity 75%, will calcium chloride take up water and dissolve? Yes, yes! The equilibrium solution is at B, 31%. Note that humidity must fall below 25%, a very dry day, before calcium chloride crystallizes out.

Return to Table of Contents

Nov. - Dec., 1958
Vol. 2, No. 6

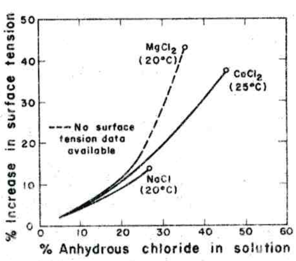
can drop below that of the salt solution. The solution dries out. If humidity is high, vapor pressure is higher than that of the salt solution, and it absorbs more water.

Nervous Tensions

Here our two salts really part company regarding behavior in roads. The reason is related to moisture retention---one usually stays dry, the other stays wet.

Calcium chloride increases tensions more than a frown in the U.N. This is not a political tension or a mental tension, but is more like the one that holds in Marilyn. It is called a surface tension and can land a snappy comeback. Surface tension of water is caused by unbalanced molecular attractions in the surface zone. Throw in some chlorides, we increase the attractions and the surface tension.

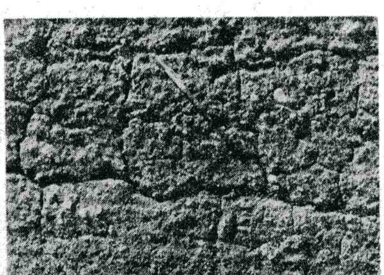
The result is that when a treated road first dries out, calcium chloride solutions occupying the tiny crevices exert more tension along water-air interfaces. The sum of these tiny tensions literally pulls the road together, increasing density as much as 15%. This will increase strength and stability (C.B.R.) several hundred percent. The slow rate of drying allowed by calcium chloride is an advantage, for shrinkage becomes uniform. Resulting cracks appear to do little harm.



If you don't believe in surface tension, just try blowing corners on a soap bubble. Surface tension of water increases with the addition of chlorides. The maximum increase is limited by solubility of each chemical (shown by circles).

Crystallization and Dispersion

Sodium chloride solutions are not too generous with surface tension, or baby's tears wouldn't drip. Salt offers other advantages instead.



During initial drying or cure, calcium chloride roads shrink and gain density. Obviously something's got to give. Pencil for scale.

Engineer tests roadbed, finds it soft and rough. Looks like a good prospect for chlorides. Naturally, we had to go outside the state for this photo, Iowa roads being smooth as a lover's sigh. This road was later stabilized with salt.

During dry weather, sodium chloride becomes concentrated in the road surface, crystallizing and cementing the surface into a dense, hard crust which inhibits shrinkage and drying. Ordinarily, shrinkage in an untreated road loosens the gravel or stone, causes washboarding, loss of stones, and dust.

But one day the rains will come, and then what? Salt crystals will dissolve and leach downward---very bad. Fortunately, such escapes are nicely policed by a curious habit of clay, which swells like a cow with the clover bloat whenever it gets a taste of sodium plus a drink of water. The clay disperses into a gel-like mass, plugging pores and inhibiting further leaching.

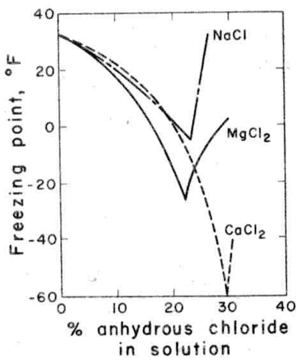
Another left-handed mechanism not well evaluated is the action of weak salt solutions on other materials in the road, particularly limestone. Five percent sodium chloride gives water twice as much zest for dissolving limestone, or calcium carbonate. Then when the water evaporates, the carbonate stays, presumably as a cement.

Chemical Sunshine

A sweet face is said to melt more ice than a salty one, but chlorides are effective nevertheless. In the face of a strong dose of chlorides ice loses all its ordinary composure, reserve, and fortitude. Its knees are weak; it turns to water. This trick is widely used to put the smile on icy streets in winter.

In a chloride-stabilized road, water simply doesn't finish freezing until the temperature sinks to subzero. In the case of calcium chloride, the temperature must hit 60 below (Fahrenheit). This is important because otherwise water in the voids freezes, expands, and pushes apart the aggregate. Field tests show that winter strength loss of chloride-treated roads is far less than strength loss in similar untreated roads. Other tests show that moisture migration and frost heave may also be reduced.

Return to Table of Contents



Chlorides melt ice by lowering the freezing point. Optimum chloride content is indicated by the lowest dip in each curve, called a <u>eutectic</u>, from Greek eutexia, to melt. As temperature lowers, water or chloride crystals freeze out until finally the last bit of solution reaches the eutectic composition and freezes.

EVIL DEEVIL: CORROSION

Nobody wants to drive on a stabilized road if it will make his car a rusty hulk. Up until now this has been almost a subversive subject, like is money wasted on the military? Obviously there are two sides to the question.

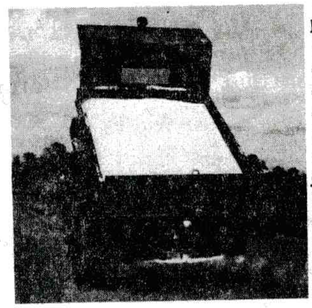
First and foremost, much less splashing occurs from a chloride-stabilized road than from city streets treated with chlorides for ice removal. City life is much more corrosive to autos, lungs and eyeballs. Best to live in the country.

Calcium or magnesium chloride in water make it acidic. Acidity is indicated by pH--high acidity, low pH. Water has a pH of 7, concentrated calcium chloride solutions have a pH in the range 4.5 to 5, and magnesium chloride solutions have a pH of about 3.9.

The corrosion rate of mild steel is not much influenced by acidity until pH becomes critically low, less than 3.5 to 4.5. Below this pH steel quickly dissolves in a fast array of hydrogen bubbles---kuzup! Apparently the critical acidity is reached by magnesium chloride, which is very corrosive. You sea coast dwellers will be happy to know that the corrosive vigor of sea water is mainly a result of magnesium chloride and should not be blamed on salt.

Sodium chloride in water makes hydrochloric acid which is balanced by an equal amount of a strong alkali, sodium hydroxide. Dilute solutions increase the corrosion rate about one-third by increasing electrolytic action. Strong solutions actually inhibit corrosion by limiting the amount of dissolved oxygen.

A final factor is that of maintaining moist conditions--highly desirable in a road, but not so pleasant on the underside of a car. Moisture is essential for corrosion. On this subject all we can do is excuse ourselves and say the factor has not been well evaluated. By interesting coincidence many cars are undercoated.



Dump truck is making like Hansel and Gretel dropping crumbs. Calcium chloride will disappear when flakes take water from the air and dissolve, or <u>deliquesce</u>. Vanishing act goes quicker and less chemical is lost if spreading is done immediately after spring rains.

MAINTENANCE

A chloride road not maintained becomes a chloride road not at all; the chlorides leach out. One alternative is a bituminous surfacing, which may solve the problem for several years. But because a chloride road is first of all a cheap road, many are left unsurfaced.

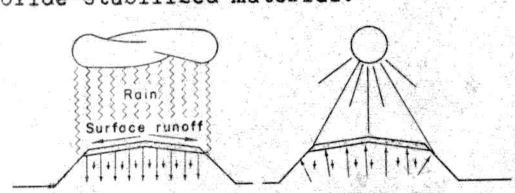
The first step towards maintenance is to select a short length of two-by-four and lightly bend it over the head of the operator of the blade grader. This action conveys a certain sense of responsibility, and also helps him to overcome intrinsic bullheadedness. Actually a good blade operator is a highly skilled artist, and he can make or ruin a stabilized soil road.

2 × 4

If a blade is used at all, it must be with a very light touch so as not to rip up that valuable, compact surface. The blade is used only to carry forward loose material to fill in the holes. Don't throw away the two-by-four.

As originally constructed, the road is built like a roof, with an "A-type" crown with flat, sloping sides. The blade should not allow this to slip away into the usual rounded crown, which drains poorly in the middle. Remember the two-by-four.

Potholes spell slow doom, because they trap rain water which can then seep through the road long after the rain is over. One of the best ways to fix potholes is to dig them out like a cavity in a tooth, then fill and tamp with pre-mixed, chloride-stabilized material.



Rain or shine, chlorides are on the move in a road. Rain causes leaching, shine brings salts back up by evaporation of water. Added to this is a permanent tendency for ion diffusion downward (short arrows).

Return to Table of Contents

Nov. - Dec., 1958
Vol. 2, No. 6

FACTS AND FINANCES

A final diversion is the cost of chlorides, closely dependent on source or manufacture.

Close to a source, the cheapest chlorides are natural brines from salt lakes or wells. These are so cheap they are often given away, and the only cost is to haul and spray onto the road.

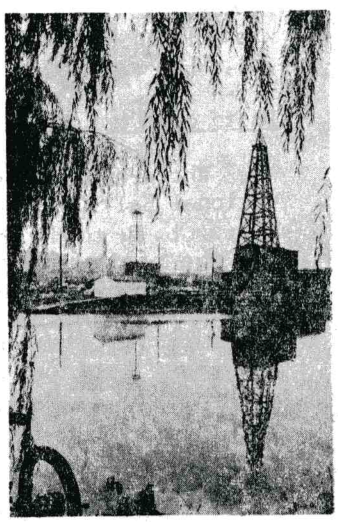
Unfortunately, natural brines often contain magnesium chloride, which is very corrosive. Then it's a matter of what do you want--dust or rust. Many natural brines are perfectly satisfactory.

Chemical industry waste brines are also used, particularly calcium chloride brine from the Solvay process for making soda ash.

Very far from a source of one of these brines, transportation costs rise, and nobody likes to pay for hauling water. A commercial crystallized product becomes cheaper overall.

Rock salt

The major source of sodium chloride is rock salt, currently available in salt mines (p.2). Salt is also produced by evaporation of brine either with heat from the sun or with steam heat evaporators. Much of this salt is first "mined" from wells, by drilling into a deep rock salt formation, pumping down water, and pumping up brine.

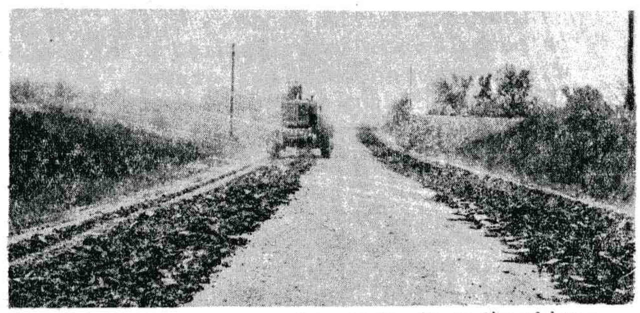


Calcium chloride

About half of the calcium chloride in the U. S. comes from refining natural brines; the other half comes from the soda ash industry. Brine is concentrated by evaporation and treated with lime to get out the magnesium chloride. Further evaporation settles sodium chloride as crystals. The remaining product is called 75% calcium chloride, chemically $CaCl_2 + 2H_2O$. This may be flaked or pelleted. Ordinary commercial flakes run 77 to 80% $CaCl_2$.

Prices

Nobody can accuse salt of being expensive; the current price for rock salt runs about $10 per ton, plus transportation. Calcium chloride costs several times more, but is still a cheap chemical.



First step towards a new face is to rip up the old one, eh, dear? Then add gravel and chloride, wet, mix and roll.

USE IN IOWA

Naturally, we Iowans like to regard ourselves as leaders in everything, our only problem being to prove it and keep leading. In this connection we now present a surreptitious preview of an in-state survey made by Dr. John B. Sheeler for the Iowa State Highway Commission.

Interviews were with county engineers known to be heavy chloride users. The tally shows 14 counties with a total of 524 miles of sodium chloride roads and 11 counties with 737 miles of calcium chloride roads. Many counties use both.

Quantities

Amount of salt used varies from 5 to 20 tons per mile, to give 2 to 4 inches of compacted road material 22 to 28 feet wide. Some counties report 8 to 12 pounds of salt per ton of soil. Salt is mixed with glacial till as the binder material.

Calcium chloride is usually applied to give 8 pounds per ton of mix, although one county uses 10 pounds per ton. For "soil" most use 3/4 inch crushed rock; a few use pit run gravel plus 12 to 25 percent glacial till for binder.

Scrapes

Many county engineers report trouble with their blade men; apparently they have not been teaching with the 2 x 4. Properly dented, a good blade man knows enough to keep his scrape shallow. The amount of blading is but a fraction of that necessary for untreated roads.

Return to Table of Contents

Either kind of chloride road may be maintained with an occasional surface shot of calcium chloride. Half the counties using salt report they apply 5 tons of calcium chloride per mile every year. On calcium roads the application varies from 5 to 20 tons per mile per year. The alternative for either is black-top.

Both kinds of stabilized roads are reported as showing a decided tendency to pit. Large pits or potholes are best repaired by hand-patching with mixtures of clay, gravel, and calcium chloride. Filling of potholes with loose, bladed material is only a temporary expedient.

Qualities

Aggregate retention on chloride-stabilized roads is reported as excellent, and is often the decisive factor in economy. One country reports annual savings of 250 tons of gravel per mile.

Chlorides rate well for dust prevention, most roads being described as slightly dusty but not completely dust-free. The traffic count varies anywhere up to 450 or 500 cars per day. Under less traffic the roads last longer. Because of the dustlessness and smoother riding qualities, chloride roads are reported as attracting traffic and easing the load on adjacent gravel roads. Winter damage is generally considered much less severe.

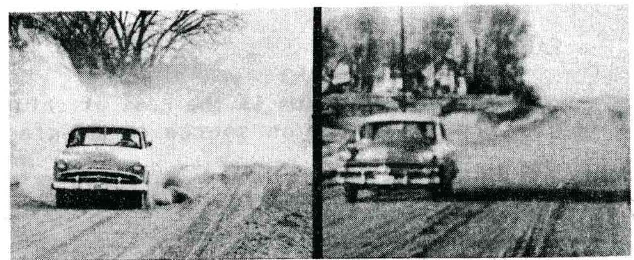
Some county engineer comments:

Salt

Black Hawk County--Most everyone is well satisfied, and gravel is conserved.
Butler--Average road life 5 years. A new road is built when the old one wears out.
Fayette--Good for 125 cars per day.
Franklin--Roads develop hard crust, stay hard in spring. Hold up until traffic exceeds 150 cars per day.
Hancock--Roads serve 2 to 4 years, then blacktopped.
Linn--Plant mix preferred.
Mitchell--75% salt, 25% calcium chloride holds road for blacktopping.

Calcium chloride

Benton County--Saves money in long run.
Chickasaw--Used with limestone or in soil-aggregate. Two roads going on 8 years.
Dallas--Large savings in aggregate and maintenance.
Linn--Plant mix with limestone.
Kossuth--Blacktop third year.
Pottawattami--Plant mix with limestone.
Winnebago--Gravel savings invaluable.



Dust is evil. It brings on discomfort, sneezes, carburetor drag, dirty ears, and blind-man's bluff around the curves. Road on the right has been treated with calcium chloride.

ACKNOWLEDGEMENTS AND REFERENCES SIGHTED

Beaucoup literature on use of calcium chloride in roads is available from the Calcium Chloride Institute, 909 Ring Blg., 18th and M Streets NW, Washington 6, D. C. For information on use of salt, contact the Salt Producers Association, 33 N LaSalle St., Chicago 2, Ill., or one of the major salt companies.

You will be pleased to know the latest word in highway engineering includes some late thrilling words on chlorides; we mean Prof. K. B. Woods' Highway Engineering Handbook, due out next summer. By coincidence the chloride stabilization section was written by Dr. D. T. Davidson and local penpal, RLH.

Photo credits

Whole-hearted thank-yous go to the International Salt Co., Scranton, Pa., for the mine shot on p. 2; to the Ohio State Highway Department for the road photos on p. 3 (r) and 5; and to the Diamond Crystal Salt Co., St. Clair, Michigan, for the well photo on p. 5. If hard pressed, we might admit to a tiny bit of retouching on p.3(r). Graphs are reproduced by permission of the McGraw-Hill Book Co. from Highway Engineering Handbook, copyright 1959.

The tab

Use of chlorides in roads is being studied under Iowa Highway Research Board Project HR-33 of the Iowa State Highway Commission and Project HR-1 with the Iowa Engineering Experiment Station. Research funds come from the Iowa State Highway Commission.

RLH

IN THE NEXT ISSUE: Soils in our 49th state.

Our last word for this year is to say hello to the next--Merry Christmas to all, and to all a good night.

Return to Table of Contents