Liquid Calcium Chloride for Dust Control and Base Stabilization of Unpaved Road Systems

Henry Kirchner and James A. Gall

The use of liquid calcium chloride on unpaved roads as a dust control agent and as a base stabilization material is examined. In the first section, a description is provided of how calcium chloride controls dust and the benefits it produces. The performance of calcium chloride is compared with that of other commonly used dust control agents. Recommended guidelines and application rates for controlling dust on unpaved roads with calcium chloride are then given. The second section provides a description of how calcium chloride stabilizes unpaved road bases and lists the seven ways the chemical helps build stronger roads. Recommended guidelines and application rates for stabilizing road bases with calcium chloride are provided.

Calcium chloride (CaCl₂) is a simple material produced from natural brine deposits found underground or from the synthetic Salvia process. It is processed into a colorless, odorless liquid, which is the material primarily used for dust control and base stabilization on unpaved roads. Calcium chloride is also processed into white flakes and white pellets. These products are occasionally used for dust control and base stabilization.

CALCIUM CHLORIDE AS A DUST CONTROL AGENT

Calcium chloride has two characteristics that enable it to be useful for dust control applications. First, it is hygroscopic. In other words, it attracts moisture from the atmosphere and surrounding environment and resists evaporation as it works to remain in its natural liquid state. Second, calcium chloride is deliquescent, which means the solid form can dissolve into a liquid by absorbing moisture from the atmosphere and surroundings. When calcium chloride is spread on low-volume unpaved roads in the spring, its moisture-attraction ability works to keep the surface damp and to keep dust down, usually throughout the summer.

Calcium chloride has other properties that contribute to the improvement and performance of unpaved roads. For example, compared with plain water, calcium chloride has a stronger moisture film, higher surface tension, lower vapor pressure, and lower freezing point. The combination of these properties enables the chemical to keep unpaved surfaces damp and to keep fines, or tiny dust particles, in place. Additionally, calcium chloride actually helps bind the aggregate particles together and, as a result, the surface becomes compacted by traffic. Over time, calcium chloride slowly penetrates the surface by several inches, which creates a stabilizing effect to the road. The longer calcium chloride is used, the more stability that is achieved. Finally, the chemical’s lower freezing point helps unpaved roads resist frost heave in late fall and early winter.

Benefits

As a rule, one car making one pass on 1 mi of untreated, unpaved road everyday can generate 1 ton of dust in 1 year. When the road is treated with a dust suppressant, however, it retains a high percentage of the fines it would otherwise lose as dust. Road superintendents from the Midwest have verbally reported up to an 85 percent reduction in fines from road treatment.

Because calcium chloride is hygroscopic, it holds fines in place. Therefore, coarse aggregates tend to stay in place, eliminating their abrasive action. This reduces the need for aggregate replacement and, in some cases, can eliminate it for long periods of time, depending on the road’s average daily traffic.

Because road materials stay in place, the frequency of blading can be reduced from 25 to 75 percent by using a dust palliative. This, in turn, can reduce labor and equipment costs. Also, fewer spot repairs are needed, which means less labor and materials are required.

Finally, less dust, less aggregate replacement, and less blading mean less repair work in general. Therefore, less fuel is used and less equipment maintenance is needed.

Comparison with Other Dust Control Materials

Many different materials under many different brand names have been used for controlling dust, which has led to confusion regarding their performance. The following is a review of some of the more commonly used dust control agents and how they compare to calcium chloride.

Oil and Asphalt Emulsions

In a year-long study commissioned by Dow Chemical and conducted by PEI Associates, Inc., an independent research...
firmed located in Golden, Colorado. sections of a road in Adams County, Colorado, were treated with an asphalt emulsion and calcium chloride. Data gathered after only 4 weeks of testing indicated that liquid calcium chloride had already achieved a dust control rating efficiency 135 percent greater than the asphalt emulsion (see Table 1).

Due to the emulsion’s poor performance, a second coating was applied after Week 4. Shortly thereafter, the emulsion-treated section was termed unsatisfactory and the emulsion was removed from testing.

The emulsion-treated section of road was visibly inferior compared with the calcium chloride—treated section. For example, while the calcium chloride section was firm, smooth, and practically dust-free, the emulsion section was severely rutted. This condition resulted because emulsions offer little aggregate binding capabilities. Instead, they coat an unpaved surface with a thin crust that can fragment under loads and leave behind potholes. It was also observed that considerable aggregate had been lost alongside the road.

In a 1979 study, Harvard University (1) compared the use of oil emulsions and calcium chloride on unpaved roads. The study is considered to be one of the most comprehensive conducted on dust control agents. It concluded that treating unpaved roads with calcium chloride is far more economical than treating them with oil. This conclusion was reached by taking the average total annualized cost of various treatments for an unpaved road and dividing it by the dust control efficiency (dust emission reduction) for each method. Specifically, to determine the cost of unpaved road treatments, the study took into account the initial capital investment for each road, the capital recovery factor (percentage of initial investment that would be paid yearly on a loan at a certain interest rate for a specified number of years), and the average annual cost of operation and maintenance.

Because oils do not perform as well as calcium chloride, they would have to be applied more frequently to achieve a similar degree of dust control. This factor probably had a greater bearing on the difference in cost between the two materials. In gathering their data, the Harvard researchers requested cost estimates of numerous state highway departments during the 1970s. Figure 1, which reflects these data, shows the mid-range of these estimates. It demonstrates that treating unpaved roads with oil can be six times more costly than using calcium chloride.

A recent article (2) referred to oil products used for dust control and noted that,

Generally, the life expectancy of dust palliatives decreases with higher traffic volumes and with higher percentages of truck traffic. This is particularly true of products that create a hard surface crust, which is subject to potholing, such as... most petroleum products.

### TABLE 1 SUMMARY OF CONTROL EFFICIENCIES. WEEKLY AVERAGES

<table>
<thead>
<tr>
<th></th>
<th>Liquid Calcium Chloride (%)</th>
<th>Asphalt Emulsion (%)</th>
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<tbody>
<tr>
<td>Week 1</td>
<td>77.3</td>
<td>43.0</td>
</tr>
<tr>
<td>Week 2</td>
<td>69.5</td>
<td>25.8</td>
</tr>
<tr>
<td>Week 3</td>
<td>74.2</td>
<td>33.6</td>
</tr>
<tr>
<td>Week 4</td>
<td>70.8</td>
<td>25.8</td>
</tr>
<tr>
<td>Overall average</td>
<td>72.6</td>
<td>31.1</td>
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calcium chloride to achieve the
on three mine haul roads located in various parts of the coun­
In 1983, the
try . The objective was to determine the cost effectiveness of
evaluated on an individual basis, particularly with respect to

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unpaved surface before or after the calcium chloride has been applied.

Lignin Sulfonate

In 1983, the U.S. Bureau of Mines (3) conducted field tests
on three mine haul roads located in various parts of the coun­
try. The objective was to determine the cost effectiveness of
achieving a minimum 50 percent level of dust control on these
roads. It was found that lignin sulfonate, a byproduct of paper
mills, costs between 1.41 and 1.46 times more than liquid
calcium chloride to achieve the 50 percent level of control

efficiency required.

Lignin sulfonate, like petroleum-based dust suppressants, provides little soil penetration. Surface coating of aggregate
is the means of dust control.

Water and Surfactant

The U.S. Bureau of Mines (3) also tested plain water and
found it to cost between 1.48 and 2.18 times more than liquid
calcium chloride to achieve the 50 percent level of control
efficiency required.

The surfactant, which is a soap-like material, was removed
from consideration because it did not allow for an estimation
of required application frequency to achieve a 50 percent level
of dust control.

Recommended Guidelines and Application Rates

Unpaved roads with an average daily traffic (ADT) of 25
usually do not need dust control. However, they should be
evaluated on an individual basis, particularly with respect to

It is necessary that about 18 percent more magnesium chloride
commercial product be applied . . . to get the same dust con­
trol effect (as calcium chloride provides). With the present
cost accounting situation the calcium chloride should come out
as being cheaper to use than magnesium chloride, while achiev­
ing the same dust binding effect.

Furthermore, magnesium chloride is generally produced by
solar evaporation. The more exposure to the sun it gets, the
higher the chemical concentration will be; the less exposure, the
lower the concentration. Because this production method
depends on the weather, magnesium chloride concentrations
and performance can vary widely.

Conversely, calcium chloride is a processed material under
strict quality-control conditions manufactured according to
ASTM standards. Chemical concentrations may vary only
slightly from batch to batch, which in turn means consistent
performance.

<p>| TABLE 2 SOLUTION CONCENTRATION AND  |
| APPLICATION RATE RECOMMENDED BY   |</p>
<table>
<thead>
<tr>
<th>SUPPLIERS</th>
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<tr>
<td>Concentration (% by weight)</td>
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<tr>
<td>Calcium chloride</td>
</tr>
<tr>
<td>Magnesium chloride</td>
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</tbody>
</table>

Many dust suppressants do not work well in sandy, non­plastic soils. Sandy soils are porous and lack the cohesive­ness to retain the suppressant. In other words, the dust control
agent tends to migrate through this type of soil.

Also, these suppressants do not work well in soils containing
greater than 25 percent clay because they are hygroscopic.
When the materials are combined, they are likely to attract
too much moisture to the clay and, therefore, tend to make
an unpaved road too damp or wet. This condition may result
in loss of road stability to support vehicle traffic.

Before treating an unpaved road with calcium chloride a
soil sample should be taken and analyzed. If the road has too
much sand or clay, an amount of the appropriate material
should be added to compensate for any deficiencies. A typical
wearing course is presented in Table 3.

The decision to use liquid or dry calcium chloride is usually
based on economic considerations and the type of storage,
mixing, and application equipment available. Liquid calcium
chloride is recommended because it can be more evenly dis­
tributed on the road. For dust control, liquid calcium chloride
is usually purchased in 30 to 42 percent solutions.

Alternatively, users can sparge (mix with water) flake or pel­let calcium chloride products on location to produce a liquid. Flake or pellet calcium chloride can also be spread
directly onto unpaved surfaces without first being put into
solution. Special consideration must be taken to make sure
adequate moisture is available for the dry calcium chloride.
Water is usually added to the unpaved surface before or after
the calcium chloride has been applied.

Because calcium chloride works by attracting moisture from
the atmosphere and surroundings, it is best to apply the chem­
ical after seasonal spring rains when there is ample moisture
in the ground. Applications should not be started during a
heavy rainfall or if rain is threatening. If it is a dry spring,
water should be sprayed on the road before application,
provided the moisture can soak into the ground and will not
run off.

<p>| TABLE 3 AVERAGE GRADATION  |
| FOR A TYPICAL WEARING COURSE |</p>
<table>
<thead>
<tr>
<th>Sieve Designation</th>
<th>Percent Passing</th>
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<tr>
<td>1 in.</td>
<td>100</td>
</tr>
<tr>
<td>3/4 in.</td>
<td>85–100</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>65–100</td>
</tr>
<tr>
<td>#4</td>
<td>55–85</td>
</tr>
<tr>
<td>#10</td>
<td>40–70</td>
</tr>
<tr>
<td>#40</td>
<td>25–45</td>
</tr>
<tr>
<td>#200</td>
<td>10–25</td>
</tr>
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Calcium chloride typically retains its moisture-attraction ability throughout the summer because it resists evaporation. Therefore, it should continue to control dust throughout this period as well. A second application is recommended in late summer or early fall to provide dust control into late fall and to help protect unpaved roads against early frost damage.

The following three steps are needed to provide effective dust control with calcium chloride.

Step 1. The road surface should be bladed to a depth sufficient to remove potholes, washing, and rutted areas, then shaped to a straight-line slope of 1/2 to 12 in. — a type “A” crown. On curves, the slope should remain the same across the entire width of the road (1/2 to 12 in.). The transition between a straight line and curve should be gradual. This shaping lets water drain off the road, which in turn helps prevent the formation of potholes. If water is allowed to stand on a road surface, it can act as a particle lubricant and create soft spots. As cars pass over these soft spots, tires can push the soil and aggregate aside and into ditches.

Any soil dams, or berms, that are created during blading should be removed. Otherwise, these buildups can restrict water drainage from the road surface. Berms can be removed by blading them smooth along with the road’s surface as part of the final touch-up in the road-shaping process.

Step 2. A 38 percent solution of liquid calcium chloride should then be applied to the road surface at the rate of 0.27 gal/yd². Experience has shown that this percentage is the ideal calcium chloride concentration for dust control. If a weaker solution were used, it would lose its dust control effectiveness in a relatively short period of time and the road would have to be retreated. A stronger calcium chloride solution would tend to bead up on the road during application rather than penetrate the surface.

Alternatively, 1.54 lb/yd² of flake calcium chloride or 1.32 lb/yd² of pellet calcium chloride can be applied to achieve effective dust control.

Step 3. As previously mentioned, dust control is usually maintained throughout the summer with minimal attention. However, a second treatment is recommended in late summer or early fall. It may be necessary to reblade the road according to Step 1 before applying calcium chloride.

CALCIUM CHLORIDE AS A BASE STABILIZATION MATERIAL

Soil stabilization is a means of upgrading the engineering properties of soils to provide maximum return on investment in road construction or improvement. Although there is no precise definition of stabilization, a soil is said to be stable when it resists change, particularly mechanical change, over long periods of time. Conversely, an unstable soil is one that breaks up, shifts, or sinks when acted upon by the normal forces of load and climate, resulting in a prematurely deteriorating surface.

Three mechanical aspects are critical to a soil’s ability to withstand loads: (a) cohesion, (b) friction, and (c) density. Cohesion refers to the ability of soil particles to stick together. Friction refers to the ability of particles to resist shifting of their position relative to each other. Density is the weight of a material to its bulk.

Damp clay has a high density and good cohesiveness. However, its low coefficient of friction permits its particles to shift along several axes and, under load, it yields easily. Gravel has a high coefficient of friction, somewhat lower density, and little or no cohesiveness. Although gravel can bear large static loads, it is also porous and therefore extremely unstable and susceptible to uneven settling, hydraulic action, and frost heave.

Because no material exhibits both a high coefficient of friction and high cohesiveness, a mixture of materials is required. In fact, several aggregate grades should be involved, ranging from coarse aggregate to fines passing a No. 200 sieve. Figure 3 shows the average gradation of a stabilized mix on a typical base course.

When all of these materials are mixed together, the larger components will leave voids, which are filled in by progressively smaller components. A chemical additive, such as calcium chloride, then coats the various-sized particles and adds density to the mix, which helps prevent their loss due to traffic or weather. This process is referred to as soil stabilization.

Compacting a subgrade is important because it can increase bearing capacity by as much as 150 percent, increase shear strength, reduce permeability, and improve overall stability. The result is a stronger, more durable road whose bituminous or concrete surface can be thinner than that of lesser-quality roads.

The density to which a roadbase can be compacted is a function both of the moisture content of the aggregate and of the compacted effort exerted upon it. Moisture content is critical. If there is too little water, particles will not have the lubrication necessary to compact properly, regardless of compacted effort. With too much moisture, hydraulic forces develop that may actually force the particles apart under compaction. The limits are strict. A deviation of only 1 percent from optimum moisture may reduce density by over 2 lb/ft³ and increase voids by as much as 8 percent.

Benefits

Compared with plain water, calcium chloride possesses a stronger moisture film due to its greater surface tension, reduced vapor pressure, and lower freezing point. These properties, in addition to the chemical’s moisture-attraction capability and its ability to resist evaporation, provide seven benefits in a program of roadbase stabilization.

Greater Density

Research and field tests have shown that adding the proper amount of calcium chloride to the roadbase aggregate (usually 0.5 percent by weight) results in a greater density in the aggregate than would be achieved by the use of water alone. A calcium chloride solution has a stronger moisture film, which enhances the lubrication effect with less moisture. The aggregate components can then slide together easily as they are mechanically compacted.

Less Compactive Effort

There are two ways to look at this benefit: (a) less compactive effort to achieve specified densities, and (b) greater densities achieved with the same compactive effort.
In one experiment, a greater density was achieved at the end of four rollings when calcium chloride had been added to the aggregate than had been achieved with nine rollings when only plain water had been added.

Figure 4 shows that the use of calcium chloride can greatly reduce the compactive effort required to achieve specific densities.

**Optimum Moisture Control**

As previously noted, unless moisture is held within optimum limits, adequate densities cannot be achieved. An unstable roadbase would result, regardless of grading or the number of rolling passes made.

It is difficult to provide an aggregate mix with the proper amount of moisture. Once achieved, it is equally difficult to maintain optimum moisture content. Calcium chloride's hygroscopic qualities, along with its ability to lower the vapor pressure of water, work to inhibit evaporation and therefore help maintain optimum moisture (see Figure 5).

**Surface Uniformity**

Because of calcium chloride’s moisture-retention capabilities, surface irregularities can be graded out and recompacted without loss of moisture content due to aeration and drying out. This can result in a smoother surface and provide a roadbase that is more uniformly dense throughout its depth.

**Effective Stage Construction**

When roads are being constructed in stages, treating the aggregate with calcium chloride can help the surface remain firm and stable. The need for frequent blading and aggregate replacement is thus reduced, as well as the costs involved with those types of maintenance.
Improved Bonding Between Base and Priming Materials

Because calcium chloride helps keep aggregate materials moist when they are being readied for paving, it helps improve the bond strength between the priming materials and the base course.

Frost Protection

The ability of calcium chloride to depress the freezing point of water helps a roadbase resist frost heave in winter. In tests using well-graded aggregate, only ½ of 1 percent calcium chloride by weight can in certain circumstances eliminate frost heave (see Figure 6).

Recommended Guidelines and Application Rates

Roadbase stabilization requires a total of 0.6 gal/yd² of liquid calcium chloride: 0.4 gal are used for stabilization, and 0.2 gal are used as a top dressing.

The following seven steps are needed to stabilize roadbases with calcium chloride.

Step 1. The road surface should be scarified to a depth that removes all potholes and other irregularities—usually a minimum of 6 in.

Step 2. If it is necessary to add aggregate to improve gradation, materials comparable to those already in place should be used. The material should be mixed with the existing aggregate at the work site. No more than 6 in. of loose aggregate at a time should be placed in a layer during the process of rebuilding the road surface.

Step 3. A 38 percent solution of liquid calcium chloride should be applied uniformly to the mixed or scarified material at the rate of 0.4 gal/yd². Alternatively, 2.27 lb/yd² of flake calcium chloride or 1.95 lb/yd² of pellet calcium chloride can be applied.

Step 4. The soil, new aggregate (if added), and calcium chloride, plus water (if necessary), should then be thoroughly mixed. This mixing can be easily accomplished with a motor grader. Mixing should begin as soon as possible after the calcium chloride is applied. The mix depth is the same as the scarification depth—up to a maximum of 6 in.

Step 5. The surface should then be bladed, shaped, and compacted to a straight-line slope of ½ to 12 in.—a type “A” crown. On curves, the slope should remain the same across the entire width of the road (1½ to 12 in.). The transition between a straight line and curve should be gradual. As previously explained, this action allows water to drain off the road.

Step 6. The road should be top dressed by applying a 38 percent solution of liquid calcium chloride to the surface at the rate of 0.2 gal/yd². Alternately, 1.14 lb/yd² of flake calcium chloride or 0.97 lb/yd² of pellet calcium chloride can be applied.

Step 7. Once the road is stabilized, dust control is usually maintained throughout the summer with minimal attention. However, for best results, a second top dressing is recommended in late summer or early fall. A 38 percent solution of liquid calcium chloride should be applied to the road surface at the rate of 0.27 gal/yd². Alternately, 1.54 lb/yd² of flake calcium chloride or 1.32 lb/yd² of pellet calcium chloride can be applied.

If necessary, the surface should be rebladed according to Step 5 before applying the calcium chloride.

SUMMARY

When used for dust control, calcium chloride holds fines in place, which in turn holds the coarse aggregate in place. This reduces aggregate replacement costs. It also reduces the frequency of blading from 25 to 75 percent, which cuts labor and equipment costs. Fewer spot repairs are required, which means less fuel and less equipment maintenance are needed.

When added to a well-graded aggregate mix for roadbase stabilization, calcium chloride helps keep moisture at an optimum level, resulting in greater densities with less compactive effort, and less dust. It also causes a better bond between the roadbase and the surface course, providing effective stage construction and frost protection.

When these advantages are combined, the life of a paved road can be expected to double and, depending on the specifications, the cost can be reduced by approximately 30 percent per mile.

In short, whether calcium chloride is used for dust control or roadbase stabilization, it is an inexpensive chemical whose cost-saving benefits easily outweigh its cost.

REFERENCES