Chloride Stabilization of Unpaved Road Aggregate Surfacing

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Abstract
There are few alternatives for improving performance of aggregate surfacing materials other than annual dust abatement treatments. In place stabilization of properly graded aggregate with chloride additives is cost effective and provides many performance and intangible benefits in many environments. This two year study identifies conditions where chloride stabilized roads have a projected life of 10 years or more if properly maintained. The greatest benefits are realized on projects where aggregate surfacing replacement costs are high and average daily traffic volumes exceed 100. Stabilization provides a much higher standard of road surface performance by improving ride quality, and reducing dust, corrugations (washboarding), and raveling (loose aggregate). Other intangible benefits include reduced sedimentation in streams, reduced aggregate resource depletion, reduced health hazards from dust, and increased road-user safety. Similar results are achieved by plant mixing additives with aggregate during crushing. This project developed guidelines for chloride stabilization of different aggregate surfacing materials in semi-arid to arid environments. Performance and cost effectiveness of chloride stabilization was measured on 12 projects and monitored for 2 seasons in 4 western States. Project monitoring included the following: construction and maintenance costs, road surface deterioration, traffic, weather conditions, environmental effects, and materials testing. Results show that treated surfacing needed blading maintenance after 25,500 vehicles, where untreated surfacing needed blading after only 3,200 vehicles; thus treated road performance life was 8 times greater than untreated. Environmental affects on trees, streams and roadside soils were insignificant.

1. INTRODUCTION

Each year, most low volume road agencies maintain thousands of miles of unpaved aggregate surfaced roads by surface blading. Blading is a costly activity that is done frequently and lasts a short time on heavily traveled roads. Road surface conditions can deteriorate so fast that blading is often recognized as an ineffective but politically necessary activity. Blading also contributes to the increase of stream sediments and contamination, loss and breakdown of expensive aggregate surfacing.

When utilized correctly, road surface stabilization with magnesium and calcium chloride materials reduces blading significantly, increases road quality and saves money. These two chlorides absorb moisture from the air and retain this moisture because they are both

deliquescent and hygroscopic. They promote greater density and capillary tension of fines in aggregate surfacing that helps bond the materials together. Application rates used for stabilization are three to five times the normal application rate used for dust abatement.

The goal in road selection was to get a broad cross section of roads—that were in relatively dry climates—in three USDA Forest Service Western Regions. Twelve roads were selected in four states. Each road had three types of test sections. Some were maintained according to usual practices, others were mixed with chloride materials, and some were untreated control sections.

Test sections were constructed with liquid and solid forms of calcium chloride and liquid magnesium chloride, and then performance was monitored for two years. Thirty-nine treated and forty untreated test sections were built with magnesium and calcium chloride mixed at 2 concentrations with crushed aggregate surfacing 2 inches deep. Chlorides were mixed to provide 1.5 and 2.0 percent pure chloride salt based on dry weight of aggregate. They were mixed in place with a motor grader and also with an agriculture type tractor tiller.

Performance monitoring, measurements, and testing were a significant part of this project. Road surface defects were measured three to four times each season to develop deterioration curves and to determine the effective life of each type of treatment. Deterioration curves’ using a condition index was the basis for performance measurement and life prediction. The primary inputs for a life cycle cost analysis were treatment life and costs for aggregate loss, construction, maintenance, and for the road user. Environmental affects were measured before and after construction by testing chloride concentration in roadside soils, trees and adjacent streams. Continuous onsite traffic and weather monitoring was conducted on all projects for the two year period. Extensive testing was done to define aggregate characteristics on all projects.

2. PROJECT SCOPE AND OBJECTIVES

From 1995 to 2000 the USDA Forest Service completed three projects using in-place stabilization with solid calcium chloride that showed promise in extending aggregate surfacing life and performance, as well as reducing maintenance (Monlux 2003). This project replicates these practices on a larger scale by including other types and forms of magnesium and calcium chloride, additional construction practices, different aggregates and climates. Monitoring efforts were intensified for road surfacing performance, weather, traffic, and effects on soil, stream water and trees. More detailed analysis was done on costs and benefits. The primary objective was to provide guidelines and tools for effective implementation of the technology.

3. TEST SECTION DESIGN

Within each road, test area location was based on similar aggregate, exposure, canopy, aspect, grade, and curvature. Three types of test sections were constructed on each project. At least one untreated control section was mixed with the blade or tractor-tiller to see if the construction process provided significant benefits by itself. At least one section was built to model the normal maintenance blading. All other sections were treated with chloride materials in...
various forms and application rates. Test section lengths ranged from 750 to 900 feet. Seventy-nine test sections were constructed.

4 TEST ROAD CONSTRUCTION

A service contract for construction was awarded to Moline Grading, Standpoint, Idaho, in September 2002. Oxford Inc., Moyie Springs, Idaho, provided, applied, and mixed all chloride materials. The Trout Creek Road project was built as a pilot project in October 2002. The remaining 11 projects were built between mid May and early July 2003. The general construction process was as follows:

- All sections were watered to assist the initial blading and shaping.
- All sections were bladed to remove ruts, washboards, potholes, and mix in loose aggregate. The road surface was shaped to a 4-percent crown.
- Where solid (dry) products were used, the road surface was watered to ensure that the aggregate would be at optimum moisture during mixing. Water was not applied to the road surface prior to mixing liquid products for fear of exceeding optimum moisture.
- For tractor-tiller mixed sections, chloride was applied and tilled into the top 2 inches of aggregate. The surface was lightly shaped to ensure a 4-percent crown and then compacted. A light surface application of chloride was spread on the finished surface.
- For blade-mixed sections, a windrow was built, sized, and flattened. The size of the windrow is based on a 2-inch compacted depth times a 1.25 swell factor. Chloride materials were spread on the flattened windrow then mixed by moving material from one side of the road to the other, two times. The mixed surfacing was spread from the windrow, then shaped to a 4-percent crown and compacted. A light surface application of chloride was spread on the finished surface.
- Twenty-two untreated control sections were built using the same methods as treated sections, except chloride materials were not used.

5. PROJECT MONITORING

5.1 Weather

Relative humidity and temperature were measured by onsite gauges on all 12 projects. Rainfall was measured onsite on six projects, and remote automated weather station data was used on the other six projects during 2003. In 2004, all projects had onsite rainfall gauges.

Average daily relative humidity ranged from 15 to 98 percent and temperature ranged from 35 to 98 degrees Fahrenheit. Average seasonal relative humidity and temperature ranged from 47 to 83 percent and from 50 to 61 degrees Fahrenheit. Precipitation during the spring, summer, and early fall was light in 2003 (0.5 to 5.5 inches) and heavy in 2004 (5.3 to 13.9 inches). About two-thirds of this precipitation occurred during the hot summer months as isolated thunderstorms dropped 0.3 to 0.5 inches of rain over a 1-hour period.
5.2 Traffic

Vehicle traffic counts were collected on all 12 projects. The South Side Road had the lowest seasonal average daily traffic (25), and the Middle Fork Payette River Road had the highest (157). Four of the 12 roads had peak daily traffic counts of over 400 vehicles with the greatest count being 922. The primary operating season is from April to November and is controlled by freezing road conditions or snowfall.

Traffic classification was provided by forest road managers and generally fit into the three categories:

- 79 percent light vehicles including trucks.
- 16 percent 2-axle trucks and light-duty trucks with trailers.
- 5 percent trucks with more than 2 axles.

5.3 Soil, Water, and Tree

Environmental influences were measured by testing chloride concentration in roadside soils, trees and adjacent streams before and after construction. Forty-eight samples of soil, from both treated and untreated sections on the road shoulder were taken before construction on each project. After 2 seasons, 48 additional samples were taken on these same locations to see if there was a significant change in chloride concentration. The data shows a rise in soil chloride levels that are below the thresholds for concern.

Chloride levels in the Tucannon River were measured before and after treatment of the Tucannon River Road. The river varied 15 to 20 feet from the road shoulder. Results indicate there is no significant change in calcium or chloride-ion levels in the water after treatment.

On 4 projects, before construction, 101 samples of conifers were taken close to the road and adjacent to a treated and an untreated test section. Locations of trees ranged from 5 to 50 feet from the road shoulder. Duplicate samples were taken from the same trees after two growing seasons to see if there was a significant increase in chloride concentration. Data from tree samples indicates the level of chloride increased, but is not a significant long-term threat to survival.

5.4 Road Surface Performance

Road surface defects were measured three to four times each season to develop performance curves and determine the effective life of each test section. All monitoring was done by one individual to improve consistency.

The un-surfaced road condition index, URCI, was used to monitor road surface performance (USACE 1995). The URCI is a road management tool for scheduling maintenance and avoiding costly repairs. Similar but less measurement-intensive methods are used by many low-volume road agencies. The distress types or defects rated for these projects are corrugations (washboards), dust, potholes, ruts, and loose aggregate (raveling).

Each distress type measured is categorized into three severity levels (low, medium, and high) and the extent of each level is measured in square feet. Each measured distress level is converted into a value and subtracted from 100 to get the condition index. A road with no defects has a condition index of 100. Values below 60 usually indicate that blading is needed.

Road surface conditions were observed to determine if blading was needed and to determine reasonable vehicle speed on each section. Vehicle speed influences user costs and provides another indication of road serviceability. Reasonable vehicle speeds and corresponding
thresholds for “blading needed” and “blading critical” are on performance curves to provide a better description of the extent of deterioration that was taking place during each season. A 25 percent reduction in vehicle speed correlates with “blading needed” and a 40 percent reduction in vehicle speed correlates with “blading critical”.

One method for describing performance is by using the life ratios. Life ratio is defined as the amount of traffic on treated sections divided by the amount of traffic on untreated sections prior to blading being needed. Essentially, the ratio is a number that represents how much longer the initial performance life of the treated sections is versus the untreated sections prior to maintenance blading. The ratios range from a low of 4 to a high of 57. Based on the average life ratios of all projects, treated sections needed blading after 25,500 vehicles and untreated needed blading after 3,200 vehicles; thus the average life ratio for all projects was 8.

6. LABORATORY TESTING OF AGGREGATE AND CHLORIDE MATERIALS

Road-surfacing aggregate on 11 of the 12 projects is good quality, well-graded crushed aggregate. Gradation tests show from 48 to 72 percent passing the #4 sieve, and 11.1 to 17.2 percent passing the #200 sieve. These types of gradations have been found to perform well in relatively dry climates because they capture the chloride ions in a relatively impervious gradation (Slesser 1943). Impervious gradations prevent rains from flushing chloride ions in the aggregate down into the subgrade. Less amount of minus #200 would be necessary if the minus #40 were plastic. Aggregates on all projects are nonplastic, including the Payette River Road aggregate that was treated with 2.5 percent bentonite clay in 1999.

The percentage of chloride used for stabilization was based on past experience on several stabilization projects. The 1.5 and 2 percent chloride salt concentrations by weight aggregate surfacing are similar to concentrations obtained by annual dust abatement treatments over a 4- to 6-year period. An indication of the optimum chloride content for a particular aggregate can be determined by running moisture density tests with various percentages of chloride, similar to an asphalt mix design. Higher rates last longer in arid areas because higher concentrations evaporate at a slower rate (Slesser 1943).

7. INTANGIBLE BENEFITS

Stream sediments are reduced when road surface blading is reduced (Foltz and Truebe 1995). This project shows that blading is reduced when road surfaces are stabilized. When stream sediments are reduced, costs are reduced or eliminated for design, construction, and maintenance of sediment control structures.

Resource damages from aggregate sources are reduced if the demand for aggregate surfacing is reduced. Road surface stabilization clearly reduces the need for aggregate replacement. Less aggregate usage would conserve aggregate resources which are scarce in many areas, and save funds currently spent for locating, drilling and surveying new sources, preparing pit development plans, securing necessary permits, and for site development and restoration.

Road user safety is increased when dust from the road surface is reduced. Chloride materials are an effective dust abatement product, as well as a stabilization agent. Less dust
reduces vehicle accidents, which reduce costs associated with vehicle repair and medical expenses, as well as decreasing loss of life. Public health costs are less when a known health hazard, such as dust, is reduced. The extent of the benefit is based on the amount type and speed of vehicular traffic, the number of vehicle occupants, and the number of individuals exposed for long periods in roadside residences and campgrounds.

Negative public opinion is generated from roads in poor condition. Public complaints require valuable employee resources that adversely affect the road agency workforce’s overall productivity.

8. OBSERVATIONS AND CONCLUSIONS

The following conclusions are from field observations and data collected during full scale monitoring during the 2003 and 2004 seasons, and limited monitoring after blading maintenance in 2005.

8.1 Treated Sections versus Untreated Sections

- Blading was needed on treated sections after 25,500 vehicles, and on untreated sections after 3,200 vehicles, thus the average initial performance period for the treated sections lasted 8 times longer than the untreated sections.
- The average speed on treated sections was 37 miles per hour and the average speed on untreated sections was 26 miles per hour for the 2-year period.
- During the 2003 season, four of the 39 treated sections needed blading one time and all 40 untreated sections needed blading 95 percent of the time. Blading became critical on several untreated sections in the first year.
- Visual observations indicate treated sections reduced the dust by approximately 90 percent, thus reducing inhalation health hazard.
- The condition of all test sections improved after periods of wet weather and over the winter season. Treated sections improved more than untreated sections.

8.2 Treated Sections

- During the first 2 years of monitoring, 13 of 39 treated sections needed blading. Six of the 13 sections had construction problems or the crown was removed by snowplowing. The predominant defects in the other seven sections were potholing, washboarding, and rutting.
- All the pothole problems existed where the crown was less than 2 percent due to snowplowing or at the centerline where the crown was flattened. Water in potholes may leach chloride from the treated surface into the subgrade.
- No distinct difference in performance existed between the 4 different products, magnesium chloride liquid, calcium chloride liquid, and calcium chloride solid at 77- and 94-percent salt concentration.
- No distinct difference existed in performance was noticed on 2 percent chloride content versus 1.5 percent. A greater difference in performance may be evident after 3 or more years of service.
Aggregate materials on 11 of 12 projects performed well when stabilized. Miller Creek Road was the exception because there was more loose aggregate material that caused raveling. All other projects were essentially 3/4-inch minus and well graded with a minus #200 range of 11.2 to 17.1 percent and no plasticity. Well-graded aggregates with this amount of minus #200 work well because chloride ions are held within a relatively impervious medium (4). Minus #200 contents between 8 and 12 percent may also work well if minus #40 portion was plastic.

No correlation existed between project performance and gradations plotted on the 0.45 power curve.

In dryer climates, treated road surfaces may dust in early spring before spring rains. These surfaces regain their treated appearance (wet look), and harden-up when rains come or when the surface is watered.

All project characteristics influence the performance of chloride-treated aggregate surfaces. The most significant appear to be aggregate characteristics, climate, maintenance blading practices, traffic speed and volume.

Humidity influences performance. However, projects with an average daily minimum humidity as low as 15% in Central Oregon performed as well as some projects with higher humidity. Periodic rains improve performance, but do not have as significant an influence as daily humidity. Projects located next to streams or that had roadside vegetation to provide shade, performed better.

Blading when moisture is below optimum or allowing the bladed surface to remain loose and dry out reduces long-term performance. The wet blading process works very well for relatively impervious gradations. The road surface is saturated after blading, and then wheel tracked to flush fines and residual chloride to the surface. When the surface dries, a hard crust develops that can last as long as the original treatment.

Pothole formation or resistance to surface erosion is not improved by chloride stabilization. Road crown is the primary deterrent to the formation of potholes and surface erosion.

8.3 Construction

Superior performance of treated sections over untreated control sections indicates that the good performance is due to stabilization agents and not the stabilization construction process.

There is no significant difference in the performance of untreated normally bladed sections and untreated compacted control sections. This indicates compaction after maintenance blading has no long-term performance benefits.

“Normal blading” practices used for removing all road surface defects were as effective as milling or blade-mixing 2 inches deep. However, the “normal blading” costs $284 per mile on test sections and removed many more defects and built better crowns than the typical maintenance blading. Typical maintenance blading costs on 8 of the 12 roads are $157 per mile. During the second season contract-bladed untreated sections developed defects more rapidly.

The best time to stabilize aggregate roads with chloride is early spring when road surface moisture content and humidity are high and late spring rains keep the surface wet while traffic flushes fines to the surface. The fines form a hard crust when dry.

Blade-mixing consistency is very dependent on operator capability and machine condition.
• Blade-mixed sections deteriorated more rapidly than tractor-tiller mixed sections, due to treatment depth inconsistencies and non-uniform mixing. Minimum depths of 2.5 inches are needed when blade mixing.
• Blade mixing liquid chlorides is not practical on roads with grades over 2 percent, because the product will run in distributor wheel tracks to sag vertical curves or off the road surface.
• Blade-mixing operations require more quality assurance and technical expertise to ensure the correct amount of aggregate is mixed with chloride and that the treated thickness is uniformly mixed to the specified depth.
• Blade mixing is not practical where road widths are less than 18 feet.
• Traffic delays and construction interruptions with blade mixing are more significant than with tractor-tiller mixing for all chloride products.

9. LITERATURE CITED

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