OTHER STABILIZED SURFACINGS (INCLUDING DUST PALLIATIVE APPLICATIONS)

CHLORIDES

GENERAL INFORMATION

Generic Name(s): Chlorides, Salts, Calcium Chloride ($CaCl_2$), Magnesium Chloride ($MgCl_2$), Sodium Chloride ($NaCl_2$)

Trade Names: *$CaCl_2$*: Dowflake, LiquidDow, Roadmaster; *$MgCl_2$*: Dust-Off, Dus-Top, DustGuard, etc.

Product Description: Chlorides are the most commonly used products for dust suppression in unbound road surfacings. These compounds, which contain chloride salts, can be mixed with other ingredients and are applied either in a liquid or solid state flakes or pellets. Chlorides draw moisture from the air to keep the road surface moist (i.e. hydroscopic) and help resist evaporation of road surface moisture (i.e. deliquescent). By keeping the road surface moist, chlorides reduce the amount of dust generated. Chlorides also facilitate compaction and promote soil stabilization.

Product Suppliers: Cargill Salt, P.O. Box 5621, Minneapolis, MN, 55440-5621, (888) 385-7258, www.cargillsalt.com;
The Dow Chemical Company, P.O. Box 1206, Midland, MI, 48642, (800) 447-4369, www.dow.com; and
Tetra Chemicals, P.O. Box 73087, Houston, TX, 77273, (281) 367-1983, www.tetratec.com.

APPLICATION

Typical Use: Dust suppressant.

Traffic Range: Very Low. Chlorides can be used on unbound road surfacing with higher traffic volumes, but more frequent applications are required.

Restrictions:

Traffic: Required application frequency will increase with increased truck traffic or increased vehicle speed.

Climate: Chlorides are not effective in very arid or very wet climates. $MgCl_2$ requires a relative humidity greater than 32% at 25ºC (77°F) and $CaCl_2$ requires a relative humidity greater than 29% at 25ºC (77°F) to be effective. $CaCl_2$ performs better at higher humidity; $MgCl_2$ performs better during long dry spells. Chlorides can be leached from an unbound surfacing by rainfall, thus requiring frequent reapplication in very wet climates. $CaCl_2$ will not be leached by rainfall as easily as $MgCl_2$.

Weather: Unbound road surfacings, including those treated with chlorides, are very susceptible to adverse weather conditions. They will soften significantly in very wet weather and during periods of thaw. Chlorides can reduce the number of freeze-thaw cycles experienced by a surfacing by reducing the freezing temperature of the moisture contained within the unbound material.

Terrain: Unbound road surfacings treated with chlorides can become slippery when wet and should not be used on road sections with steep grades or tight curves.

Soil Type: Chlorides should be used in conjunction with competent unbound road surfacing materials (e.g. well-graded gravels). A moderate amount of fines is required to facilitate retention of the chlorides (10 to 25% range).

Other: None.

Other Comments: $CaCl_2$ is slightly more effective than $MgCl_2$ at absorbing water and decreasing evaporation. Chlorides can cause corrosion damage to vehicles. Sodium chloride is not as effective as $CaCl_2$ or $MgCl_2$ and is typically only used in cases when other chloride products are not available.

DESIGN

SLC: N/A

Other Design Values: N/A

Base/Subbase Requirements: Unbound road surfacings, including those treated with chloride, should be designed with adequate base and/or subbase support.

Other Comments: Chlorides work best on engineered aggregate surfaces rather than native or uncontrolled, variable materials.

CONSTRUCTION

Availability of Experienced Personnel: Chlorides are a commonly used dust suppressant and experienced contractors are, in general, widely available. Availability may be limited for projects in remote areas. Maintenance crews are used by some agencies for chloride application.

Materials: Chloride additives, which contain chloride salts, can be mixed with other ingredients and are applied either in a liquid or solid state (flakes or pellets). $MgCl_2$ is more readily available in the western United States and $CaCl_2$ is more readily available in the central and eastern United States.

Equipment: Equipment required for chloride application includes: haul vehicles, spreader (for flakes or pellets) or tanker with spray bar (for liquid), grading equipment (i.e. bulldozer or motor grader), water truck (for flakes or pellets), and pneumatic tire roller. Equipment is widely available in urban areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Chlorides are obtained from natural brine deposits or as a byproduct of other manufacturing processes. Flakes or pellets are commonly provided in bulk or in 36 or 45 kg (80 or 100 lb) bags. Liquid chloride solutions are transported by rail car or tanker truck. Pellets have the highest chloride concentration, followed by flakes and liquid solution. As an alternative to sprayed-on or in-place mixing, the chloride additive can be mixed with the unbound surfacing material in a pug mill prior to placement.

Placement Process: Chlorides are typically sprayed on. The road surface should be graded to promote drainage and prevent ponding on the road surface that can soften the road surface and underlying subgrade. The top 50 to 100 mm (2 to 4 inches) of the road surface may be scarified and loosened, either with a disc or grading equipment, before chloride application. Scarifying the surface allows the chlorides to penetrate evenly and quickly into the road surface. The unbound surfacing material should be moist prior to chloride application if flakes or pellets are used. The chloride additive is applied uniformly using a spreader for pellets or flakes or a tanker with a spray bar for liquid chloride solutions. A water truck must be used to spray the surface and dissolve all flakes and pellets, when used. Chlorides can be blended with the surfacing material using a disc or grading equipment to improve performance, but is generally not as cost-effective as the sprayed-on application. If the surface is scarified, a pneumatic tire roller should be used to compact the surfacing material after the chloride additive is applied and mixed.

Weather Restrictions: Do not apply chlorides if rain is likely within 24 hours or during periods of prolonged sub-freezing temperatures.

Construction Rate: Chloride application rates can typically be about 3,300 to 5,000 m^2/hr (4,000 to 6,000 yd^2/hr).

Lane Closure Requirements: If the roadway surface is scarified prior to treatment, the roadway lane(s) being treated are closed during construction, so adequate traffic control is needed. The roadway can be opened to traffic as soon as the construction equipment is cleared from the roadway. If the chloride is applied to the surface without scarifying the surface, lane closures are not required.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: Chlorides are commonly used dust suppressants and have been used on roadway projects for more than 50 years; an extensive amount of research, design and construction information, and project experience is available.

Life Expectancy: Life expectancy varies depending on traffic and rainfall. The life expectancy decreases with increasing traffic, vehicle speed, and rainfall. Based on one published survey (Birst and Hough, 1999), $CaCl_2$ is effective for 3 to 6 months (71%) and 6 to 12 months (21%). $MgCl_2$ is effective for 3 to 6 months (33%) and 6 to 12 months (42%). In the majority of the cases, no benefit is seen after one year.

Ride Quality: Chloride additives do not affect initial ride quality of the unbound road surfacing; however, chlorides help to decrease the rate of serviceability loss due to potholes and washboarding by reducing the amount of surface particle loss.

Main Distress / Failure Modes: Rutting, washboarding, potholes, dust.

Preservation Needs: All unbound road surfacings should be inspected on a regular basis and maintenance undertaken as appropriate. Periodic grading can correct surface rutting. Regrading can be difficult due to flaking of the treated surfacing.

SAFETY

Hazards: During construction, exposure to chlorides can cause skin and eye irritation. Loose aggregate chips can create a windshield hazard.

Skid Resistance: Unbound road surfacings generally have poor to average skid resistance. Unbound road surfacings treated with chlorides can become slippery when wet

Road Striping Possible?: No.

Other Comments: Chlorides can increase visibility by reducing dust generation by 50% or more.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Chlorides are obtained from natural brine deposits or as a byproduct of other manufacturing processes.

Delivery and Haul Requirements: Chlorides must be hauled from the nearest manufacturer or supplier. Chlorides are generally widely available; however, haul distances may be significant for remote sites. $MgCl_2$ is more readily available in the western United States and $CaCl_2$ is more readily available in the central and eastern United States.

Potential Short-Term Construction Impacts: Chlorides act as a defoliant and may impact vegetation adjacent to the roadway during construction.

Potential Long-Term Environmental Impacts:

Leachate: There is a potential for leaching of chlorides from the road surface in moderate to heavy rains.

Surface Runoff: The amount of surface runoff will be determined by the unbound surfacing material and will not be significantly affected by the chlorides.

Erosion: Chlorides will reduce the amount of erosion compared to an untreated unbound surfacing.

Water quality: Water quality can be impacted by chlorides when leaching occurs unless an adequate buffer zone is provided. Public drinking water standards require chloride levels not to exceed 250 mg/L (PPM). Chlorides should not be used when shallow groundwater conditions exist because it may cause groundwater contamination.

Aquatic species: Chlorides can potentially impact aquatic species if a buffer zone is not provided. A buffer zone of at least 8 m (25 ft.) is recommended between chloride-treated roads and bodies of water. Criteria for protection of aquatic species require levels of less than 600 mg/L (PPM) for chronic exposure and 1200 mg/L (PPM) for short-term exposure. Trout can be affected by concentrations as low as 400 mg/L (PPM).

Plant quality: Chlorides can potentially impact certain plant species; susceptible species include alder, birch, pine, hemlock, larch, poplar, ash, spruce, ornamentals, maple, and numerous species of shrubs and grasses. Chloride use should be restricted within 8 to 9 m (25 to 30 ft.) of susceptible vegetation.

Air Quality: Chlorides reduce dust generation by 50% or more.

Other: Chlorides can initiate corrosive effects in steel and aluminum alloys.

Ability to Recycle/Reuse: Chloride-treated roadway materials can be fully recycled as a pavement construction material. Potential environmental impacts should be considered prior to reuse of chloride-treated materials.

Other Environmental Considerations: Heat is generated by mixing $CaCl_2$ flakes or pellets with water. For unbound road surfacings, tire/road noise depends on the gradation and surface roughness, but is generally high.

AESTHETICS

Appearance: Chlorides do not significantly alter the appearance of the road surfacing, which will be determined by the unbound surfacing aggregate type and source; however, chlorides may darken the appearance of the surfacing. The surfacing may also appear mottled or blotchy due to segregated fines absorbing more of the chlorides.

Appearance Degradation Over Time: All unbound road surfacing deteriorate over time. Chlorides do not affect the change in appearance over time.

COST

Supply Price: $360 to $450/Mg ($400 to $500/ton).

Supply+Install Price: $0.30 to $0.60/$m^2$ ($0.25 to $0.50/$yd^2$) for surface treatment.

EXAMPLE PROJECTS

Buenos Aires National Wildlife Refuge, AZ.
Deschutes National Forest, OR.
Winema National Forest, OR.

SELECT RESOURCES

Birst, S., and Hough, J. (1999). *Chemical Additive Usage on Unpaved Roads in Mountain Plains States*, UGPTI Department Publication No. 130, Upper Great Plains Transportation Institute, North Dakota State University, 119 pp.

USDA Forest Service (1999), *Dust Palliative Selection and Application Guide*, San Dimas Technology and Development Center, 23 pp.

CLAY ADDITIVES

GENERAL INFORMATION

Generic Name(s): Clay Additives, Clay Filler, Bentonite, Montmorillonite

Trade Names: Central Oregon Bentonite, Pelbron, Stabilite, Volclay, and others.

Product Description: Clay additives are naturally occurring soils composed of the mineral montmorillonite. Montmorillonite is a highly plastic clay mineral with a high affinity for water. Clay additives are typically used to stabilize nonplastic crushed aggregates; the cohesive properties of the clay additive help to bind the aggregate particles and prevent raveling and washboarding. The clay additive will also attach to fines in the aggregate mix to reduce fugitive dust. Some dust is still to be expected with clay-stabilized aggregates, so additional dust suppressants are also used in conjunction with the clay additive when dust is an important concern.

Product Suppliers: American Colloid Company, 1500 West Shure Drive, Arlington Heights, IL 60004, (800) 426-5564, www.colloid.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and clay additive products are available.

APPLICATION

Typical Use: Dust suppressant, soil stabilizer.

Traffic Range: Very Low to Low (AADT < 250). Above this traffic range, the surface will require more frequent product mixing and surface grading.

Restrictions:

Traffic: None.

Climate: None; however, wet and/or cold climates will lead to more rapid deterioration and more frequent maintenance requirements.

Weather: Clay-stabilized aggregate roads are very susceptible to adverse weather conditions. They can quickly become impassable in very wet weather and, in areas subject to freezing temperatures, will soften significantly during thaw periods.

Terrain: None.

Soil Type: The effectiveness of clay additives is affected by the aggregate mineralogy; negatively charged montmorillonite will adhere well to limestone, but will be repelled by a negatively charged igneous rock aggregate. Clay additives generally provide no benefit for high plasticity soils or soils with more than 20% to 30% fines.

Other: None.

Other Comments: None.

DESIGN

SLC: 0.10 to 0.14.

Other Design Values: None.

Base/Subbase Requirements: The road should be designed as a unbound gravel/aggregate road. The need for a subbase layer will depend on subgrade characteristics and traffic loading.

Other Comments: The road surface should be sloped to promote surface drainage and prevent ponding on the road surface that can promote softening of the treated materials.

CONSTRUCTION

Availability of Experienced Personnel: Clay additive application is relatively straightforward and qualified contractors are, in general, widely available. Maintenance crews often can be used by agencies for clay additive applications.

Materials: Clay additives are naturally occurring soils composed of the mineral montmorillonite. Material is mined from sources in the northwestern United States and Mississippi. Clay additives can be applied in a dry form or as a slurry.

Equipment: Equipment required for clay additive application includes: tanker or water truck with spray bar, grading equipment (i.e. bulldozer or motor grader), and roller. A pugmill can be used to achieve more uniform mixing. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Thorough mixing is required to create a uniform mixture. The clay additive can be mixed with the aggregate in a pugmill (results in most uniform mixture) or in-place using a pulverizer, disc, or blade mixing.

Placement Process: For new construction projects where the aggregate must be hauled to the site, the clay additive (dry) should be thoroughly mixed with the aggregate in a pugmill before the aggregate is shipped to the site. This method provides the most uniform mixing. Alternatively, If the aggregate is in place, the aggregate should be loosened to the desired treatment depth. The clay additive is then applied uniformly to the loosened aggregate surface. If the additive is applied in dry form, a spreader is used; if the additive is applied in slurry form, a spray truck is used. Once applied, the clay additive is mixed with the aggregate using a pulverizer, disc, or by blade mixing. For the dry additive, a water truck is used to wet the mixture; water is provided to get the material to an optimum moisture content for compaction. Soda ash (dispersing agent) can be added to the water to reduce clumping when higher percentages (greater than 5%) of clay additive are applied. Once mixed, the treated material is graded and compacted.

Weather Restrictions: Avoid construction during rain or snow events and when the subgrade is saturated or frozen.

Construction Rate: Clay additive construction rates are in the range of 2,000 to 5,000 m^2/day (2,400 to 6,000 yd^2/day) for a mixing depth of 100 mm (4 in.).

Lane Closure Requirements: The roadway lane should be closed during construction, but can be opened to traffic once construction is complete.

Other Comments: The required application rate will vary based on the characteristics of the material to be treated and the degree of stabilization desired. Test sections are recommended to determine/verify the appropriate application rate.

SERVICEABILITY

Reliability and Performance History: Clay additives are commonly used in some regions of the United States, but not in other areas; limited research, design and construction information, and documented project experience are available.

Life Expectancy: Life expectancy varies depending on traffic and weather conditions. Typical life expectancy is 2 to 4 years. Life expectancy could be longer if routine maintenance is performed.

Ride Quality: Ride quality depends on the aggregate used for surface material. Clay additives do not provide any improvement in ride quality; however, clay additives can reduce the rate of deterioration over the serviceable life. By reducing particle loss and washboarding, surface distress is reduced and ride quality is preserved.

Main Distress / Failure Modes: Rutting, washboarding, potholes, raveling

Preservation Needs: Periodic grading/reshaping/compaction and localized repair may be required, typically every 3 to 6 months. Regrading does not negatively affect the clay additive's performance.

SAFETY

Hazards: Clay additives can contain a small amount of crystalline silica (typically 1% to 3%); crystalline silica dust can be an inhalation hazard for construction crews. Proper construction practices and engineering controls should be utilized to minimize exposure risks.

Skid Resistance: Excessive quantities of clay additives in a treated aggregate or a wet climate can cause roads stabilized with clay additives to become slippery. No noticeable change in skid resistance was noticed in a study where the clay additive application rate was varied between 3% and 12%.

Road Striping Possible?: No.

Other Comments: Clay additives can typically reduce road dust by 20% (1.5% clay additive treatment) to 70% (9% clay additive treatment). Studies have shown that clay additives can reduce road dust by 60% to 70% the first year, 40% to 50% the second year, and 20% to 30% the third year. In some cases, the driving public may not perceive any reduction in road dust generation because the improvement is not as dramatic as the dust reduction associated with some other dust control products. Clay additives can reduce the amount of flying aggregate particles by binding the surface particles.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Clay additives are naturally occurring materials that are mined for commercial use.

Delivery and Haul Requirements: Clay additives must be transported to the site from the distributor. Haul distances may be significant for remote sites.

Potential Short-Term Construction Impacts: Construction process can damage vegetation adjacent to the road, but off-site impacts can be mitigated by careful application.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Clay additives can reduce the permeability of the surface material and, thus promote more surface runoff. However, surface runoff water quality is not generally impacted by clay additives.

Erosion: Clay additives reduce the erodibility of the unbound roadway surface by binding surface particles together.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: The treated aggregate can be reused as an aggregate for appropriate applications, considering the modified properties and gradation of the treated material.

Other Environmental Considerations: Clay additives are natural materials, and therefore are typically nontoxic, nonhazardous, noncorrosive, and generally environmentally friendly.

AESTHETICS

Appearance: The addition of clay additives does not significantly alter the appearance of an aggregate road. The appearance will be of an aggregate surface with the overall color determined by the aggregate type and source.

Appearance Degradation Over Time: Without maintenance, clay-treated aggregate roads deteriorate over time in terms of surface uniformity.

COST
Supply Price: $145 to $181/Mg ($160 to $200/ton). **Supply+Install Price**: $10.60 to $14.10/$m^3$ ($8.10 to $10.80/$yd^3$) for an aggregate stabilized with clay.
EXAMPLE PROJECTS
Minutemen Missile Access Roads in Colorado, Montana, Nebraska, and Wyoming.
SELECT RESOURCES
Bergeson, K.L., and Brocka, S.G. (1996). "Bentonite Treatment for Fugitive Dust Control," Proceedings of the 1996 Semisesquicentennial Transportation Conference, Ames, IA.

ELECTROLYTE EMULSIONS

GENERAL INFORMATION

Generic Name(s): Electrolyte Stabilizers, Ionic Stabilizers, Sulfonated Oils, Electrochemical Stabilizers, Acids

Trade Names: CBR Plus, Condor SS, Road Bond EN-1, SA-44 System, Terrabond Clay Stabilizer, Terrastone, and others.

Product Description: Many of the emulsions for dust suppression and/or soil stabilization are proprietary in nature and the exact composition and stabilization mechanisms are not publicly available; therefore, it is often difficult to group or classify the various emulsions accurately.

Electrolyte emulsions contain chemicals that affect the electro-chemical bonding characteristics of soils and replace water molecules within the soil structure. The treated soil loses its affinity for water. When applied at low application rates to the surface of the unbound road surface, electrolyte emulsions perform well for dust suppression. They bond soil particles together and so reduce dust generation. At higher application rates, electrolyte emulsions can be used to stabilize soils. When applied and compacted properly, the treated soil can be stabilized to form a firm to hard bound layer that can be used as a road surfacing.

Most of the information available on electrolyte emulsions comes from brochures and literature provided by the manufacturer. Therefore, it may be difficult to find independent test information for a particular product. The performance and applicability of electrolyte emulsions can vary from one product to the next. In addition, products are frequently reformulated; so, historical case studies may no longer be representative of a current product. As a result, product specific testing and/or performance verification is recommended when selecting an electrolyte emulsion.

Product Suppliers: CBR Plus North America, 580 Hornby Street, Suite 640, Vancouver, BC Canada, V6C3B6, (604) 683-0430, www.cbrplus.com; and

C.S.S. Technology, Inc., P.O. Box 1618, Granbury, TX 76048, (817) 279-1136, www.csstech.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and electrolyte emulsion products are available.

APPLICATION

Typical Use: Dust suppressant, soil stabilizer.

Traffic Range: Very Low to Low (AADT < 250).

Restrictions:

Traffic: Required application frequency will increase with increased truck traffic or increased vehicle speed. Additional traffic loading restrictions may be required depending on the material being treated (e.g. the load-carrying capacity of a clay soil is typically much less than that of a granular material).

Climate: None.

Weather: Minor grading/reshaping and localized repair may be required after heavy rainfalls.

Terrain: None.

Soil Type: Categorically speaking, electrolyte emulsions work on a variety of soils as long as a minimum amount of clay particles are present (greater than 10%) and the plasticity index is greater than 10. Electrolyte emulsions generally work best on soils with 10% to 20% clay, but are effective on soils with higher clay contents as well.

Other: None.

Other Comments: None.

DESIGN

SLC: N/A for dust suppression applications; typically 0.08 to 0.14 (increases with increased quality of treated material) for stabilization applications.

Other Design Values: Electrolyte emulsions can increase the soil strength by 30% to 50%, in terms of CBR, for example. Stabilized natural soil road surfacings are for very low traffic applications, and generally are designed empirically and are not subject to structural analysis.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support. In cases where natural soils are stabilized in situ, no subbase layer is provided.

Other Comments: The road surface should be graded to promote surface drainage and prevent ponding on the road surface that can promote softening of the treated materials.

CONSTRUCTION

Availability of Experienced Personnel: Electrolyte emulsions are a commonly used dust suppressant and soil stabilizer and experienced contractors are, in general, widely available. Maintenance crews are used by some agencies for spray-on applications.

Materials: Electrolyte emulsion products are typically purchased in liquid concentrate form. Water is required to dilute the electrolyte concentrate once it is delivered to the site.

Equipment: Equipment required for electrolyte emulsion application includes: tanker or water truck with spray bar, grading equipment (i.e. bulldozer or motor grader), and roller. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Electrolyte concentrate must be mixed with water to achieve the desired concentration level prior to application. Dilution ratios of 1 part electrolyte concentrate mixed with 100 to 600 parts water or more are common.

Placement Process: Electrolyte emulsions can be applied by a sprayed-on method or mixed-in method, but mixed-in method is most common. Recommended mixing depth for dust suppression and stabilization ranges from 25 to 50 mm (1 to 2 in.) and 100 to 200 mm (4 to 8 in.), respectively. The moisture content of the soil prior to treatment should be below optimum for compaction so that the soil moisture content will be near optimum once the electrolyte emulsion is added, considering the water provided by the emulsion; if the material is very dry or saturated, processing to achieve moisture content adjustments is recommended prior to treatment. For dust suppression applications, scarifying the surface allows the electrolyte emulsion to penetrate evenly and quickly into the road surface. For soil stabilization applications, the soil is loosened to the desired treatment depth. The electrolyte emulsion is then applied uniformly using a tanker or water truck with a spray bar and mixed with the loose soil. The electrolyte emulsion is often applied in multiple passes to get better overall mixing. Once mixed, the treated material is graded and compacted.

Weather Restrictions: Do not apply electrolyte emulsions if is raining or if temperatures are below freezing.

Construction Rate: Electrolyte emulsion application rates are in the range of 2,000 to 5,000 m^2/day (2,400 to 6,000 yd^2/day).

Lane Closure Requirements: The roadway lane should be closed during construction, but can be opened to traffic once construction is complete.

Other Comments: The required application rate will vary based on the characteristics of the material to be treated and the degree of stabilization desired. Test sections are recommended to determine/verify the appropriate application rate.

SERVICEABILITY

Reliability and Performance History: Electrolyte emulsions are a common dust suppressant and soil stabilizer and were initially developed more than 40 years ago. Research, design and construction information, and project experience are available. Performance can vary significantly between different products and is influenced by traffic, soil type, weather conditions, application method and rate, and contractor performance. As a result, product specific testing and/or performance verification is recommended when selecting an electrolyte emulsion.

Life Expectancy: Life expectancy varies depending on traffic and weather conditions. Typical life expectancy is 3 to 5 years for stabilization applications, with some treated surfaces still in service after 15 years or more. Electrolyte emulsions do not leach from the soil; therefore, the treatment is "permanent", in theory. When an effective electrolyte emulsion product is applied in the proper situation, constructed properly, and maintained, good performance and long life expectancies are realized.

Ride Quality: Ride quality depends on the treated aggregate. Ride quality deteriorates over the serviceable life. Electrolyte emulsions do not provide any improvement in ride quality; however, the rate of deterioration is less than the rate for untreated surfaces. By reducing particle loss and washboarding, surface distress is reduced and ride quality is preserved. Electrolyte emulsions can reduce aggregate loss by 50% or more.

Main Distress / Failure Modes: Dust, rutting, washboarding, potholes.

Preservation Needs: Periodic grading may be required, typically every 6 months to 1 year. For dust suppression applications, grading should be performed in a manner such that the stabilized "surface crust" is not broken.

SAFETY

Hazards: Some electrolyte products are highly acidic in their concentrated form. Proper handling and mixing procedures should be followed when mixing the concentrated liquid with water to create an emulsion.

Skid Resistance: Electrolyte emulsion-treated materials form a firm to hard, skid resistant surface.

Road Striping Possible?: No.

Other Comments: Electrolyte emulsions can typically reduce road dust by 60% to 80%.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Electrolyte emulsions are typically byproducts or intermediate products of various manufacturing processes. Sulfonated D-limonene and sulfonated naphthalene are two of the chemicals that can be primary components of electrolyte emulsions.

Delivery and Haul Requirements: Electrolyte concentrate must be hauled to the site from the distributor. Haul distances may be significant for remote sites. Hauling requirements are reduced somewhat by the fact that the product is shipped in concentrated form and can be mixed with water at the site.

Potential Short-Term Construction Impacts: Spills or runoff during the emulsion mixing process could have a negative impact on nearby vegetation, water quality, or aquatic species.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Electrolyte emulsion-treated soil is relatively impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by electrolyte emulsion treatments.

Erosion: Electrolyte emulsions reduce the erodibility of the unbound roadway surface by binding surface particles together.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: The treated soil/aggregate can be reused in any manner similar to the untreated material.

Other Environmental Considerations: Environmental impacts of electrolyte emulsions may vary between different proprietary products; specific product information should be collected and reviewed prior to product use. Once diluted to normal application rates, electrolyte emulsions are typically nontoxic, nonhazardous, noncorrosive, and generally environmentally friendly.

AESTHETICS

Appearance: The addition of electrolyte emulsion does not significantly alter the appearance of a soil or aggregate road. The appearance will be of a soil/aggregate surface with the overall color determined by the soil/aggregate type and source. The treated soil /aggregate will have a slightly darker appearance than the parent material.

Appearance Degradation Over Time: Without maintenance, electrolyte emulsion-treated roads deteriorate over time in terms of surface uniformity.

COST

Supply Price: N/A

Supply+Install Price: \$0.40 to \$0.80/m^2 (\$0.35 to \$0.70/yd^2).

EXAMPLE PROJECTS

City of Calgary, Canada.
Ozark National Forest, AR.

SELECT RESOURCES

Scholen, Douglas E. (1992). Non-Standard Stabilizers, FHWA-FLP-92-011, U.S. Department of Transportation, Washington, D.C., 113 pp.

USDA Forest Service (1999), *Dust Palliative Selection and Application Guide*, San Dimas Technology and Development Center, 23 pp.

ENZYMATIC EMULSIONS

GENERAL INFORMATION

Generic Name(s): Enzymatic Emulsions, Enzymes

Trade Names: Bio Cat 300-1, EMC SQUARED, Perma-Zyme 11X, Terrazyme, UBIX No. 0010, and others.

Product Description: Many of the emulsions for dust suppression and/or soil stabilization are proprietary in nature and the exact composition and stabilization mechanisms are not publicly available; therefore, it is often difficult to group or classify the various emulsions accurately.

Enzymatic emulsions contain enzymes (protein molecules) that react with soil molecules to form a cementing bond that stabilizes the soil structure and reduces the soil's affinity for water. Categorically speaking, enzymatic emulsions work on a variety of soils as long as a minimum amount of clay particles are present. When applied at low application rates to the surface of the unbound road surface, enzymatic emulsions perform well for dust suppression. They bond soil particles together and so reduce dust generation. At higher application rates, enzymatic emulsions can be used to stabilize soils. When applied and compacted properly, the treated soil can be stabilized to form a dense, firm to hard, water-resistant bound layer that can be used as a road surfacing.

Most of the information available on enzymatic emulsions comes from brochures and literature provided by the manufacturer. Therefore, it may be difficult to find independent test information for a particular product. The performance and applicability of enzymatic emulsions can vary from one product to the next. In addition, products are frequently reformulated; so, historical case studies may no longer be representative of a current product. As a result, product specific testing and/or performance verification is recommended when selecting an enzymatic emulsion.

Product Suppliers: C.S.S. Technology, Inc., P.O. Box 1618, Granbury, TX 76048, (817) 279-1136, www.csstech.com; and

Enfra LLC, 13521 Tea House Street, Santa Ana, CA 92705, (714) 397-4076, www.permazymeusa.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and enzymatic emulsion products are available.

APPLICATION

Typical Use: Dust suppressant, soil stabilizer.

Traffic Range: Very Low to Low (AADT < 250).

Restrictions:

Traffic: Required application frequency will increase with increased truck traffic or increased vehicle speed. Additional traffic loading restrictions may be required depending on the material being treated (e.g. the load-carrying capacity of a clay soil is typically much less than that of a granular material).

Climate: None.

Weather: Enzymatic emulsion-treated surfaces can become slippery when wet, particularly with soils with high clay content (greater than 20% or 30%). Minor grading/reshaping and localized repair may be required after heavy rainfalls.

Terrain: None.

Soil Type: Categorically speaking, enzymatic emulsions work on a variety of soils as long as a minimum amount of clay particles are present (greater than 10%) and the plasticity index is greater than 8. Enzymatic emulsions generally work best on soils with 12% to 24% clay, plasticity index between 8 and 35. Enzymatic emulsions work best when the moisture content is 2% to 3% below optimum moisture content for compaction.

Other: None.

Other Comments: None.

DESIGN

SLC: N/A for dust suppression applications; typically 0.08 to 0.14 (increases with increased quality of treated material) for stabilization applications.

Other Design Values: Enzymatic emulsions can increase the soil strength by 30% to 300%.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support.

Other Comments: The road surface should be graded to promote surface drainage and prevent ponding on the road surface that can promote softening of the treated materials.

CONSTRUCTION

Availability of Experienced Personnel: Enzymatic emulsions are not as commonly used as some other dust suppressant and soil stabilizer products, but experienced contractors are, in general, available.

Materials: Enzymatic emulsion products are typically purchased in liquid concentrate form. Water is required to dilute the enzymatic concentrate once it is delivered to the site.

Equipment: Equipment required for enzymatic emulsion application includes: tanker or water truck with spray bar, grading equipment (i.e. bulldozer or motor grader), and roller. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Enzymatic concentrate must be mixed with water to achieve the desired concentration level prior to application. Dilution ratios of 1 part enzymatic concentrate mixed with 100 to 500 parts water are common.

Placement Process: Enzymatic emulsions can be applied by a sprayed-on method or mixed-in (windrowing) method, but mixed-in method is most common. Recommended mixing depths for dust suppression and stabilization range from 25 to 50 mm (1 to 2 in.) and 100 to 200 mm (4 to 8 in.), respectively. The moisture content of the soil prior to treatment should be below optimum for compaction so that the soil moisture content will be below or near optimum once the enzymatic emulsion is added, considering the water provided by the emulsion; if the material is very dry or saturated, processing to achieve moisture content adjustments is recommended prior to treatment. For dust suppression applications, scarifying the surface allows the enzymatic emulsion to penetrate evenly and quickly into the road surface. For soil stabilization applications, the soil is loosened to the desired treatment depth. The enzymatic emulsion is then applied uniformly using a tanker or water truck with a spray bar and mixed with the loose soil. The enzymatic emulsion is often applied in multiple passes to get better overall mixing. Once mixed in place, the treated material is graded and compacted.

Weather Restrictions: Do not apply enzymatic emulsions if rain is likely within 24 hours or if temperatures are below 4 °C (40 °F) or 16 °C (60 °F), depending on the product used.

Construction Rate: Enzymatic emulsion construction rates are in the range of 2,000 to 5,000 m^2/day (2,400 to 6,000 yd^2/day).

Lane Closure Requirements: The roadway lane should be closed during construction, but can be opened to light traffic once construction is complete. The stabilized material should be allowed to cure for 2 to 3 days before normal traffic, including heavy loads, are allowed onto the surface.

Other Comments: The required application rate will vary based on the characteristics of the material to be treated and the degree of stabilization desired. Test sections are recommended to determine/verify the appropriate application rate.

SERVICEABILITY

Reliability and Performance History: Enzymatic emulsions are still relatively new compared to some other commonly used dust suppressant and soil stabilizer products. Limited research, design and construction information, and project experience are available. Performance can vary significantly between different products and is influenced by traffic, soil type, weather conditions, application method and rate, and contractor performance. As a result, product specific testing and/or performance verification is recommended when selecting an enzymatic emulsion.

Life Expectancy: Life expectancy varies depending on traffic and weather conditions. Typical life expectancy is 5 to 7 years for stabilization applications, with some treated surfaces still in service after 12 years or more. When an effective enzymatic emulsion product is applied in the proper situation, constructed properly, and maintained, good performance and long life expectancies are realized.

Ride Quality: Ride quality depends on the treated aggregate. Ride quality deteriorates over the serviceable life. Enzymatic emulsions do not provide any improvement in ride quality; however, the rate of deterioration is less than the rate for untreated surfaces. By reducing particle loss and washboarding, surface distress is reduced and ride quality is preserved. Enzymatic emulsions can reduce aggregate loss by 50% or more.

Main Distress / Failure Modes: Dust, rutting, washboarding, potholes.

Preservation Needs: Periodic grading may be required, typically every 1 year and possibly after heavy rainfalls. For dust suppression applications, grading should be performed in a manner such that the stabilized "surface crust" is not broken. For soil stabilization applications, additional sprayed-on applications may be required periodically to extend the serviceable life.

SAFETY

Hazards: Proper handling and mixing procedures should be followed when mixing the concentrated liquid with water to create an emulsion.

Skid Resistance: Enzymatic emulsion-treated materials form a firm to hard, skid resistant surface. However, the road can become slippery when wet when the surface contains high clay content (greater than 20% or 30% clay).

Road Striping Possible?: No.

Other Comments: Enzymatic emulsions can typically reduce road dust by a significant amount.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Enzymes are natural materials that are manufactured from natural materials or obtained as byproducts of the food processing and manufacturing industries.

Delivery and Haul Requirements: Enzymatic concentrate must be hauled to the site from the distributor. Haul distances may be significant for remote sites. Hauling requirements are reduced somewhat by the fact that the product is shipped in concentrated form and can be mixed with water at the site.

Potential Short-Term Construction Impacts: Spills or runoff during the emulsion mixing process could have a negative impact on nearby vegetation, water quality, or aquatic species.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Enzymatic emulsion-treated soil is relatively impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by enzymatic emulsion treatments

Erosion: Enzymatic emulsions reduce the erodibility of the unbound roadway surface by binding surface particles together.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: The treated soil/aggregate can be reused in any manner similar to the untreated material.

Other Environmental Considerations: Environmental impacts of enzymatic emulsions may vary between different proprietary products; specific product information should be collected and reviewed prior to product use. Once diluted to normal application rates, enzymatic emulsions are typically biodegradable, nontoxic, nonhazardous, noncorrosive, and generally environmentally friendly.

AESTHETICS

Appearance: The addition of enzymatic emulsion does not significantly alter the appearance of a soil or aggregate road. The appearance will be of a soil/aggregate surface with the overall color determined by the soil/aggregate type and source. The treated soil /aggregate will have a slightly darker appearance than the parent material.

Appearance Degradation Over Time: Without maintenance, enzymatic emulsion-treated roads deteriorate over time in terms of surface uniformity.

COST

Supply Price: N/A

Supply+Install Price: \$2.40 to \$4.80/m^2 (\$2.00 to \$4.00/yd^2) for mixing to a depth of 150 mm (6 in.).

EXAMPLE PROJECTS

Laguna Atascosa National Wildlife Refuge, Rio Hondo, TX.
Auto Tour Roads, Buenos Aires National Wildlife Refuge, Pima County, AZ.

SELECT RESOURCES

Scholen, Douglas E. (1992). Non-Standard Stabilizers, FHWA-FLP-92-011, U.S. Department of Transportation, Washington, D.C., 113 pp.

USDA Forest Service (1999), *Dust Palliative Selection and Application Guide*, San Dimas Technology and Development Center, 23 pp.

LIGNOSULFONATES

GENERAL INFORMATION

Generic Name(s): Lignosulfonates, Lignin, Lignin Sulfate, Lignin Sulfides

Trade Names: Dustac, RB Ultra Plus, Polybinder, DC-22, Calbinder, and others.

Product Description: Lignosulfonates are derived from the lignin that naturally binds cellulose fibers together to give trees firmness. They have cementitious properties that bind the road surface particles together. Lignosulfonates also draw moisture from the air to keep the road surface moist (i.e. hydroscopic). When applied at low application rates to the top 25 mm (1 in.) of an unbound road surfacing, lignosulfonates are well suited for dust suppression because they bond soil particles together and help to maintain a moist road surface, and so reduce dust generation. At higher application rates and deep mixing, typically 100 to 200 mm (4 to 8 in.), lignosulfonates can be used to stabilize subgrade or base materials containing fines. Lignosulfonates increase the compressive strength and load bearing capacity of the treated material, bind materials to reduce particle loss, and provide a firm to hard dust-free surface.

Product Suppliers: Representative list of manufacturers and suppliers can be obtained from: Lignin Institute, 5775 Peachtree-Dunwoody Road, Suite 500-G, Atlanta, GA 30342, (404) 252-3663, www.lignin.info.

APPLICATION

Typical Use: Dust suppressant, soil stabilizer.

Traffic Range: Very Low to Low (AADT < 250).

Restrictions:

Traffic: Required application frequency will increase with increased truck traffic or increased vehicle speed. Additional traffic loading restrictions may be required depending on the material being treated (e.g. the load-carrying capacity of a clay soil is typically much less than that of a sand or gravel).

Climate: Lignosulfonates work best in arid to moderate precipitation areas; they perform poorly in extremely wet regions.

Weather: Lignosulfonate-treated surfaces can become slippery when wet, particularly with soils with high fines content or plasticity. Minor grading/reshaping and localized repair may be required after heavy rainfalls.

Terrain: Because lignosulfonate-treated surfaces can become slippery when wet, they are not recommended for areas with steep terrain and regular precipitation.

Soil Type: Lignosulfonates can be used for a variety of soil types, but are most cost effective for soils having 8% to 30% fines and a plasticity index greater than 8. They do not work as well for sandy soils; permeable soils allow rapid leaching of product. For soils with high clay contents, the treated soils tend to remain slightly plastic, permitting reshaping and additional compaction under vehicle loads. Some studies have shown little to no improvement for soils with a high plasticity index (i.e. greater than 20).

Other: None.

Other Comments: None.

DESIGN

SLC: N/A for dust suppression applications; typically 0.08 to 0.14 (increases with increased quality of treated material) for stabilization applications.

Other Design Values: Lignosulfonates can increase the dry strength of soils by a factor of 2 or 3.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support.

Other Comments: The road surface should be graded to promote surface drainage and prevent ponding on the road surface that can promote leaching and softening of the treated materials. For soil stabilization applications, a thin asphalt surface treatment (e.g. chip seal) can be placed on top of the stabilized layer to reduce surface water infiltration into the stabilized material and, thus, reducing leaching of the lignosulfonates.

CONSTRUCTION

Availability of Experienced Personnel: Lignosulfonates are a commonly used dust suppressant and soil stabilizer and experienced contractors are, in general, widely available. Maintenance crews are used by some agencies for spray-on applications.

Materials: Lignosulfonates are a waste by-product of the pulp and paper industry. The main component of lignosulfonates is lignin, which comes from trees. Lignosulfonates can be purchased in liquid concentrate or dry powder form. Water is required to dilute the lignosulfonate once it is delivered to the site.

Equipment: Equipment required for lignosulfonate application includes: tanker or water truck with spray bar, grading equipment (i.e. bulldozer or motor grader), and steel drum vibratory roller. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Lignosulfonates must be mixed with water to achieve the desired concentration level prior to application.

Placement Process: When used for dust suppression, lignosulfonates can be applied by a sprayed-on method or mixed-in method, with mixed-in being more effective, but more costly. When used for soil stabilization, the mixed-in method is used. Recommended mixing depth for dust suppression and stabilization ranges from 25 to 50 mm (1 to 2 in.) and 100 to 200 mm (4 to 8 in.), respectively. The moisture content of the soil prior to treatment should be close to optimum for compaction; if the material is very dry or saturated, processing to achieve moisture content adjustments is recommended prior to treatment. For dust suppression applications, scarifying the surface allows the lignosulfonates to penetrate evenly and quickly into the road surface. For soil stabilization applications, the soil is loosened to the desired treatment depth. The lignosulfonate is then applied uniformly using a tanker or water truck with a spray bar and mixed with the loose soil. The lignosulfonate is often applied in multiple passes to get better overall mixing. Once mixed, the treated material is graded and compacted.

Weather Restrictions: Do not apply lignosulfonates if rain is likely within 24 hours or if the soil/aggregate is frozen.

Construction Rate: Lignosulfonate application rates are in the range of 3,300 to 5,000 m^2/hr (4,000 to 6,000 yd^2/hr). for spray-on applications.

Lane Closure Requirements: For spray-on applications, the road may remain open during application, although it is preferable to allow some time for the lignosulfonate to infiltrate into the surface material. For mixed-in applications, the lane should be closed during construction, but can be opened to traffic once construction is complete.

Other Comments: The required application rate will vary based on the characteristics of the material to be treated and the degree of stabilization desired. Higher application rates are needed for higher clay contents. Multiple applications are often required to obtain the desired performance. Test sections are recommended to determine/verify the appropriate application rate.

SERVICEABILITY

Reliability and Performance History: Lignosulfonate is a very common dust suppressant and soil stabilizer and has been used on projects for more than 50 years. Research, design and construction information, and project experience are available. Performance can vary significantly based on traffic, soil type, weather conditions, application method and rate, contractor performance, and manufacturer.

Life Expectancy: Life expectancy varies depending on traffic and rainfall. Typical life expectancy can range from several months to more than a year for dust suppressant applications and 3 to 5 years for stabilization applications.

Ride Quality: Ride quality depends on the material being stabilized. Lignosulfonates do not provide any improvement in ride quality; however, they can reduce the rate of deterioration over the serviceable life. By reducing particle loss and washboarding, surface distress is reduced and ride quality is preserved. Lignosulfonates can reduce aggregate loss by 50% or more.

Main Distress / Failure Modes: Dust, rutting, washboarding, potholes.

Preservation Needs: For dust suppressant applications, little to no preventative maintenance is required due to the short life expectancy. For soil stabilization applications, additional sprayed-on lignosulfonate applications may be required periodically, yearly to several times per year. Periodic patching or road grading may also be required. For mixed-in applications, regrading should not reduce lignosulfonate effectiveness.

SAFETY

Hazards: Concentrated lignosulfonate is corrosive to aluminum due to its acidity.

Skid Resistance: When dry, lignosulfonate-treated materials form a firm to hard, skid resistant surface. However, the surface can become slippery when wet, particularly with soils with high fines content or plasticity.

Road Striping Possible?: No.

Other Comments: Lignosulfonates can typically reduce road dust by more than 50%.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Lignosulfonates are a waste byproduct of the paper pulp industry. The main component of lignosulfonates is lignin, which comes from trees.

Delivery and Haul Requirements: Lignosulfonate products must be hauled to the site from the distributor. Haul distances may be significant for remote sites. Delivery and haul requirements will vary depending on whether the lignosulfonate is purchased in liquid concentrate or dry powder form.

Potential Short-Term Construction Impacts: Spills or runoff into surface water or infiltration into groundwater during construction can lower dissolved oxygen levels, possibly resulting in fish kills or increases in groundwater concentrations of iron, sulfur compounds, and other pollutants.

Potential Long-Term Environmental Impacts:

Leachate: Lignosulfonates are water soluble, so products can be leached from the road surface, particularly during heavy or sustained periods of rainfall.

Surface Runoff: The percentage of surface runoff versus infiltration into the road surface will vary depending on the treated soil type and gradation.

Erosion: Lignosulfonates reduce the erodibility of the unbound roadway surface by binding surface particles together.

Water quality: Lignosulfonates applied as a dust palliative have a minimal impact on water quality. Lignosulfonates discharged at high-level concentrations into water bodies have been shown to increase the biological oxygen demand (BOD) of the water body. The BOD of small streams may be increased by leaching of lignosulfonates from the road surface.

Aquatic species: At normal application rates, lignosulfonates are not expected to impact aquatic species; however, leaching of lignosulfonates from the road surface during extended heavy rain events may increase the BOD of small streams, which may negatively impact aquatic species.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: With time, the lignosulfonates will degrade or leach from the soil. The treated soil/aggregate can be reused in any manner similar to the untreated material.

Other Environmental Considerations: Environmental impacts of lignosulfonates may vary between different proprietary products; specific product information should be collected and reviewed prior to product use. At normal application rates, lignosulfonates are typically biodegradable, nontoxic, nonhazardous, noncorrosive, and generally environmentally friendly. Few studies are available that document the affects of leaching of surface applied lignosulfonates on the BOD of streams or the rate at which lignosulfates move through soil. Best Management Practices (BMPs) should be employed to prevent lignosulfates from reaching water bodies.

AESTHETICS

Appearance: The addition of lignosulfonate does not significantly alter the appearance of a soil or aggregate road. The appearance will be of a soil/aggregate surface with the overall color determined by the soil/aggregate type and source.

Appearance Degradation Over Time: Without maintenance, lignosulfonate-treated roads deteriorate over time in terms of surface uniformity.

COST

Supply Price: N/A

Supply+Install Price: \$0.30 to \$0.60/m^2 (\$0.25 to \$0.50/yd^2) for surface application (spray-on method).

EXAMPLE PROJECTS

Buenos Aires National Wildlife Refuge, Pima County, AZ.
CR-12/29, Larimer County, CO.

SELECT RESOURCES

Lignin Institute, (404) 252-3663, www.lignin.info
Lunsford, Lt. G.D. and Mahoney, J. (2001). *Dust Control on Low-Volume Roads: A Review of Techniques and Chemicals Used*, Report No. FHWA-LT-01-002, Federal Highway Administration, Washington, D.C., 58 pp.
USDA Forest Service (1999), *Dust Palliative Selection and Application Guide*, San Dimas Technology and Development Center, 23 pp.

ORGANIC PETROLEUM EMULSIONS

GENERAL INFORMATION

Generic Name(s): Organic Petroleum Emulsions, Emulsified Asphalt, Cutback Asphalt, Dust Oil, Bituminous Binder, Prime Coats

Trade Names: CSS-1, MC-70, Fuel Oil, Duo Prime Oil, Asphotac, Coherex, PennSuppress-D, Road Pro, and others.

Product Description: Organic petroleum products include cutback asphalts, asphalt emulsions, modified asphalt emulsions, and emulsified oils. These products can be used for dust suppression or to stabilize soils. These products bind soil particles together due to the adhesive properties of the asphalt component of the products. Organic petroleum products work on a variety of soil types with up to 25 to 30% clay fines and a plasticity index (PI) of less than 10. The penetration depth decreases as the amount of fines increases; therefore, lower viscosity mixtures should be used for soils with fines. The surface can be scarified to increase penetration depth and decrease penetration time. Organic petroleum products can be sprayed on or mixed in, depending on the particular product (most are sprayed on). Several manufacturers recommend that their product be applied in two separate applications. A product specific analysis is needed to determine or verify the product's environmental impact.

Most of the information available on petroleum emulsions comes from brochures and literature provided by the manufacturer. Therefore, it may be difficult to find independent test information for a particular product. The performance and applicability of petroleum emulsions can vary from one product to the next. In addition, products are frequently reformulated; so, historical case studies may no longer be representative of a current product. As a result, product specific testing and/or performance verification is recommended when selecting a petroleum emulsion.

Product Suppliers: Representative list of manufacturers, suppliers, and contractors can be obtained from:
Asphalt Emulsion Manufacturers Association, PMB 250, 3 Church Circle, Annapolis, MD 21401, (410) 267-0023, www.aema.org;
American Refining Group, Inc., 77 North Kendall Ave., Bradford, PA 16701, (814) 368-1200, www.amref.com; and
Midwest Industrial Supply, Inc., P.O. Box 8431, Canton, OH 44711, (800) 321-0699, www.midwestind.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and petroleum emulsion products are available.

APPLICATION

Typical Use: Dust suppressant, soil stabilizer.

Traffic Range: Very Low to Low.

Restrictions:

Traffic: Required application frequency will increase with increased truck traffic or increased vehicle speed.

Climate: None.

Weather: None.

Terrain: None.

Soil Type: Categorically speaking, petroleum emulsions provide effective dust control and soil stabilization on a variety of soils, including sands, silts, and clays. Certain manufacturers may recommend which soil types their product is best suited for. Organic petroleum products work on a variety of soil types with up to 25 to 30% clay fines and a plasticity index (PI) of less than 10.

Other: Surfaces treated with petroleum emulsions are susceptible to damage by snow plowing operations. Well-maintained surfaces are less susceptible to damage than worn surfaces and mixed-in applications are less susceptible than sprayed-on applications.

Other Comments: None.

DESIGN

SLC: N/A for dust suppression applications; 0.10 to 0.25 for soil stabilization. Value will vary with soil type, petroleum emulsion product, and application rate. Laboratory mixing should be performed to determine the strength of the stabilized material. Using laboratory strength testing results, an estimate of the SLC can be made using correlations or engineering judgment.

Other Design Values: None.

Base/Subbase Requirements: Where local soils are stabilized to form a road surfacing, it is unlikely that an imported base or subbase layer will be included.

Other Comments: The road surface should be sloped to promote surface drainage and prevent ponding on the road surface that can promote softening of the treated materials.

CONSTRUCTION

Availability of Experienced Personnel: Contractors experienced in the application of petroleum dust suppressants and soil stabilizers are, in general, widely available.

Materials: Most petroleum emulsions are typically purchased in liquid emulsion form, but are diluted prior to application. Of the emulsified asphalts, SS-1, SS-1h, CSS-1, and CSS-1h are commonly used. Other petroleum emulsion products are composed of oils or petroleum resins. Waste oils should not be used. Cutback asphalts can be used, although there are environmental concerns associated with cutback asphalts.

Cutback Asphalt: Advantages of cutback asphalts include a lower application temperature, 30 to 115 °C (85 to 240 °F), and higher asphalt percentages than emulsified asphalts (approximately 80% compared to approximately 60%). Disadvantages of cutback asphalts include hydrocarbon emissions into the atmosphere during the evaporation process and potential fire hazards during construction due to the use of solvents in the cutback asphalt. Due to environmental concerns, the use of cutback asphalts has been prohibited in some areas.

Emulsified Asphalt: Advantages of emulsified asphalt include cooler application temperature (20 to 85 °C [70 to 185 °F]) than cutback asphalts and the water that evaporates is environmentally safe.

Equipment: Equipment required for petroleum emulsion application includes: tanker or water truck with spray bar, disc or rotary mixer, grading equipment (i.e. bulldozer or motor grader), and roller. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Emulsified or cutback asphalts are mixed at a stationary asphalt plant and shipped to the site. Other petroleum emulsion products are shipped in emulsion form from the supplier. Some products will be diluted with water, at typical dilutions of about 4 parts water to 1 part emulsion.

Placement Process: Petroleum emulsions can be applied by a sprayed-on method or mixed-in method, although most petroleum products are used for dust suppression and are applied by the sprayed-on method. Recommended mixing depths for dust suppression and stabilization ranges from 25 to 50 mm (1 to 2 in.) and 100 to 150 mm (4 to 6 in.), respectively. For dust suppression applications, scarifying the surface allows the petroleum emulsion to penetrate evenly and quickly into the road surface. For soil stabilization applications, the soil is loosened to the desired treatment depth. The petroleum emulsion is then applied uniformly using a tanker or water truck with a spray bar and mixed with the loose soil using a disc, rotary mixer, or blading equipment. The petroleum emulsion is often applied in multiple passes to get better overall mixing. Once mixed, some products require time for the excess water and/or hydrocarbons to evaporate before the material is graded and compacted. Even when the mixed-in method is used, some of the emulsion (up to 40%) is saved for a spray-on application prior to compaction. This spray-on application is applied to ensure that a good crust is formed at the surface.

Weather Restrictions: Weather restrictions can very between products. In general, do not apply petroleum emulsions if rain is likely within 24 hours or if temperatures are below 10 °C (50 °F).

Construction Rate: Petroleum emulsion application rates are in the range of 2,000 to 5,000 m^2/day (2,400 to 6,000 yd^2/day).

Lane Closure Requirements: For sprayed-on applications, the roadway can remain open, although emulsion splash/spray on vehicles can be a problem. For mixed-in applications, the roadway lane should be closed during construction, but can be opened to traffic once construction is completed.

Other Comments: The required dilution and application rates will vary based on the petroleum emulsion product used, characteristics of the material to be treated, and the degree of stabilization desired.

SERVICEABILITY

Reliability and Performance History: Emulsified and cutback asphalts are commonly used products. Research, design and construction information, and project experience are available. For other petroleum emulsion products, the amount of available information varies from product to product. Performance can vary significantly between different products and is influenced by traffic, soil type, weather conditions, application method and rate, and contractor performance. As a result, product specific testing and/or performance verification is recommended when selecting a petroleum emulsion.

Life Expectancy: Life expectancy varies depending on application rate and depth, traffic, and weather conditions. Typical life expectancy is 6 to 9 months for dust suppression applications. Typical life expectancy is 5 to 9 years for stabilization applications.

Ride Quality: Ride quality depends on the material being stabilized. Petroleum emulsions do not provide any improvement in ride quality; however, they can reduce the rate of deterioration over the serviceable life. By reducing particle loss and washboarding, surface distress is reduced and ride quality is preserved. Petroleum emulsions can reduce aggregate loss by 50% or more.

Main Distress / Failure Modes: Dust, cracking, raveling, washboarding, potholes.

Preservation Needs: For soil stabilization applications, additional light sprayed-on applications may be required periodically to extend the serviceable life. The first maintenance application is typically 1 to 1.5 years after initial construction; subsequent applications typically occur every 2 to 3 years. Localized patching and repair work may be required periodically.

SAFETY

Hazards: When cutback asphalts are used, the solvents used can create a health hazard (fumes) and a fire/explosion hazard during construction; proper engineering controls and construction practices should be utilized to minimize safety risks.

Skid Resistance: Petroleum emulsion-treated materials form a firm to hard, skid resistant surface. However, skid resistance is reduced significantly in wet weather.

Road Striping Possible?: No.

Other Comments: Petroleum emulsions can typically reduce road dust by a significant amount. Field tests have shown that particular petroleum emulsion products reduced fugitive dust by at least 50% to 90% after three months, 20% to 40% after six months, and 10% or less after 12 months.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Petroleum emulsions primarily consist of manufactured petroleum products, including asphalt, oils, or petroleum resins.

Delivery and Haul Requirements: Petroleum emulsion must be hauled to the site from the distributor. Haul distances may be significant for remote sites.

Potential Short-Term Construction Impacts: Construction processes may impact vegetation adjacent to the roadway. Hydrocarbon emissions into the atmosphere can be a significant impact if cutback asphalts are used. Spills or runoff during the emulsion mixing process could have a negative impact on nearby vegetation, water quality, or aquatic species. A spill prevention and containment plan should be in place to minimize the potential for off site runoff of spills.

Potential Long-Term Environmental Impacts:

Leachate: None once the petroleum emulsion has cured.

Surface Runoff: Petroleum emulsion-treated soil is relatively impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by petroleum emulsion treatments.

Erosion: Petroleum emulsions reduce the erodibility of the unbound roadway surface by binding surface particles together. Sediment loading in surface runoff water can be reduced by more than 50%.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: The treated soil/aggregate may be reused as a construction material, depending on any environmental concerns related to the emulsion used.

Other Environmental Considerations: Environmental impacts of petroleum emulsions may vary between different proprietary products; specific product information should be collected and reviewed prior to product use. Most petroleum emulsions are typically nontoxic, nonhazardous, noncorrosive, and generally environmentally friendly, although some may contain toxic materials. Some petroleum emulsion products may contain carcinogenic polycyclic aromatic hydrocarbons.

AESTHETICS

Appearance: The addition of petroleum emulsion generally alters the appearance of a soil or aggregate road by changing the color to dark brown or dark gray.

Appearance Degradation Over Time: Without maintenance, petroleum emulsion-treated roads deteriorate over time in terms of surface uniformity.

COST

Supply Price: N/A

Supply+Install Price: \$3.00 to \$4.00/m^2 (\$2.50 to \$3.30/yd^2).

EXAMPLE PROJECTS

Vermount Road, Franklin County , KS.

SELECT RESOURCES

USDA Forest Service (1999), *Dust Palliative Selection and Application Guide*, San Dimas Technology and Development Center, 23 pp.

SYNTHETIC POLYMER EMULSIONS

GENERAL INFORMATION

Generic Name(s): Synthetic Polymer Emulsions, Polyvinyl Acetate, Vinyl Acrylic

Trade Names: Aerospray 70A, Earthbound, Liquid Dust Control, PolyPavement, PX-300, Soil Sement, TerraBond, and more.

Product Description: Many of the emulsions for dust suppression and/or soil stabilization are proprietary in nature and the exact composition and stabilization mechanisms are not publicly available; therefore, it is often difficult to group or classify the various emulsions accurately.

Synthetic polymer emulsions primarily consist of acrylic or acetate polymers that are specifically produced for dust control or soil stabilization, or are by-products from the adhesive or paint industries. The polymers cause a chemical bond to form between soil particles, creating a dense and water-resistant road surface. In general, polymer emulsions can be used on most soils; however, certain products are more effective on specific soil types. When applied at low application rates (sprayed-on or mixed-in) to the surface of the unbound road surface, synthetic polymer emulsions perform well for dust suppression. They bond soil particles together and so reduce dust generation. At higher application rates (mixed-in), synthetic polymer emulsions can be used to stabilize soils. Graded aggregates can be stabilized to form a very hard bound layer that can be used as a road surfacing.

Most of the information available on synthetic polymer emulsions comes from brochures and literature provided by the manufacturer. Therefore, it may be difficult to find independent test information for a particular product. The performance and applicability of synthetic polymer emulsions can vary from one product to the next. In addition, products are frequently reformulated; so, historical case studies may no longer be representative of a current product. As a result, product specific testing and/or performance verification is recommended when selecting a synthetic polymer emulsion.

Product Suppliers: Enviroseal Corporation, 1019 SE Holbrook Ct., Port Lucie, FL 34952, (800) 775-9474, www.enviroseal.com; and

Midwest Industrial Supply, Inc., P.O. Box 8431, Canton, OH 44711, (800) 321-0699, www.midwestind.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and synthetic polymer emulsion products are available.

APPLICATION

Typical Use: Dust suppressant, soil stabilizer.

Traffic Range: Very Low to Low (AADT < 250).

Restrictions:

Traffic: Required application frequency will increase with increased truck traffic or increased vehicle speed. Additional traffic loading restrictions may be required depending on the material being treated (e.g. the load-carrying capacity of a clay soil is typically much less than that of an aggregate material).

Climate: Synthetic polymer emulsions require a period of dry weather after construction to dry out and begin curing. In extremely wet climates, a sufficient dry spell may not occur for the initial drying of the stabilized material.

Weather: For extended periods of wet weather (greater than 2 weeks), some materials treated with synthetic polymer emulsion will soften and have reduced abrasion resistance.

Terrain: None.

Soil Type: Categorically speaking, synthetic polymer emulsions provide effective dust control and soil stabilization on a variety of soils, including sands, silts, and clays. Certain manufacturers may recommend which soil types their product is best suited for. In general, synthetic polymer emulsions work best for silty sand materials with fines content between 5% and 20% and plasticity index below 8. For granular materials with little

to no fines (less than 2%), an excessive amount of polymer may be required for stabilization.

Other: Surfaces treated with synthetic polymer emulsions are susceptible to damage by snowplowing operations. Well-maintained surfaces are less susceptible to damage than worn surfaces and mixed-in applications are less susceptible than sprayed-on applications.

Other Comments: None.

DESIGN

SLC: N/A for dust suppression applications; 0.05 to 0.20 for soil stabilization. Value will vary with soil type, synthetic polymer product, and application rate. Laboratory mixing should be performed to determine the strength of the stabilized material. Using laboratory strength testing results, an estimate of the SLC can be made using correlations or engineering judgment.

Other Design Values: The unconfined compressive strength of soils stabilized with synthetic polymers can range from 5.5 to 15.1 MPa (800 to 2,200 psi). Synthetic polymer emulsions can increase the soil strength by up to 200%.

Base/Subbase Requirements: Roadway should be designed with adequate base and/or subbase support to prevent rutting, potholes, etc.

Other Comments: The road surface should be graded to promote surface drainage and prevent ponding on the road surface that can promote softening of the treated materials.

CONSTRUCTION

Availability of Experienced Personnel: Contractors experienced in the application of dust suppressants and soil stabilizers are, in general, widely available. Contractors will experience using a particular product may be limited in a certain area. Contractors should work closely with the product supplier's technical representative to ensure that the product is applied properly.

Materials: Synthetic polymer emulsions are typically purchased in liquid concentrate form. Water is required to dilute the polymer concentrate once it is delivered to the site.

Equipment: Equipment required for synthetic polymer emulsion application includes: tanker or water truck with spray bar, disc or rotary mixer, grading equipment (i.e. bulldozer or motor grader), and roller. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Synthetic polymer concentrate must be mixed with water to achieve the desired concentration level prior to application.

Placement Process: Synthetic polymer emulsions can be applied by a sprayed-on method or mixed-in method. Recommended mixing depths for dust suppression and stabilization ranges from 25 to 50 mm (1 to 2 in.) and 100 to 200 mm (4 to 8 in.), respectively. For dust suppression applications, scarifying the surface allows the synthetic polymer emulsion to penetrate evenly and quickly into the road surface. For soil stabilization applications, the soil is loosened to the desired treatment depth. The synthetic polymer emulsion is then applied uniformly using a tanker or water truck with a spray bar and mixed with the loose soil using a disc, rotary mixer, or blading equipment. The synthetic polymer emulsion is often applied in multiple passes to get better overall mixing. Once mixed, the treated material is graded and compacted. Even when the mixed-in method is used, some of the emulsion (up to 40%) is saved for a spray-on application prior to compaction. This spray-on application is applied to ensure that a good crust is formed at the surface.

Weather Restrictions: Do not apply synthetic polymer emulsions if rain is likely within 48 hours or if temperatures are below 6 °C (42 °F).

Construction Rate: Synthetic polymer emulsion application rates are in the range of 2,000 to 5,000 m^2/day (2,400 to 6,000 yd^2/day).

Lane Closure Requirements: For sprayed-on applications, the roadway can remain open, although emulsion splash/spray on vehicles can be a problem. For mixed-in applications, the roadway lane should be closed during construction, but can be opened to traffic once the stabilized material has dried, typically after less than 1 or 2 hours (warm, sunny weather) to 1 day (cool, cloudy weather). Synthetic polymer emulsions will take approximately 30 days to cure completely and develop their full strength.

Other Comments: The required application rate will vary based on the characteristics of the material to be treated and the degree of stabilization desired. Laboratory tests and/or test sections are recommended to determine/verify the appropriate application rate.

SERVICEABILITY

Reliability and Performance History: Synthetic polymer emulsions are commonly used dust suppressant and soil stabilizer products. Limited research, design and construction information, and project experience are available. Performance can vary significantly between different products and is influenced by traffic, soil type, weather conditions, application method and rate, and contractor performance. As a result, product specific testing and/or performance verification is recommended when selecting a synthetic polymer emulsion.

Life Expectancy: Life expectancy varies depending on application rate and depth, traffic, and weather conditions. Typical life expectancy is 6 months to 1 year for dust suppression applications. Typical life expectancy is 5 to 10 years for stabilization applications.

Ride Quality: Ride quality depends on the material being stabilized. Synthetic polymer emulsions do not provide any improvement in ride quality; however, they can reduce the rate of deterioration over the serviceable life. By reducing particle loss and washboarding, surface distress is reduced and ride quality is preserved. Synthetic polymer emulsions can reduce aggregate loss by 50% or more.

Main Distress / Failure Modes: Dust, rutting, washboarding, potholes.

Preservation Needs: For soil stabilization applications, additional light sprayed-on applications may be required periodically to extend the serviceable life. The first maintenance application is typically 1 to 1.5 years after initial construction; subsequent applications typically occur every 2 to 3 years. Localized patching and repair work may be required periodically.

SAFETY

Hazards: Proper handling and mixing procedures should be followed when mixing the concentrated liquid with water to create an emulsion. Rutting can lead to water accumulation on the pavement surface, causing a driving hazard.

Skid Resistance: Synthetic polymer emulsion-treated materials form a firm to hard, skid resistant surface.

Road Striping Possible?: No.

Other Comments: Synthetic polymer emulsions can typically reduce road dust by a significant amount. Field tests have shown that a particular synthetic polymer product reduced fugitive dust by at least 95% after three months and at least 80% after 11 months.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Synthetic polymer emulsions primarily consist of acrylic or acetate polymers that are specifically produced for dust control or soil stabilization, or are by-products from the adhesive or paint industries.

Delivery and Haul Requirements: Synthetic polymer concentrate must be hauled to the site from the distributor. Haul distances may be significant for remote sites. Hauling requirements are reduced somewhat by the fact that the product is shipped in concentrated form and can be mixed with water at the site.

Potential Short-Term Construction Impacts: Construction processes may impact vegetation adjacent to the roadway.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Tests have shown that synthetic polymer emulsions can reduce surface runoff by about 20% compared to the untreated soil.

Erosion: Synthetic polymer emulsions reduce the erodibility of the unbound roadway surface by binding surface particles together. Sediment loading in surface runoff water can be reduced by 50%.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: The treated soil/aggregate can be reused in any manner similar to the untreated material.

Other Environmental Considerations: Environmental impacts of synthetic polymer emulsions may vary between different proprietary products; specific product information should be collected and reviewed prior to product use. Categorically speaking, synthetic polymer emulsions are typically nontoxic, nonhazardous, noncorrosive, and generally environmentally friendly.

AESTHETICS

Appearance: The addition of synthetic polymer emulsion does not significantly alter the appearance of a soil or aggregate road. The appearance will be of a soil/aggregate surface with the overall color determined by the soil/aggregate type and source.

Appearance Degradation Over Time: Without maintenance, synthetic polymer emulsion-treated roads deteriorate over time in terms of surface uniformity.

COST

Supply Price: $0.80 to $4.25/L ($3.00 to $16.00/gal)

Supply+Install Price: $2.40 to $14.30/$m^2$ ($2.00 to $12.00/$yd^2$) for mixing to a depth of 150 mm (6 in.).

EXAMPLE PROJECTS

Kelso Dunes Access Road, Mojave National Preserve, CA.
Auto Tour Roads, Buenos Aires National Wildlife Refuge, Pima County, AZ.

SELECT RESOURCES

USDA Forest Service (1999), *Dust Palliative Selection and Application Guide,* San Dimas Technology and Development Center, 23 pp.

TREE RESIN EMULSIONS

GENERAL INFORMATION

Generic Name(s): Tree Resin Emulsions, Tall Oil Emulsions, Pitch Emulsions, Pine Tar Emulsions

Trade Names: Dustbinder, Dustrol EX, Enduraseal 200, RESIN PAVEMENT, RESINPAVE, ROAD OYL, TerraPave, and others.

Product Description: Tree resin emulsions are derived from tree resins (mainly pine, fir, and spruce) combined with other additives to produce an emulsion that can be used for dust suppression or soil stabilization. When applied at low application rates to the top 25 mm (1 in.) of an unbound road surfacing, tree resin emulsions are well suited for dust suppression because they bond soil particles together and so reduce dust generation. At higher application rates and deep mixing, typically 100 to 200 mm (4 to 8 in.), tree resin emulsions can be used to stabilize subgrade or base materials containing fines. Graded aggregates (typical maximum particle size less than 10 mm [3/8 in.]) can be stabilized to form a relatively hard surface layer that can be used as a road surfacing; the stabilized aggregate is purported to be up to three times stronger than asphalt concrete. The bound aggregate surfacing is usually 50 mm (2 in.) thick.

Most of the information available on tree resin emulsions comes from brochures and literature provided by the manufacturer. Therefore, it may be difficult to find independent test information for a particular product. The performance and applicability of tree resin emulsions can vary from one product to the next. In addition, products are frequently reformulated; so, historical case studies may no longer be representative of a current product. As a result, product specific testing and/or performance verification is recommended when selecting a tree resin emulsion.

Product Suppliers: ARR-MAZ Products, LP, 621 Winter Haven, FL 33880, (800) 541-8926, www.roadproductscorp.com.

Representative product suppliers and trade names are provided for informational purposes only. Inclusion of this information is not an endorsement of any product or company. Additional suppliers and tree resin emulsion products are available.

APPLICATION

Typical Use: Dust suppressant, soil stabilizer.

Traffic Range: Very Low to Low (AADT < 250); above this traffic range, the surface will require more frequent product applications and surface grading.

Restrictions:

Traffic: Required application frequency will increase with increased truck traffic or increased vehicle speed. Additional traffic loading restrictions may be required depending on the material being treated (e.g. the load-carrying capacity of a clay soil is typically much less than that of a sand or gravel material).

Climate: Tree resin emulsions can be used in all climates, but work best in areas with arid or moderate precipitation conditions.

Weather: For extended periods of wet weather (greater than 2 weeks), some materials treated with tree resin emulsion will soften and allow ruts to form.

Terrain: Surfaces treated with tree resin emulsions can become slippery when wet, particularly with soils with high fines content or high plasticity; therefore, tree resin emulsions are not recommended for steep terrain applications in wet climates.

Soil Type: Categorically speaking, tree resin emulsions provide effective dust control and soil stabilization on a variety of soils, including sands, silts, and clays. Certain manufacturers may recommend which soil types their product is best suited for. In general, tree resin emulsions work best for silty sand materials with fines content between 5% and 30% and plasticity index below 8. Tree resin emulsions provide little to no improvement for soils with high plasticity (plasticity index greater than 30). For granular materials with little to no fines (less than 2%), an excessive amount of tree resin emulsion may be required for stabilization.

Other: Surfaces treated with tree resin emulsions are susceptible to damage by snowplowing operations. Well-maintained surfaces are less susceptible to damage than worn surfaces and mixed-in applications are less susceptible than sprayed-on applications.

Other Comments: None.

DESIGN

SLC: N/A for dust suppression applications; 0.10 to 0.30 for soil stabilization (lower values for clay soils, higher values for granular materials). Value will vary with soil type, tree resin product, and application rate. Laboratory mixing should be performed to determine the strength of the stabilized material. Using laboratory strength testing results, an estimate of the SLC can be made using correlations or engineering judgment.

Other Design Values: Tree resin emulsions can increase the unconfined compressive strength of clay soils by 25% to 75% or more. The compressive strength of granular materials treated with tree resin emulsions can be 3 times greater than HACP.

Base/Subbase Requirements: Where local soils are treated with tree resin emulsion to form a stabilized surfacing, it is unlikely that an imported base/subbase layer would be provided. The stabilized zone and underlying soil should be designed to provide adequate structural support for traffic.

Other Comments: The road surface should be sloped to promote surface drainage and prevent ponding on the road surface that can promote softening of the treated materials.

CONSTRUCTION

Availability of Experienced Personnel: Contractors experienced in the application of dust suppressants and soil stabilizers are, in general, widely available. Contractors will experience using a particular product may be limited in a certain area. Contractors should work closely with the product supplier's technical representative to ensure that the product is applied properly.

Materials: Tree resin emulsions are typically purchased in liquid concentrate form. Water is required to dilute the resin concentrate once it is delivered to the site.

Equipment: Equipment required for tree resin emulsion application includes: tanker or water truck with spray bar, disc or rotary mixer, grading equipment (i.e. bulldozer or motor grader), and roller. For treatment of aggregates, a pugmill for mixing is recommended. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Tree resin concentrate must be mixed with water to achieve the desired concentration level prior to application. For stabilization of aggregates, mixing the aggregate and emulsion in a pugmill is recommended.

Placement Process: Tree resin emulsions can be applied by a sprayed-on method or mixed-in method. Recommended mixing depths for dust suppression and stabilization ranges from 25 to 50 mm (1 to 2 in.) and 100 to 200 mm (4 to 8 in.), respectively. For dust suppression applications, scarifying the surface allows the tree resin emulsion to penetrate evenly and quickly into the road surface. For soil stabilization applications, the soil is loosened to the desired treatment depth. The tree resin emulsion is then applied uniformly using a tanker or water truck with a spray bar and mixed with the loose soil using a disc, rotary mixer, or blading equipment. The tree resin emulsion is often applied in multiple passes to get better overall mixing. Once mixed, the treated material is graded and compacted. Even when the mixed-in method is used, some of the emulsion (up to 40%) is saved for a spray-on application prior to compaction. This spray-on application is applied to ensure that a good crust is formed at the surface.

For mixing with aggregates to form a bound surfacing, the aggregate and emulsion are mixed in a pugmill, spread onto the prepared base, and compacted. The surface is then sprayed with a light spray-on application of tree resin emulsion.

Weather Restrictions: Do not apply tree resin emulsions if rain is likely within 48 hours or if temperatures are below 6 °C (42 °F).

Construction Rate: Tree resin emulsion application rates are in the range of 2,000 to 5,000 m^2/day (2,400 to 6,000 yd^2/day).

Lane Closure Requirements: For sprayed-on applications, the roadway can remain open, although emulsion splash/spray on vehicles can be a problem. For mixed-in applications, the roadway lane should be closed during construction, but can be opened to traffic once the stabilized material has dried, typically after 1 to 4 days. Tree resin emulsions will take approximately 30 days to cure completely and develop their full strength.

Other Comments: The required application rate will vary based on the characteristics of the material to be treated and the degree of stabilization desired. Laboratory tests and/or test sections are recommended to determine/verify the appropriate application rate. Some project managers have reported that tree resin emulsions are messy and difficult to work with.

SERVICEABILITY

Reliability and Performance History: Tree resin emulsions are commonly used dust suppressant and soil stabilizer products. Limited research, design and construction information, and project experience are available. Performance can vary significantly between different products and is influenced by traffic, soil type, weather conditions, application method and rate, and contractor performance. As a result, product specific testing and/or performance verification is recommended when selecting a tree resin emulsion.

Life Expectancy: Life expectancy varies depending on application rate and depth, traffic, and weather conditions. Typical life expectancy is 6 months for dust suppression applications. Typical life expectancy is 5 to 10 years or more for stabilization applications.

Ride Quality: Ride quality depends on the material being stabilized. Synthetic polymer emulsions do not provide any improvement in ride quality; however, they can reduce the rate of deterioration over the serviceable life. By reducing particle loss and washboarding, surface distress is reduced and ride quality is preserved. Tree resin emulsions can significantly reduce aggregate loss.

Main Distress / Failure Modes: Dust, rutting, washboarding, potholes.

Preservation Needs: For soil stabilization applications, additional light sprayed-on applications may be required periodically to extend the serviceable life. The first maintenance application is typically 1 to 1.5 years after initial construction; subsequent applications typically occur every 2 to 3 years. Localized patching and repair work may be required periodically.

SAFETY

Hazards: Proper handling and mixing procedures should be followed when mixing the concentrated liquid with water to create an emulsion. Rutting can lead to water accumulation on the pavement surface, causing a driving hazard.

Skid Resistance: Tree resin emulsion-treated materials form a firm to hard, skid resistant surface. However, surfaces treated with tree resin emulsions can become slippery when wet, particularly with soils with high fines content or high plasticity.

Road Striping Possible?: No.

Other Comments: Tree resin emulsions can typically reduce road dust by a significant amount. Field tests have shown that a particular tree resin emulsion product reduced fugitive dust by at least 70% after 3 months, 50% after 6 months, and 30% after 12 months.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: Tree resin emulsions are derived from tree resins (mainly pine, fir, and spruce) combined with other additives. The tree resins are a byproduct of the pulp and paper industry.

Delivery and Haul Requirements: Tree resin concentrate must be hauled to the site from the distributor. Haul distances may be significant for remote sites. Hauling requirements are reduced somewhat by the fact that the product is shipped in concentrated form and can be mixed with water at the site.

Potential Short-Term Construction Impacts: Construction processes may impact vegetation adjacent to the roadway. Large tree resin emulsion spills during construction could potentially impact water quality and aquatic species in nearby streams. A spill prevention and containment plan should be in place to reduce the probability of spills and off-site runoff.

Potential Long-Term Environmental Impacts:

Leachate: None once the product has cured.

Surface Runoff: Tree resin emulsions can reduce the permeability of surface materials, resulting in an increase in surface runoff. However, surface runoff water quality is not generally impacted by tree resin emulsion-treated surfacings. In parking areas, oil and other vehicle fluids can be collected by surface runoff, affecting the water quality.

Erosion: Tree resin emulsions reduce the erodibility of the unbound roadway surface by binding surface particles together. Sediment loading in surface runoff water can be significantly reduced.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: The treated soil/aggregate can be reused in any manner similar to the untreated material.

Other Environmental Considerations: Environmental impacts of tree resin emulsions may vary between different proprietary products; specific product information should be collected and reviewed prior to product use. Categorically speaking, tree resin emulsions are typically nontoxic, nonhazardous, noncorrosive, and generally environmentally friendly.

AESTHETICS

Appearance: The addition of tree resin emulsion does not significantly alter the appearance of a soil or aggregate road. The appearance will be of a soil/aggregate surface with the overall color determined by the soil/aggregate type and source.

Appearance Degradation Over Time: Without maintenance, tree resin emulsion-treated roads deteriorate over time in terms of surface uniformity.

COST

Supply Price: N/A

Supply+Install Price: \$21.40 to \$53.60/m^2 (\$18.00 to \$45.00/yd^2) for 50 mm (2 in.) thick stabilized aggregate layer.

EXAMPLE PROJECTS

Chicago Center for Green Technology, Chicago, IL.

SELECT RESOURCES

USDA Forest Service (1999), *Dust Palliative Selection and Application Guide*, San Dimas Technology and Development Center, 23 pp.