## PAVED AND SEALED SURFACES

## ASPHALT SURFACING–SURFACE TREATMENTS OR LAYERS (NON-STRUCTURAL)

## *CAPE SEAL*

### GENERAL INFORMATION

**Generic Name(s):** Cape Seal

**Trade Names:** N/A

**Product Description:** A Cape seal is a thin surface treatment constructed by applying a slurry seal or microsurfacing to a newly constructed chip seal. A Cape seal is more than the placement of one type of surface treatment over another; it is designed to be an integrated system where the primary purpose of the slurry is to fill voids in the chip seal. The slurry helps prevent chip loss and the chips prevent undue traffic abrasion and erosion of the slurry. Cape seals provide a durable, sealed roadway surfacing that has excellent skid resistance and is smoother than chip seals.

**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.

### APPLICATION

**Typical Use:** Road surfacing, corrective or preventative maintenance treatment for minor surface irregularities, small cracks, raveling, and loss of surface friction and to improve ride quality.

**Traffic Range:** Low to High (AADT < 2,000) for road surfacing; Low to High for corrective or preventative maintenance treatment.

**Restrictions:**

*Traffic*: None.

*Climate*: None.

*Weather*: None.

*Terrain*: Cape seals are generally not used for roadway gradients steeper than 12%.

*Soil Type*: N/A

*Other*: Cape seals are less susceptible to damage from snow plows than single chip seals or slurry seals in snow plowing areas.

**Other Comments:** The grade of asphalt cement needs to be selected based on service temperature ranges and traffic volumes. Cape seals are effective in areas where HACP is not available and high resistance to shearing forces is required.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** For new road construction/reconstruction, Cape seals are usually constructed over an aggregate base course. Since the Cape seal does not add structural capacity to the roadway, the base/subbase must be designed to support the anticipated traffic loading. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to Cape seal placement. A prime coat is sometimes used above the aggregate base prior to Cape seal application.

**Other Comments:** Cape seal performance is highly dependent on the quality of workmanship and the component materials used.

**CONSTRUCTION**

**Availability of Experienced Personnel**: The two components of Cape seals, chip seals and slurry seals or microsurfacing, are commonly used surfacings and experienced contractors are, in general, widely available. However, fewer contractors have experience in constructing Cape seals as an integrated system and availability may be limited in some areas.

**Materials**: Cape seals are comprised of chips seals overlain by slurry seals or microsurfacing. Chip seals are constructed of a bituminous binding agent (emulsified asphalt or paving grade asphalt cement) and clean, uniform-sized crushed aggregate chips, typically 6 to 19 mm (1/4 to 3/4 in.). Modified asphalt cements can be used to enhance certain performance characteristics. Advantages of emulsified asphalt include a cooler application temperature (20 to 85 °C [70 to 185 °F]) than paving grade asphalts, and the water that evaporates is environmentally safe. Cutback asphalts are not recommended for use in Cape seals.

Slurry seals are constructed of a mixture of emulsified asphalt, dense-graded crushed fine aggregate, mineral filler or other additives, and water. The emulsified asphalt is usually cationic and quick-setting. Modified asphalt emulsions can be used to enhance certain performance characteristics.

Microsurfacing is constructed of a mixture of polymer-modified emulsified asphalt, dense-graded crushed fine aggregate, mineral filler or other additives, and water. Polymers are added to the emulsified asphalt to increase mixture stiffness and flexibility, which leads to better rut and crack resistance. Special quick-setting emulsifiers are used for the emulsified asphalt.

**Equipment**: Equipment required for Cape seal construction includes: asphalt distributor, aggregate spreader, pneumatic-tired roller, mechanical broom, and slurry seal or microsurfacing mixing machine. Equipment is locally available in most large urban areas and regionally available in more remote areas.

**Manufacturing/Mixing Process**: For the chip seal, the binding agent (either an emulsified asphalt or asphalt cement) is produced by an asphalt supplier and shipped to the site. Aggregate is usually crushed and separated by size to obtain uniform-sized chips for use. If the chips are to be pre-coated with bituminous materials, this action is performed at the plant before the chips are shipped to the site. For the slurry seal or microsurfacing, the mixing machine carries all the unmixed materials and, when construction commences, combines the materials in exact mix proportions in a continuous flow pugmill. For continuous operation, haul vehicles must replenish materials to the mixing machine.

**Placement Process**: The bituminous binding agent is sprayed onto the prepared working surface at the specified application rate (typically 10-15% less than for a chip seal) by the distributor; then, the aggregate chips are spread onto the surface at the specified application rate (typically 10% less than for chip seal) using an aggregate spreader. After the aggregate chips are placed, the surface is rolled with a pneumatic-tired roller to embed and realign the aggregate chips in the binder. Once the binding agent has hardened, the road surface should be swept with a mechanical broom to remove all loose chips from the surface. The chip seal component is allowed to cure for four to ten days before the slurry seal or microsurfacing is applied. The chip seal surface should be broomed before the slurry seal or microsurfacing is applied. Once the slurry seal or microsurfacing has cured, the Cape seal can be reopened to traffic.

**Weather Restrictions**: Do not construct any component of the Cape seal if it is raining or there is an imminent risk of rain. The specified minimum air temperature for Cape seal placement varies between different agencies, but is normally 10 °C (50 °F) or above. When using asphalt emulsion, do not apply when freezing temperatures are expected within 24 hours.

**Construction Rate**: Cape seal construction consists of two separate processes, chip seal construction and slurry seal or microsurfacing construction. Cape seal construction rates are commonly 8,400 $m^2$/day (10,000 $yd^2$/day).

**Lane Closure Requirements**: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The chip seal surface can be opened to traffic at lower speeds as soon as it is constructed. Normal traffic speeds can be allowed once the loose chips have been swept from the roadway surface. The roadway lane(s) must be closed again for slurry seal or microsurfacing placement, but can be reopened after curing (typically one hour for microsurfacing or one to twelve hours for slurry seals). Road surface striping may be performed after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Cape seals have been used with success in South Africa, where they were developed, and Australia for more than 40 years. The technology was introduced to the United States in 1977. Cape seal use in the United States has been limited, but is commonly used in some areas (e.g. California). The amount of design and construction information available is fairly limited; project experience will vary by region.

**Life Expectancy:** Life expectancy varies depending on mix types, traffic volumes and degree of routine maintenance. Typical serviceable lives range from 7 to 15 years (average 9 years). Chip seals placed over aggregate or stabilized bases are generally more susceptible to premature structural failures as opposed to chip seals placed over an existing paved roadway.

**Ride Quality:** Cape seals, similar to other non-structural asphalt surfacings, do not improve ride quality; ride quality is mainly determined by the roughness of the underlying layer. On a properly prepared application surface, a good to very good ride quality can be achieved after construction.

**Main Distress / Failure Modes:** Delamination of slurry seal, bleeding, shoving, cracking, raveling, loss of surface friction.

**Preservation Needs:** Cape seals require little, if any, preventative maintenance treatments.

**SAFETY**

**Hazards**: Road splash/spray can reduce visibility during periods of higher traffic volume.

**Skid Resistance**: Provided high quality aggregates are used, Cape seals provide excellent skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: Because Cape seals provide a high-quality road surfacing, there is a tendency for higher road usage and speeding.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) are manufactured products. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** Bituminous binding agent, aggregates, and any additives must be hauled to the site. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: If paving grade asphalt cement is used, significant heat is generated during the placement process. Construction processes may impact vegetation adjacent to the roadway. If clean aggregates are not used for chip seal construction, dust can be a problem during construction.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Cape seals are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by Cape seal surfacings.

*Erosion:* None.

*Water quality*: None.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Cape seals can be pulverized and reused as an unbound or stabilized material.

**Other Environmental Considerations:** The amount of heat generation associated with Cape seal construction is significantly less when emulsified asphalt is used, compared to hot laid paving grade asphalt cement. For Cape seals, tire/road noise is typically low to moderate with the same or slightly higher noise level than HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)], but with a lower noise level than chip seals.

**AESTHETICS**

**Appearance:** Immediately after placement, the Cape seal's appearance is generally black with a relatively smooth texture. A Cape seal's appearance can be modified with the careful selection of colored aggregates and by the use of pigments in the binding agent.

**Appearance Degradation over Time:** Over time, the Cape seal surface will wear, exposing more of the aggregate and modifying the appearance.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$2.70 to \$3.60/$m^2$ (\$2.25 to \$3.00/$yd^2$).

**EXAMPLE PROJECTS**

Salinas and Sacramento, CA.

**SELECT RESOURCES**

Asphalt Emulsion Manufacturers Association, (410) 267-0023, www.aema.org.
Asphalt Institute. *A Basic Asphalt Emulsion Manual*, Manual Series No. 19 (MS-19), Third Edition, Lexington, Kentucky, 120 pp.
USDA Forest Service (1999), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center.

## *CHIP SEAL*

### GENERAL INFORMATION

**Generic Name(s):** Chip Seal, Single Surface Treatment, Bituminous Surface Treatment

**Trade Names:** N/A

**Product Description:** A chip seal is a single thin surface treatment constructed by spraying a bituminous binding agent and immediately spreading and rolling a thin aggregate cover. The bituminous binding agent can be an emulsified asphalt, cutback asphalt, or asphalt cement. The aggregate used is a single-sized crushed aggregate chip; the maximum chip size is most commonly 6 to 9.5 mm (1/4 to 3/8 in.), although larger chips have been used successfully on roads with heavy truck traffic. The thickness of the constructed chip seal layer is equal to the maximum size of the aggregate chips used.

**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; and

California Chip Seal Association, 14929 Slover Avenue, Fontana, CA 92335, www.chipseal.org.

### APPLICATION

**Typical Use:** Road surfacing; preventative maintenance treatment for small cracks, bleeding, raveling, and loss of surface friction. Chip seals are a widely used alternative for surfacing low volume roads. They protect underlying materials from water and erosion and provide a relatively smooth riding surface. In general, chip seals provide an economical and relatively durable surface that is safe under normal weather and driving conditions. Chip seals can also be placed over new or existing HACP to modify, maintain, or improve the surface texture and friction properties and/or seal small cracks.

**Traffic Range:** Very Low to Medium when chip seal is placed over aggregate base, Very Low to High (typically AADT < 2,000) when chip seal is placed over existing HACP.

**Restrictions:**

*Traffic*: Chip seals should generally be limited to traffic mixes with less than 15% trucks. The use of chip seals should be avoided in areas with frequent truck turning or braking.

*Climate*: None.

*Weather*: None.

*Terrain*: Chip seals are generally not used for roadway gradients steeper than 8%.

*Soil Type*: N/A

*Other*: Chip seals can be damaged by plowing in snow plowing areas. Chip seals should not be applied to pavements with majority of ruts greater than 12 mm (0.5 in.) deep.

**Other Comments:** The grade of asphalt cement needs to be selected based on service temperature ranges and traffic volumes. Chip seals can also be used over old chip seals to provide a continuous build-up of surfacing over time.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** Chip seals are often constructed over an aggregate base course. Since chip seals do not add structural capacity to the roadway, the base/subbase must be designed to support the anticipated traffic loading. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to chip seal placement. A prime coat is sometimes used above the aggregate base prior to chip seal application.

**Other Comments:** Chip seal performance is highly dependent on the quality of workmanship and the component materials used.

**CONSTRUCTION**

**Availability of Experienced Personnel**: Chip seals are a commonly used surfacing and experienced contractors are, in general, widely available. Maintenance crews are used by some agencies for chip seal construction.

**Materials**: Chip seals are constructed of a bituminous binding agent (emulsified asphalt, cutback asphalt, or asphalt cement) and clean, uniform-sized crushed aggregate chips, typically 6 to 9.5 mm (1/4 to 3/8 in.). Modified asphalt cements can be used to enhance certain performance characteristics. Some agencies require that chips be pre-coated with a bituminous material to improve adhesion and reduce the amount of loose chips. Pre-coated aggregates are not recommended for use with emulsified asphalt.

*Paving Grade Asphalt Cement:* Advantages of using paving grade asphalt cement is that it cures quickly, does not require any additives in the asphalt cement, and the material achieves full strength as soon as it cools. Disadvantages of asphalt cement include a high application temperature (121 to 177 °C [250 to 350 °F]) and the need to place the aggregate quickly before that asphalt cement cools.

*Cutback Asphalt*: Advantages of using cutback asphalts include cooler application temperatures (30 to 115 °C [85 to 240 °F]) than paving grade asphalts and higher asphalt percentages than emulsified asphalts (approximately 80% compared to approximately 60%). Disadvantages of cutback asphalts include higher cost than emulsified asphalts, 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 a cooler application temperature (20 to 85 °C [70 to 185 °F]) than paving grade or cutback asphalts, and the water that evaporates is environmentally safe.

**Equipment**: Equipment required for chip seal construction includes: asphalt distributor, aggregate spreader, pneumatic-tired roller, and mechanical broom. Equipment is widely available in most areas, but availability may be limited in remote areas.

**Manufacturing/Mixing Process**: The binding agent (either an emulsified or cutback asphalt or asphalt cement) is produced by an asphalt supplier and shipped to the site. Aggregate is usually crushed and separated by size to obtain uniform-sized chips for use. If the chips are to be pre-coated with bituminous materials, this action is performed at the plant before the chips are shipped to the site.

**Placement Process**: The bituminous binding agent is sprayed onto the prepared working surface by the distributor; then, the aggregate chips are spread onto the surface using an aggregate spreader. After the aggregate chips are placed, the surface is rolled with a pneumatic-tired roller to embed and realign the aggregate chips in the binder. The surface should be rolled before the binding agent begins to set. The constructed surface should consist of a single layer of aggregate chips with about two-thirds of the voids being filled with the binding agent. The time available for rolling before the binder hardens will depend on the type of binding agent, binder temperature when it is placed, air temperature, and wind, but can range from several minutes to several hours or more. Once the binding agent has hardened, the road surface should be swept with a mechanical broom to remove all loose chips from the surface. A fog seal can be applied to the chip seal after construction to improve the bonding of the chips to the road surface.

**Weather Restrictions**: Do not construct chip seals if it is raining or there is an imminent risk of rain, or, if using emulsified asphalt, when freezing temperatures are expected within 48 hours. The specified minimum air temperature for chip seal placement varies between different agencies, but is normally 10 °C (50 °F) or above.

**Construction Rate**: Chip seal construction rates are in the range of 25,000 $m^2$/day (30,000 $yd^2$/day).

**Lane Closure Requirements**: The roadway lane(s) being constructed is closed during construction, so adequate traffic control is needed. The chip seal surface can be opened to traffic at lower speeds as soon as it is constructed. Normal traffic speeds can be allowed once the loose chips have been swept from the roadway surface. Road surface striping may be performed after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Chip seals are a very common roadway surfacing and have been used on 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 construction materials used, environmental conditions, and traffic volumes. Typical serviceable lives range from 3 to 7 years (average 5 years). Chip seals placed over aggregate or stabilized bases are generally more susceptible to premature structural failures as opposed to chip seals placed over an existing paved roadway.

**Ride Quality:** Chip seals, similar to other non-structural asphalt surfacings, do not improve ride quality; ride quality is mainly determined by the roughness of the underlying layer. On a properly prepared application surface, a good to very good ride quality can be achieved after construction. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Cracking, raveling, bleeding, loss of surface friction.

**Preservation Needs:** Preventative maintenance includes periodic crack sealing. Fog seals can be applied to extend the serviceable life of chip seals.

**SAFETY**

**Hazards**: Rutting can lead to water accumulation on the pavement surface, causing a driving hazard. Road splash/spray can reduce visibility during periods of higher traffic volume. Loose aggregate chips can create a windshield hazard. When cutback asphalts are used, the solvents 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**: Provided high quality aggregates are used, chip seals provide good to excellent skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: Because chip seals can provide a high-quality road surfacing, there is a tendency for higher road usage and speeding.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) or solvents (for cutback asphalts) are manufactured products. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** Bituminous binding agent and aggregate must be hauled to the site. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: If paving grade asphalt cement is used, significant heat is generated during the placement process. Construction processes may impact vegetation adjacent to the roadway. Asphalt binder spills should be promptly contained from spreading off-site and removed. If clean aggregate is not used, dust can be a problem during construction and sweeping. Excess loose chips can be thrown/ brushed/ washed from the surface into the surrounding environment. Hydrocarbon emissions into the atmosphere can be a significant impact if cutback asphalts are used.

Cutback asphalts can potentially impact water quality and aquatic species due to runoff if heavy rains occur before the cutback asphalt cures. Surface runoff should be properly contained or managed during the curing stage when the project is adjacent to bodies of water.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Chip seals are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by chip seal surfacings. In parking areas, oil and other vehicle fluids can be collected by surface runoff, affecting the water quality.

*Erosion:* Chip seals are a bound surface and are not particularly susceptible to surface erosion. Some aggregate loss can be expected due to a combination of traffic and erosional processes.

*Water quality*: Chip seals have a minimal impact on water quality. Water quality could be affected by sediment loading from dust or crushed chips from the chip seal surface.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Chip seals can be pulverized and reused as an unbound or stabilized material.

**Other Environmental Considerations:** The amount of heat generation associated with chip seal construction varies significantly with the type of bituminous binding agent used. Paving grade asphalt cement results in the highest level of heat generation, with cutback asphalt seals generating less heat and emulsified asphalt seals generating even less heat. For chip seals, tire/road noise is typically low to moderate with a slightly higher [2 dB(A)] noise level than HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)].

**AESTHETICS**

**Appearance:** Immediately after placement, the chip seal's appearance is influenced by the black bituminous binder and the aggregate chip color. If the chips are pre-coated, the chip seal will be black and will not be characterized by the natural aggregate color. A chip seal's appearance can be modified with the careful selection of colored aggregates and by the use of pigments in the binding agent.

**Appearance Degradation Over Time:** Over time, the chip seal surface will wear, exposing more of the aggregate. The use of preventative maintenance treatments, such as fog seals, will add a black appearance to the surface.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$1.00 to \$1.50/$m^2$ (\$0.80 to \$1.25/$yd^2$).

**EXAMPLE PROJECTS**

Chip seals are used extensively throughout the United States.
Utah State Route 9, near Springdale, UT (Access road to Zion National Park).

**SELECT RESOURCES**

Asphalt Emulsion Manufacturers Association, (410) 267-0023, www.aema.org
Asphalt Institute. *A Basic Asphalt Emulsion Manual*, Manual Series No. 19 (MS-19), Third Edition, Lexington, Kentucky, 120 pp.
Janisch, D.W., and Gaillard, F.S. (1998). *Minnesota Seal Coat Handbook*, Draft Report, Minnesota Local Road Research Board, Maplewood, MN, 116 pp.
USDA Forest Service (1999a), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center.

## *CHIP SEAL OVER GEOTEXTILE*

### GENERAL INFORMATION

**Generic Name(s):** Geotextile-Reinforced Chip Seal, Chip Seal over Paving Fabric

**Trade Names:** Numerous products available.

**Product Description:** A chip seal is a single thin surface treatment constructed by spraying a bituminous binding agent and immediately spreading and rolling a thin aggregate cover. The bituminous binding agent can be an emulsified asphalt, cutback asphalt, or asphalt cement. The aggregate used is a single-sized crushed aggregate chip; the maximum chip size is most commonly 6 to 9.5 mm (1/4 to 3/8 in.), although larger chips have been used successfully on roads with heavy truck traffic. A chip seal over geotextile is constructed by applying a tack coat to a prepared bound surfacing, immediately embedding a geotextile layer onto the prepared surface, and then constructing a traditional chip seal on top.

**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; and

Asphalt Interlayer Association, www.aia-us.org.

### APPLICATION

**Typical Use:** Road surfacing; preventative maintenance treatment for small cracks, raveling, and loss of surface friction. The geotextile reinforcement acts as a moisture barrier and reduces reflection cracking of the chip seal. Even after the chip seal begins to crack, the geotextile reinforcement continues to prevent or greatly reduce moisture infiltration from the surface into the underlying layers.

**Traffic Range:** Very Low to Medium when chip seal is placed over an existing surface treatment, Very Low to High (typically AADT < 2,000) when chip seal is placed over existing HACP.

**Restrictions:**

*Traffic*: Chip seals over geotextile should generally be limited to traffic mixes with less than 15% trucks. Chip seal over geotextile use should be limited in areas with trucks turning or braking. Slippage has occurred when used in applications with large shearing forces at the surface (e.g. tight radius curves, breaking at intersections, etc.)

*Climate*: None.

*Weather*: None.

*Terrain*: Chip seals over geotextile are generally not used for roadway gradients steeper than 8%.

*Soil Type*: N/A

*Other*: Chip seals over geotextile can be damaged by plowing in snow plowing areas. In areas where snow plowing is common, a double chip or Cape seal over geotextile is recommended instead of a single chip seal over geotextile.

**Other Comments:** The grade of asphalt cement needs to be selected based on service temperature ranges and traffic volumes. The inclusion of a geotextile does not protect the chip seal from normal wear and loss of aggregate, so it does not necessarily extend the serviceable life of the treatment. The main benefit of adding a geotextile is to create a waterproofing membrane that keeps water from entering the base aggregate. A dry base has about 40% higher load bearing capacity than the same base section when saturated. The geotextile also protects the chip seal from distresses migrating upwards through the pavement. Therefore, it is usually justified where a chip seal has been chosen to be placed over an asphalt concrete pavement which is badly fatigue cracked but is not pumping or deflecting under load. Geotextile fabrics should never be placed over pavements exuding water from an underground source; the water will strip the geotextile and chip seal off of the pavement.

Asphalt Surfacings (non-structural) Chip Seal over Geotextile: Page 2 of 5

**DESIGN**

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** Chip seals over geotextile can be constructed over an aggregate base course. Since chip seals do not add significant structural capacity to the roadway, the base/subbase must be designed to support the anticipated traffic loading. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to geotextile and chip seal placement.

**Other Comments:** Chip seal over geotextile performance is highly dependent on the quality of workmanship and the component materials used. The most important elements of chip seal over geotextile construction is to ensure that the fabric is fully bonded to the existing surface, and saturated from the tack coat binder prior to chip seal construction.

**CONSTRUCTION**

**Availability of Experienced Personnel**: Chip seals over geotextile are not a commonly used surfacing and the availability of experienced contractors is limited in many areas.

**Materials**: Chip seals are constructed of a bituminous binding agent (emulsified asphalt, cutback asphalt, or asphalt cement) and clean, uniform-sized crushed aggregate chips, typically 6 to 9.5 mm (1/4 to 3/8 in.). Modified asphalt cements can be used to enhance certain performance characteristics. Some agencies require that chips be pre-coated with a bituminous material to improve adhesion and reduce the amount of loose chips. Nonwoven geotextiles are manufactured from polypropylene textile. The geotextile used should meet the requirements of AASHTO 1996 M-288 guidelines for paving fabric. A commonly recommended geotextile is 4.1 oz. polypropylene needle punched 101 pound grab tensile strength fabric.

*Paving Grade Asphalt Cement:* Advantages of using paving grade asphalt cement is that it cures quickly, does not require any additives in the asphalt cement, and the material achieves full strength as soon as it cools. Disadvantages of asphalt cement include a high application temperature (121 to 177 °C [250 to 350 °F]) and the need to place the aggregate quickly before that asphalt cement cools. Paving grade asphalt cement should be used for placement of the geotextile.

*Cutback Asphalt*: Advantages of using cutback asphalts include cooler application temperatures (30 to 115 °C [85 to 240 °F]) than paving grade asphalts and higher asphalt percentages than emulsified asphalts (approximately 80% compared to approximately 60%). Disadvantages of cutback asphalts include higher cost than emulsified asphalts, 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. Cutback asphalts should not be used for placement of the geotextile.

*Emulsified Asphalt*: Advantages of emulsified asphalt include a cooler application temperature (20 to 85 °C [70 to 185 °F]) than paving grade or cutback asphalts, and the water that evaporates is environmentally safe. Emulsified asphalt should not be used for placement of the geotextile.

**Equipment**: Equipment required for chip seal over geotextile construction includes: asphalt distributor, aggregate spreader, pneumatic-tired roller, mechanical broom, and mechanical laydown equipment. Mechanical laydown equipment can consist of: a dedicated piece of equipment, a bolt-on attachment to an existing piece of equipment, or a laydown device attached to the spreader truck. Manual laydown equipment is not recommended because the extra time (compared to mechanical laydown equipment) needed allows the tack coat to cool and precludes good embedment of the geotextile, preventing full initial fabric saturation. Equipment is widely available in most areas, but availability may be limited in remote areas.

**Manufacturing/Mixing Process**: The binding agent (either an emulsified or cutback asphalt or asphalt cement) is produced by an asphalt supplier and shipped to the site. Aggregate is usually crushed and separated by size to obtain uniform-sized chips for use. If the chips are to be pre-coated with bituminous materials, it is performed at the plant before the chips are shipped to the site.

**Placement Process**: Before construction begins, the existing surface should be cleaned of water and debris and cracks greater than 3 mm (0.125 in.) wide should be cleaned and sealed. A tack coat is applied to the prepared surface and the geotextile is rolled out onto the tack coat using mechanical laydown equipment to minimize the amount of wrinkling or folding. The tack coat should be such that it saturates the geotextile without having excess material that can cause bleeding at the surface. Sand is sprinkled on the geotextile surface (optional) and pneumatic rollers are used to roll the geotextile to ensure full saturation and intimate contact between the geotextile and underlying pavement. After rolling, any excess sand is swept from the surface with mechanical brooms. At this point, the chip seal can be constructed. The bituminous binding agent is sprayed onto the prepared working surface by the distributor; then, the aggregate chips are spread onto the surface using an aggregate spreader. After the aggregate chips are placed, the surface is rolled with a pneumatic-tired roller to embed and realign the aggregate chips in the binder. The surface should be rolled before the binding agent begins to set. The constructed surface should consist of a single layer of aggregate chips with about two-thirds of the voids being filled with the binding agent. The time available for rolling before the binder hardens will depend on the type of binding agent, binder temperature when it is placed, air temperature, and wind, but can range from several minutes to several hours. Once the binding agent has hardened, the road surface should be swept with a mechanical broom to remove all loose chips from the surface. A slurry seal can be applied to the chip seal after construction to improve the bonding of the chips to the road surface.

**Weather Restrictions**: Do not construct chip seals over geotextile if it is raining or there is an imminent risk of rain. The specified minimum air temperature for chip seal placement varies between different agencies, but is normally 10 °C (50 °F) or above.

**Construction Rate**: Chip seal over geotextile construction rates are in the range of 8,400 $m^2$/day (10,000 $yd^2$/day). The chip seal can be constructed the same day that the geotextile is placed.

**Lane Closure Requirements**: The roadway lane(s) being constructed is closed during construction, so adequate traffic control is needed. The chip seal surface can be opened to traffic at lower speeds as soon as it is constructed. Normal traffic speeds can be allowed once the loose chips have been swept from the roadway surface. Road surface striping may be performed after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Chip seals over geotextile are not a very common roadway surfacing. Some research, design and construction information, and project experience is available. Performance histories give mixed results regarding the performance of chip seals over geotextile. Many failures can be attributed to poor construction or improper use of the surfacing. On the other hand, agencies familiar with this type of surfacing and who use experienced contractors have reported good results.

**Life Expectancy:** Life expectancy varies depending on construction materials used, environmental conditions, and traffic volumes. Typical serviceable lives range from 3 to 7 years (average 5 years). Longer serviceable lives, typically 10 to 20 years, are possible if a double chip seal or Cape seal is constructed over the geotextile.

**Ride Quality:** Chip seals over geotextile, similar to other non-structural asphalt surfacings, do not improve ride quality; ride quality is mainly determined by the roughness of the underlying layer. On a proper prepared application surface, a good to very good ride quality can be achieved after construction. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Raveling, bleeding, loss of chips and surface friction, slippage of the surfacing.

**Preservation Needs:** Preventative maintenance may include periodic crack sealing.

**SAFETY**

**Hazards**: Road splash/spray can reduce visibility during periods of higher traffic volume. Loose aggregate chips can create a windshield hazard. 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**: Provided high quality aggregates are used, chip seals provide good to excellent skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: Because chip seals over geotextile can provide a high-quality road surfacing, there is a tendency for higher road usage and speeding.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) or solvents (for cutback asphalts) are manufactured products. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used. Nonwoven geotextiles are manufactured from polypropylene textile specifically for use as a construction material.

**Delivery and Haul Requirements:** Bituminous binding agent, aggregate, and geotextile must be hauled to the site. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: If paving grade asphalt cement is used, significant heat is released during the placement process. Construction processes may impact vegetation adjacent to the roadway. If clean aggregate is not used, dust can be a problem during construction and sweeping. Excess loose chips can be thrown/brushed/washed from the surface into the surrounding environment. Hydrocarbon emissions into the atmosphere can be a significant impact if cutback asphalts are used.

Cutback asphalts can potentially impact water quality and aquatic species due to runoff if heavy rains occur before the cutback asphalt cures. Surface runoff should be properly contained or managed during the curing stage when the project is adjacent to bodies of water.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Chip seals over geotextile are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by chip seal over geotextile surfacings

*Erosion:* Chip seals over geotextile are a bound surface and are not particularly susceptible to surface erosion. Some aggregate loss can be expected due to a combination of traffic and erosional processes.

*Water quality*: Chip seals over geotextile have a minimal impact on water quality. Water quality could be affected by sediment loading from dust or crushed chips from the chip seal surface.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Chip seals over geotextile can be pulverized and reused as an unbound or stabilized material. The presence of the geotextile may eliminate hot or cold in-place recycling options.

**Other Environmental Considerations:** The amount of heat generation associated with chip seal construction varies significantly with the type of bituminous binding agent used. Paving grade asphalt cement results in the highest level of heat generation, with cutback asphalt seals generating less heat and emulsified asphalt seals generating even less heat. For chip seals over geotextile, tire/road noise is typically low to moderate with the same or slightly higher [2 dB(A)] noise level than HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)].

**AESTHETICS**

**Appearance:** Immediately after placement, the chip seal's appearance is influenced by the black bituminous binder and the aggregate chip color. A chip seal's appearance can be modified with the careful selection of colored aggregates and by the use of pigments in the binding agent.

**Appearance Degradation Over Time:** Over time, the chip seal surface will wear, exposing more of the geotextile fabric. The use of preventative maintenance treatments, such as fog seal or slurry seal, will add a black appearance to the surface.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$3.40 to \$4.80/$m^2$ (\$2.80 to \$4.00/$yd^2$).

**EXAMPLE PROJECTS**

Yaqui Pass Road, San Diego County, CA.
City of Sunnyvale, CA.

**SELECT RESOURCES**

Asphalt Emulsion Manufacturers Association, (410) 267-0023, www.aema.org.
Asphalt Interlayer Association, www.aia-us.org.

## *FOG SEAL*

### GENERAL INFORMATION

**Generic Name(s):** Fog Seal

**Trade Names:** N/A

**Product Description:** A fog seal is a light application of emulsified asphalt diluted with water. Fog seals were used extensively in the past to seal new pavements immediately after construction. They often performed poorly due to excessive slipperiness when wet and bleeding during hot weather; these problems where mainly due to excessive application rates or inappropriate choice of seal materials. Currently, fog seals are predominately used to enrich oxidized asphalt surfaces or to seal very small cracks and surface voids.

**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.

### APPLICATION

**Typical Use:** Preventative maintenance treatment for small cracks, oxidation, and raveling.

**Traffic Range:** Very Low to High.

**Restrictions:**

*Traffic*: Fog seal use is sometimes restricted on high volume roadways due to concerns over reduced skid resistance and short life expectancy; for high volume applications, a high degree of construction experience and quality control is required.

*Climate*: None.

*Weather*: None.

*Terrain*: Fog seal may not be appropriate for winding roads due to slipperiness.

*Soil Type*: N/A

*Other*: None.

**Other Comments:** Fog seals should not be used on roadway surfaces with low skid resistance. Fog seals work best on coarse or porous surfaces where the emulsified asphalt can penetrate the surfacing. When applied to smooth, dense surfacings, fog seals can lie on top of the existing surface and create a slippery surface. Fog seals can extend the life of roadway surfacings and can be used as a "holding" strategy (i.e. delay the need for major maintenance or rehabilitation). Fog seals are often used on newly constructed chip seals to provide a uniform black color and to minimize aggregate loss.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** N/A

**Other Comments:** None.

### CONSTRUCTION

**Availability of Experienced Personnel**: Fog seals are a commonly used maintenance treatment and experienced contractors are, in general, widely available. Maintenance crews are used by some agencies for fog seal application.

**Materials**: Fog seals consist of slow-setting emulsified asphalt diluted with water. The emulsified asphalt can be diluted with up to five parts (typically one part) water to one part emulsified asphalt. Modified asphalt cements, including rejuvenators, can be used to enhance the fog seal's effectiveness. Quick setting asphalt emulsions such as CQS-1h may be used to decrease cure time.

**Equipment**: Fog seal application only requires an asphalt distributor truck.

**Manufacturing/Mixing Process**: The emulsified asphalt must be diluted with water prior to fog seal application. The dilution ratio should be such that the entire surfacing is covered without excessive ponding that can create a slippery surface. Extended storage of a diluted asphalt emulsion is not recommended.

**Placement Process**: The diluted emulsified asphalt is applied cold with application temperatures ranging from 20° to 85°C (70° to 185°F). The diluted emulsified asphalt is sprayed onto the prepared working surface by the distributor. Typical application rates for the diluted emulsified asphalt are 0.45 to 0.70 liter/$m^2$ (0.10 to 0.15 gal/$yd^2$). A uniform coverage of the fog seal should be achieved for best performance.

**Weather Restrictions**: Do not construct fog seals if it is raining or there is an imminent risk of rain. The specified minimum air temperature for fog seal application varies between different agencies, but is normally 4 °C (40 °F) or above.

**Construction Rate**: Fog seal application rates are commonly 25,200 $m^2$/day (30,000 $yd^2$/day).

**Lane Closure Requirements**: The roadway lane(s) being treated is closed during construction, so adequate traffic control is needed. The fog seal surface can be opened to traffic after the emulsified asphalt has set, typically 1 to 3 hours, depending on the weather. Road surface striping may be performed after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Fog seals are a very common roadway surfacing treatment; an extensive amount of construction information and project experience is available.

**Life Expectancy:** Life expectancy varies depending on construction materials used, environmental conditions, and traffic volumes. Typical serviceable lives range from 1 to 3 years (average 2 years).

**Ride Quality:** Fog seals do not affect the ride quality of a roadway.

**Main Distress / Failure Modes:** Surface wear, bleeding.

**Preservation Needs:** None.

**SAFETY**

**Hazards**: None.

**Skid Resistance**: Fog seals can lower the skid resistance of a surfacing and create a slippery surface if it is applied too thick.

**Road Striping Possible?**: Yes.

**Other Comments**: None.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents are manufactured products. Water is a natural resource.

**Delivery and Haul Requirements:** Emulsified asphalt must be hauled to the site. Haul distances may be significant for remote sites.

Asphalt Surfacings (non-structural)



**Potential Short-Term Construction Impacts**: Spraying processes may impact vegetation adjacent to the roadway, especially in windy conditions.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Fog seals help seal the surfacing, which promotes surface runoff. However, surface runoff water quality is not generally impacted by fog seals.

*Erosion:* None.

*Water quality*: None.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Fog seal treatments are too thin to recycle. However, fog seal-treated asphalt materials can be pulverized and reused as an unbound or stabilized material.

**Other Environmental Considerations:** The amount of heat generation associated with fog seal application is significantly less than hot laid surfacings.

**AESTHETICS**

**Appearance:** Immediately after placement, fog seals are black. A fog seal's appearance can be modified with the use of pigments in the emulsified asphalt.

**Appearance Degradation Over Time:** Over time, the fog seal surface will wear, typically in strips or patches, exposing the underlying roadway material.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$0.25 to \$0.60/$m^2$ (\$0.20 to \$0.50/$yd^2$).

**EXAMPLE PROJECTS**

Fog seals are used extensively throughout the United States, mainly as a maintenance treatment.

**SELECT RESOURCES**

Asphalt Emulsion Manufacturers Association, (410) 267-0023, www.aema.org
Asphalt Institute. *A Basic Asphalt Emulsion Manual*, Manual Series No. 19 (MS-19), Third Edition, Lexington, Kentucky, 120 pp.
USDA Forest Service (1999), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center.

## *MICROSURFACING*

### GENERAL INFORMATION

**Generic Name(s):** Microsurfacing

**Trade Names:** Microsurfacing, Ralumac, Macroseal

**Product Description:** Microsurfacing, an enhanced slurry seal, is composed of a mixture of polymer-modified emulsified asphalt, dense-graded crushed fine aggregate, mineral filler or other additives, and water. The main difference between microsurfacing and slurry seals is that microsurfacing can be placed with a thickness up to about three times the size of the largest aggregate in the mix; slurry seals are applied at the thickness of the largest aggregate in the mix. High quality materials and careful mix design are used to create a high-stability mix that is quick-setting and can be placed at thicknesses up to 38 mm (1.5 in.) for rut filling. In addition to rut-filling, microsurfacing is used as a preventative maintenance treatment for roadways with bituminous surfacing.

**Product Suppliers:** Representative list of manufacturers, suppliers, and contractors can be obtained from: International Slurry Surfacing Association, PMB 250, 3 Church Circle, Annapolis, MD 21401, (410) 267-0023, www.slurry.org

### APPLICATION

**Typical Use:** Preventative maintenance or corrective treatment for minor surface irregularities, small cracks (less than 6 mm [0.25 in.] wide), rutting (fill ruts up to 38 mm [1.5 in.] deep in one pass), raveling, bleeding, and loss of surface friction and to improve ride quality.

**Traffic Range:** Very Low to High. Typically used for AADT>400.

**Restrictions:**

*Traffic*: None.

*Climate*: None.

*Weather*: None.

*Terrain*: None.

*Soil Type*: N/A

*Other*: Microsurfacing is less susceptible to damage from snow plows than single chip seals or slurry seals in snow plowing areas.

**Other Comments:** Microsurfacing is smoother than chip seals and may be preferred by non-vehicular users (i.e. bicyclists, in-line skaters, etc.) in recreational areas. When microsurfacing is used to address pavement rutting, the cause of rutting should be established in advance. Microsurfacing can rehabilitate rutting due to densification but is not a solution for correcting rutting due to inadequate structural capacity or high instability (i.e. shoving).

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** N/A

**Other Comments:** None.

**CONSTRUCTION**

**Availability of Experienced Personnel**: Microsurfacing construction generally requires experienced specialty contractors. In remote areas, specialty contractors may not be locally available, but they are generally available on a statewide or regional level.

**Materials**: Microsurfacing is constructed of a mixture of polymer-modified emulsified asphalt, dense-graded crushed fine aggregate, mineral filler or other additives, and water. Polymers are added to the emulsified asphalt to increase mixture stiffness and flexibility, which leads to better rut resistance, durability, and crack resistance. Special quick-setting emulsifiers are used for the emulsified asphalt. Aggregates should consist of 100% crushed high quality aggregate. The maximum aggregate size varies with gradation type: 6 mm (1/4 in.) for Type II slurry, and 9 mm (3/8 in.) for Type III slurry. Type II gradation is typically used for medium volume roadways and Type III gradation is typically used for rut filling and high volume roadways.

**Equipment**: Microsurfacing requires a special microsurfacing machine with an attached spreader box with a double strike-off blade design. The microsurfacing unit can be truck-mounted or self-propelled. When filling ruts over 12 mm (0.5 in.), a special rut box should be used to address the ruts individually. Equipment is locally available in many large urban areas and regionally available in more remote areas. The microsurfacing unit should be calibrated using site-specific materials and mix proportions prior to each construction job.

**Manufacturing/Mixing Process**: The microsurfacing unit carries all the unmixed materials and, when construction commences, combines the materials in exact mix proportions in a continuous flow pugmill. For continuous operation, haul vehicles must replenish materials to the mixing machine.

**Placement Process**: It is important that any areas of base failure be repaired before microsurfacing is applied. A tack coat is usually not required unless the surface is extremely dry and raveled or consists of concrete or brick. The microsurfacing mix is automatically fed into a spreader box attached to the rear of the equipment and applied to the roadway. Microsurfacing is commonly applied at a rate of 11 to 16 $kg/m^2$ (20 to 30 $lb/yd^2$) with a corresponding thickness of 9 to 16 mm (0.375 to 0.625 in.). Rolling or compaction is seldom required but may be beneficial in areas of minimal traffic such as parking lots or airports. For high volume applications, two lifts of microsurfacing can be placed, consisting of a leveling layer and a surface layer.

**Weather Restrictions**: Do not place microsurfacing if it is raining or there is an imminent risk of rain, or there is a danger of freezing within 24 hours. The specified minimum air temperature for microsurfacing placement is normally 10 °C (50 °F) or above.

**Construction Rate**: Microsurfacing construction rates can typically be about 450 Mg/day (500 tons/day) or about 10.5 lane-km per day (6.6 lane-miles per day) with a continuous run operation.

**Lane Closure Requirements**: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. Depending on the type of emulsified asphalt used and weather conditions, roads can usually be opened to straight rolling traffic about one hour after placement. Road surface striping may be performed after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Microsurfacing was pioneered in Germany in the 1960s and 1970s and introduced to the United States in 1980. Most agencies have some experience with microsurfacing while some have extensive experience. Microsurfacing research reports, design and construction guidelines, and performance data are available.

**Life Expectancy:** Life expectancy varies depending on mix types, traffic volumes and environmental conditions. Typical serviceable lives range from 5 to 8 years (average 7 years).

**Ride Quality:** Microsurfacing can improve the ride quality of a previously paved roadway by filling in ruts and other defects. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Bleeding, removal, and wear of the microsurfacing due to tire abrasion.

**Preservation Needs:** Fog seals can be applied to extend the serviceable life of microsurfacing.

**SAFETY**

**Hazards**: Road splash/spray can reduce visibility during periods of higher traffic volumes.

**Skid Resistance**: Microsurfacing provides excellent skid resistance and is frequently used to restore skid resistance to worn HACP.

**Road Striping Possible?**: Yes.

**Other Comments**: Because microsurfacing provides a high-quality road surfacing, there is a tendency for higher road usage and speeding.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) are manufactured products. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** Emulsified asphalt, aggregates, and additives must be hauled to the site. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: None.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Microsurfacing is impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted.

*Erosion:* None.

*Water quality*: None.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Microsurfacing can be pulverized and reused as an unbound or stabilized material.

**Other Environmental Considerations:** Microsurfacing is cold-mixed and cold-laid and has much lower energy requirements and heat generation compared to hot mixed and hot-placed road surfacings. For microsurfacing, tire/road noise is typically low to moderate with a slightly higher noise level than HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)]., but with a lower noise level than chip seals.

**AESTHETICS**

**Appearance:** Microsurfacing is typically black in appearance, similar to HACP. Microsurfacing's color can be modified by the use of pigments in the microsurfacing mix.

**Appearance Degradation Over Time:** Over time, the microsurfacing may wear, exposing more of the aggregate and modifying the appearance. As microsurfacing approaches the limit of its service life it becomes streaky and the underlying asphalt pavement becomes exposed. The use of preventative maintenance treatments, such as fog seals, will maintain the black surface color.

Asphalt Surfacings (non-structural) Microsurfacing: Page 4 of 4

**COST**

**Supply Price**: N/A

**Supply+Install Price**: $105 to $132/Mg ($95 to $120/ton) or $3.10 to $3.90/$m^2$ ($2.60 to $3.30/$yd^2$).

**EXAMPLE PROJECTS**

Campground access roads and parking lots; Keystone Lake, Skiatook Lake, and Oologah Lake, OK; Army Corps of Engineers project.
Interstate 75, Wayne County, MI, from I-94 Interchange to 8-Mile Road.

**SELECT RESOURCES**

International Slurry Surfacing Association, (410) 267-0023, www.slurry.org.
Asphalt Institute. *A Basic Asphalt Emulsion Manual*, Manual Series No. 19 (MS-19), Third Edition, Lexington, Kentucky, 120 pp.
International Slurry Seal Association (2003). *Recommended Performance Guidelines for Micro-Surfacing*, A143, International Slurry Seal Association, 16 pp.
USDA Forest Service (1999), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center.

## *MULTIPLE SURFACE TREATMENTS (SEALS)*

### GENERAL INFORMATION

**Generic Name(s):** Multiple Surface Treatments, Double Chip Seal, Triple Chip Seal, Sandwich Seal

**Trade Names:** N/A

**Product Description:** A chip seal is a single thin surface treatment constructed by spraying a bituminous binding agent and immediately spreading and rolling a thin aggregate cover. The bituminous binding agent can be an emulsified asphalt, cutback asphalt, or asphalt cement. To increase the service life or durability of the surfacing, double or triple chip seals are often applied. Double and triple chip seals consist of 2 and 3 layers of chip seal, respectively. The first chip seal has the largest aggregate size (generally up to 19 mm [3/4 in.]) and determines the thickness of the completed surface layer. For each successive layer, the aggregate size is approximately one-half the size of the aggregate in the previous layer. Each additional layer partially fills in the voids in the previous layer. This technique greatly reduces particle loss and extends the service life of the surfacing. Multiple surface treatments are less susceptible to the effects of minor construction defects than a single chip seal.

A sandwich seal is similar to a double chip seal, except the first layer of asphalt binder is omitted. A large aggregate, typically 15 to 19 mm (5/8 to 3/4 in.), is placed, followed by asphalt emulsion and another layer of smaller aggregate, typically 6 to 13 mm (1/4 to 1/2 in.). The emulsion application rate is more than the amount typical for a single chip seal, but less than the rate for a double chip seal. Sandwich seals are useful as a corrective measure for bleeding on existing roadway surfaces.

**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; or

California Chip Seal Association, 14929 Slover Avenue, Fontana, CA 92335, www.chipseal.org.

### APPLICATION

**Typical Use:** Road surfacing; preventative maintenance treatment for small cracks, bleeding, raveling, and loss of surface friction. Multiple surface treatments are a widely used alternative for surfacing low volume roads. They protect underlying materials from water and erosion and provide a relatively smooth riding surface. In general, multiple surface treatments provide an economical and relatively durable surface that is safe under normal weather and driving conditions. Multiple surface treatments can also be placed over new or existing HACP to modify, maintain, or improve the surface texture and friction properties and/or seal small cracks. However, it should be noted that a multiple surface treatment is not as durable as well constructed HACP. Multiple surface treatments may also be used as a crack relief layer or membrane prior to the application of new HACP.

**Traffic Range:** Very Low to Medium when multiple surface treatments are placed over aggregate base, Very Low to High (typically AADT < 2000) when multiple surface treatments are placed over existing HACP.

**Restrictions:**

*Traffic*: Multiple surface treatments should generally be limited to traffic mixes with less than 15% trucks. The use of multiple surface treatments should be avoided in areas with frequent truck turning or braking.

*Climate*: None.

*Weather*: None.

*Terrain*: Multiple surface treatments are not recommended for roadway gradients steeper than 8%.

*Soil Type*: N/A

*Other*: Multiple surface treatments can be damaged by snowplow operations, but are more durable that single chip seals.

**Other Comments:** The grade of asphalt cement needs to be selected based on service temperature ranges and traffic volumes. Local practice or supplier recommendations should be followed. Multiple surface treatments are more appropriate than single chip seals for new road construction over a base material while single chip seals are used more often as a preventative maintenance treatment over an existing sealed or paved surface. Multiple surface treatments are less sensitive to minor construction defects than single chip seals.

**DESIGN**

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** Multiple surface treatments are often constructed over an aggregate base course. Since multiple surface treatments do not add significantly to the structural capacity of the roadway, the base/subbase is designed to support the anticipated traffic loading. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to surface treatment placement. A prime coat is sometimes used above the aggregate base prior to surface treatment application.

**Other Comments:** Multiple surface treatment performance is highly dependent on the quality of workmanship and the component materials used.

**CONSTRUCTION**

**Availability of Experienced Personnel**: Multiple surface treatments are a commonly used surfacing and experienced contractors are, in general, widely available. Maintenance crews are used by some agencies for multiple surface treatment construction.

**Materials**: Multiple surface treatments are constructed of a bituminous binding agent (emulsified asphalt, cutback asphalt, or asphalt cement) and clean, crushed aggregate chips. The first layer has the largest aggregate size (generally up to 19 mm [3/4 in.]) and determines the thickness of the surface layer thickness. For each successive layer, the aggregate size is approximately one-half the size of the aggregate in the previous layer. Modified asphalt cements can be used to enhance certain performance characteristics. Some agencies require that chips be pre-coated with a bituminous material to improve adhesion and reduce the amount of loose chips. Pre-coated chips are not generally recommended when using emulsified asphalt.

*Paving Grade Asphalt Cement:* Advantages of using paving grade asphalt cement is that it cures quickly, does not require any additives in the asphalt cement, and the material achieves full strength as soon as it cools. Disadvantages of asphalt cement include a high application temperature (121 to 177 °C [250 to 350 °F]) and the need to place the aggregate quickly before that asphalt cement cools.

*Cutback Asphalt*: Advantages of using cutback asphalts include cooler application temperatures (30 to 115 °C [85 to 240 °F]) than paving grade asphalts and higher asphalt percentages than emulsified asphalts (approximately 80% compared to approximately 60%). Disadvantages of cutback asphalts include higher cost than emulsified asphalts, 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 a cooler application temperature (20 to 85 °C [70 to 185 °F]) than paving grade or cutback asphalts, and water that evaporates is environmentally safe.

**Equipment**: Equipment required for multiple surface treatment construction includes: asphalt distributor, aggregate spreader, pneumatic-tired roller, and mechanical broom. Equipment is widely available in most areas, but availability may be limited in remote areas.

**Manufacturing/Mixing Process**: The binding agent (either an emulsified or cutback asphalt or asphalt cement) is produced by an asphalt supplier and shipped to the site. Aggregate is usually crushed and separated by size to obtain uniform-sized chips for use. If the chips are to be pre-coated with bituminous materials, it is performed at the plant before the chips are shipped to the site.

**Placement Process**: The bituminous binding agent is sprayed onto the prepared working surface by the distributor; then, the aggregate chips are spread onto the surface using an aggregate spreader. After the aggregate chips are placed, the surface is rolled with a pneumatic-tired roller to embed and realign the aggregate chips in the binder. The surface should be rolled before the binding agent begins to set. The time available for rolling before the binder hardens will depend on the type of binding agent, binder temperature when it is placed, air temperature, and wind, but can range from several minutes to several hours or more. Once the binding agent has hardened, the road surface should be swept with a mechanical broom to remove all loose chips from the surface. This process is repeated for each additional treatment layer. The initial application of bituminous binding agent is omitted when constructing a sandwich seal. A fog seal can be applied to the multiple surface treatment after construction to improve the bonding of the chips to the road surface.

**Weather Restrictions**: Do not construct multiple surface treatments if it is raining or there is an imminent risk of rain. When using emulsified asphalt, do not apply when freezing temperatures are expected within 24 hours. The specified minimum air temperature for multiple surface treatment placement varies between different agencies, but is normally 10 °C (50 °F) or above.

**Construction Rate**: Chip seal construction rates are in the range of 12,500 $m^2$/day (15,000 $yd^2$/day) for each treatment layer. Depending on the number of treatment layers and curing times, multiple surface treatments can be constructed in one to several days.

**Lane Closure Requirements**: The roadway lane(s) being constructed is closed during construction, so adequate traffic control is needed. The surfacing can be opened to traffic at lower speeds as soon as it is constructed. Normal traffic speeds can be allowed once the loose chips have been swept from the roadway surface. Road surface striping may be performed after the final treatment layer is constructed and lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Multiple surface treatments are a very common roadway surfacing and have been used on projects for more than 50 years; an extensive amount of research, design and construction information, and project experience is available. Performance reliability and life expectancy varies with materials used, construction practices, and application. Local project experience can be a useful resource.

**Life Expectancy:** Life expectancy varies depending on construction materials used, environmental conditions, and traffic volumes. Typical serviceable lives range from 4 to 8 years (average 6 years). Multiple surface treatments placed over aggregate or stabilized bases are generally more susceptible to premature structural failures as opposed to multiple surface treatments placed over an existing paved roadway.

**Ride Quality:** Multiple surface treatments, similar to other non-structural asphalt surfacings, do not improve ride quality; ride quality is mainly determined by the roughness of the underlying layer. On a properly prepared application surface, a good to very good ride quality can be achieved after construction. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Loss of Chips and Surface Friction, Bleeding, Potholing.

**Preservation Needs:** Preventative maintenance includes periodic crack sealing. Fog seals can be applied to extend the serviceable life of multiple surface treatments.

**SAFETY**

**Hazards**: Rutting can lead to water accumulation on the pavement surface, causing a driving hazard. Road splash/spray can reduce visibility during periods of higher traffic volume. Loose aggregate chips can create a windshield hazard. When cutback asphalts are used, the solvents used can create a health hazard (fumes) and a fire/explosion hazard during storage and construction; proper engineering controls and construction practices should be utilized to minimize safety risks.
**Skid Resistance**: Provided high quality aggregates are used and they are well bonded to the surface, multiple surface treatments provide good to excellent skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: Because multiple surface treatments can provide a high-quality road surfacing, there is a tendency for higher road usage and speeding.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) or solvents (for cutback asphalts) are manufactured products. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** Bituminous binding agent and aggregate must be hauled to the site. Haul distances may be significant for remote sites, unless local aggregate sources can be identified.

**Potential Short-Term Construction Impacts**: If paving grade asphalt cement is used, significant heat is generated during the placement process. Construction processes may impact vegetation adjacent to the roadway. If clean aggregate is not used, dust can be a problem during construction and sweeping. Excess loose chips can be thrown/brushed/washed from the surface into the surrounding environment. Hydrocarbon emissions into the atmosphere can be a significant impact if cutback asphalts are used. Cutback asphalts can potentially impact water quality and aquatic species due to runoff if heavy rains occur before the cutback asphalt cures. Surface runoff should be properly contained or managed during the curing stage when the project is adjacent to bodies of water.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Multiple surface treatments are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by multiple surface treatment surfacings

*Erosion:* Multiple surface treatments are a bound surface and are not susceptible to surface erosion. Some aggregate loss may be possible due to a combination of traffic and erosional processes.

*Water quality*: Multiple surface treatments have a minimal impact on water quality. Water quality could be affected by sediment loading from dust or crushed chips from the multiple surface treatment surface.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Multiple surface treatments can be pulverized and reused as an unbound or stabilized material.

**Other Environmental Considerations:** The amount of heat generation associated with multiple surface treatments construction varies significantly with the type of bituminous binding agent used. Paving grade asphalt cement results in the highest level of heat generation, with cutback asphalt seals generating less heat and emulsified asphalt seals generating even less heat. For multiple surface treatments, tire/road noise is typically low to moderate with the same or slightly higher [2 dB(A)] noise level than HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)].

**AESTHETICS**

**Appearance:** Immediately after placement, the multiple surface treatment's appearance is influenced by the black bituminous binder and the aggregate chip color. If the chips are pre-coated, the multiple surface treatments will be black and will not be characterized by the natural aggregate color. A multiple surface treatment's appearance can be modified with the careful selection of colored aggregates and by the use of pigments in the binding agent.

**Appearance Degradation Over Time:** Over time, the multiple surface treatment will wear, exposing more of the aggregate. The use of preventative maintenance treatments, such as fog seals, will add a black appearance to the surface.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$1.50 to \$3.00/$m^2$ (\$1.25 to \$2.50/$yd^2$).

**EXAMPLE PROJECTS**

Multiple surface treatments are used extensively throughout the United States.
Antelope House and Mummy Cave Overlook Roads, Canyon de Chelly National Monument, AZ.

**SELECT RESOURCES**

Asphalt Emulsion Manufacturers Association, (410) 267-0023, www.aema.org.
Asphalt Institute. *A Basic Asphalt Emulsion Manual*, Manual Series No. 19 (MS-19), Third Edition, Lexington, Kentucky, 120 pp.
Janisch, D.W., and Gaillard, F.S. (1998). *Minnesota Seal Coat Handbook*, Draft Report, Minnesota Local Road Research Board, Maplewood, MN, 116 pp.
USDA Forest Service (1999), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center.

## *OPEN GRADED FRICTION COURSE*

### GENERAL INFORMATION

**Generic Name(s):** Open Graded Friction Course (OGFC)

**Trade Names:** N/A

**Product Description:** Open graded friction course (OGFC) is a porous hot mix asphalt concrete wearing course, containing little sand or dust and with high air voids content (typically from 15 to 25%). The open graded friction course is designed to allow water to drain through to an impermeable barrier and, following the cross slope of the roadway, drain into a side ditch. The drainage capacity of an OGFC is a direct function of the air voids. OGFC has very good frictional properties, provides quick drainage, and reduces hydroplaning, splash/spray from vehicles, headlight glare, and road noise. OGFC is also less susceptible to deformation than HACP.

**Product Suppliers:** Representative list of manufacturers, suppliers, and contractors can be obtained from: National Asphalt Pavement Association, 5100 Forbes Blvd., Lanham, MD 20706, (888) HOT-MIXX, www.hotmix.org.

### APPLICATION

**Typical Use:** Road surfacing.

**Traffic Range:** Very Low to High. OGFC is used mainly on medium and high volume roads; on very low to low volume roads, the low volume of traffic allows dust and other materials that can clog the OGFC pores to accumulate on the road surface.

**Restrictions:**

*Traffic*: OGFC is not recommended for areas subjected to significant heavy vehicle braking or turning.

*Climate*: OGFC use in cold climates, where snow and ice are common, is limited and requires special winter maintenance procedures. Because OGFC has an open structure, it can freeze sooner than conventional asphalt concrete mixes. Snow and ice control should be limited to snow plowing and chemical deicers. Road crew must apply road salt at lower application rates, but more frequently. Winter maintenance sand cannot be used because it can clog the pores of the OGFC mix.

*Weather*: None.

*Terrain*: None.

*Soil Type*: N/A

*Other*: None.

**Other Comments:** None.

### DESIGN

**SLC:** N/A; structural capacity of OGFC is not considered in the structural design of the pavement system. OGFC is normally used to increase frictional properties of the road surface and improve driving conditions. It is placed directly above conventional HACP layers.

**Other Design Values**: N/A

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

**Other Comments:** The grade of asphalt cement needs to be selected based on service temperature ranges and traffic volumes. Traditionally, asphalt cement grades have been designated as pen grade (60/70, 85/100, etc.) or by viscocity grades (AC-20, AC-30, etc.). Currently, asphalt cements are specified by Performance Grades (PG), such as PG 64-22, indicating the high and low temperature range in °C. The use of polymers to expand the temperature range of an asphalt will improve rutting resistance at high temperatures and reduce thermal cracking at low temperatures.

OGFC is typically only used as a surface wearing course with a maximum layer thickness of 19 mm (0.75 in.). In a typical OGFC pavement structure, the underlying binder course is impermeable and the water entering through the surface course is drained to ditches. The water must be allowed to drain freely out of the pavement at the pavement's edge.

The primary mix performance problems are raveling and stripping of underlying layers. Gap-graded mixes with low fines content (high air voids) may have asphalt binder draindown problems, i.e. loss of asphalt binder. Polymers and other additives are used to control draindown, improve adhesion, and improve resistance to aging.

**CONSTRUCTION**

**Availability of Experienced Personnel**: OGFC is a commonly used surfacing in many states and experienced contractors are, in general, widely available. Availability may be limited for projects in remote areas.

**Materials**: Open graded friction course (OGFC) consists of porous HACP, containing little sand or dust and with high air voids content (typically from 15 to 25%). HACP is composed of a blend of coarse and fine aggregate with asphalt cement as a binder. Polymer modified asphalt cements and fibers are frequently used to control draindown, improve adhesion, and improve resistance to raveling and oxidation.

**Equipment**: Equipment required for OGFC construction includes: haul vehicles, asphalt distributor (if tack coat is applied), asphalt paver machine, and compaction equipment (i.e. static steel wheel roller). Equipment is widely available in urban areas, but availability may be limited in remote areas.

**Manufacturing/Mixing Process**: OGFC is hot mixed at an asphalt plant by mixing specified proportions of the heated material components together to form a uniform mixture. Asphalt concrete mixes are normally mixed at temperatures between 132 to 163 °C (270 to 325 °F). After mixing, the product is placed in trucks to be transported to the project site. The asphalt concrete mix must arrive on-site and be placed before it cools. When transported in insulated vehicles with a tarp cover, the asphalt mixture can remain at an adequate temperature for up to approximately 1.5 hours.

**Placement Process**: A tack coat is usually applied to the binder course before OGFC is placed. Upon arrival at the site, the OGFC mixture is transferred from the haul vehicles into the paver hopper, spread onto the prepared working surface by the paver, and leveled by a screed at the rear of the asphalt paver. The OGFC is then rolled with compaction equipment to seat the material before the asphalt binder solidifies, which occurs at about 85 °C (185 °F) for neat asphalt and 115 °C (240 °F) for polymer modified asphalt. The time available for compaction before the mix has cooled will depend on the mix temperature when it is placed, layer thickness, air temperature, and wind, but can range from several minutes to more than 30 minutes.

**Weather Restrictions** Do not place OGFC if it is raining or there is ponded water on the prepared paving surface or if the surface is frozen. The specified minimum air temperature for asphalt concrete placement varies between different agencies, but is normally about 16 °C (60 °F).

**Construction Rate**: OGFC placement rates will depend on the speed that the asphalt concrete mixture is delivered, layer thickness, and paving width. Placement rates can be 0.2 m/sec (40 ft/min) or higher. Typical production rates are 900 to 1,360 Mg/day (1,000 to 1,500 tons/day).

**Lane Closure Requirements**: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The paving is relatively fast so can be done during a night lane closure, assuming temperature requirements can be met, to minimize traffic disruption. The OGFC surface can be opened to traffic as soon as the OGFC has cooled and construction equipment is cleared from the roadway. Road surface striping may be performed before or after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** OGFC is a common roadway surfacing and has been used on roadway projects for about 50 years; an extensive amount of research, design and construction information, and project experience is available. Many states experienced problems with OGFC in the 1970s, leading them to stop using OGFC. Mix design improvements, including use of polymers and additives, have since led to improvements in OGFC performance and increased usage.

**Life Expectancy:** Life expectancy for OGFC typically ranges from 8 to 12 years.

**Ride Quality:** OGFC ride quality is very good. OGFC has good frictional characteristics, eliminates hydroplaning on the pavement surface, and significantly reduces the level of road/tire noise. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Raveling, shoving, stripping (in underlying layer), cracking.

**Preservation Needs:** Preventative maintenance includes crack sealing every 2 to 5 years. Asphalt seals can be used to extend the life of OGFC, but they will reduce the water-removing function of an OGFC.

**SAFETY**

**Hazards**: None.

**Skid Resistance**: OGFC provides very good to excellent skid resistance, thereby reducing the potential for wet skidding and hydroplaning accidents.

**Road Striping Possible?**: Yes.

**Other Comments**: Because OGFC provides a high-quality road surfacing, there is a tendency for higher road usage and speeding. Because OGFC has an open structure, it can freeze sooner than conventional asphalt concrete mixes. OGFC can reduce water spray by 90% compared to a dense-graded surface.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** OGFC must be hauled from an asphalt plant unless a mobile asphalt plant is assembled. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: Significant heat is generated during the OGFC mixing and placement process. Construction processes may impact vegetation adjacent to the roadway.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* OGFC is designed to allow infiltration of surface water into the surfacing layer. The water collected in the pavement is drained to the pavement edges. Surface runoff water quality is not generally impacted by OGFC roadways.

*Erosion:* OGFC is a bound material and is not susceptible to surface erosion. Shoulders and base material should be protected from fast moving water.

*Water quality*: OGFC does not impact water quality.

*Aquatic species*: OGFC does not impact aquatic species.

*Plant quality*: OGFC does not impact plant quality.

*Air Quality*: OGFC does not impact air quality.

*Other*: None.

**Ability to Recycle/Reuse:** OGFC can be fully recycled as a pavement construction material.

**Other Environmental Considerations:** OGFC's characteristic black surface will absorb heat from sunlight; select aggregates and pigments can be used to lighten the color and increase heat reflectivity of the surface. OGFC typically reduce tire/road noise by 3 decibels compared to conventional HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)] and 5 decibels compared to PCCP.

**AESTHETICS**

**Appearance:** Immediately after placement, OGFC is generally black with a coarse surface texture.

**Appearance Degradation Over Time:** Over time, OGFC can change color to a wide range of gray-blacks and occasionally has a brown or red sheen, depending on the predominant aggregate color. With maintenance activities, such as crack sealing, the surface appearance deteriorates further.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: $250 to $300/Mg ($225 to $275/ton), or $11.00 to $13.40/$m^2$ ($9.20 to $11.20/$yd^2$) for 19 mm (0.75 in.) thick layer.

**EXAMPLE PROJECTS**

State transportation agencies in Georgia, Oregon, and Texas have used OGFC on numerous highway and Interstate projects.

**SELECT RESOURCES**

Asphalt Institute, (859) 288-4960, www.asphaltinstitute.org.
National Asphalt Pavement Association (NAPA), (888) HOT-MIXX, www.hotmix.org.

## *OTTA SEAL*

### GENERAL INFORMATION

**Generic Name(s):** Otta Seal, Graded Gravel Seal

**Trade Names:** N/A

**Product Description:** An Otta seal is an asphalt surface treatment constructed by placing a graded aggregate on top of a thick application of relatively soft bituminous binding agent. The bituminous binding agent can be an emulsified asphalt, cutback asphalt, or asphalt cement. The binder works its way into the aggregate with rolling and traffic. In comparison to other surface treatments, material and construction specifications are not as strict. Local aggregates that would not meet the requirements for high quality paving aggregate are often used in Otta seals. The requirements on aggregate gradation, particle shape and strength are also relaxed.

**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.

### APPLICATION

**Typical Use:** Road surfacing.

**Traffic Range:** Very Low to Low for a single Otta seal; Very Low to High (AADT < 2000) for a double Otta seal.

**Restrictions:**

*Traffic*: Double Otta seals are not recommended for roadways with frequent truck traffic or areas subject to trucks turning or braking.

*Climate*: None.

*Weather*: None.

*Terrain*: Single Otta seals are generally not used for roadway gradients greater than 8%. Double Otta seals are generally not used for roadway gradients greater than 12%.

*Soil Type*: N/A

*Other*: Single Otta seals can be damaged by snow plow operations.

**Other Comments:** Otta seals have been used as an impermeable surfacing for moisture-susceptible gravel roads with low bearing capacity (i.e. roads during spring thaw period). The Otta seal shields the base material from moisture infiltration and is flexible enough to withstand the relatively large deflections associated with low bearing capacity roads without exhibiting significant distress. If there is permanent deformation of the base, the Otta seal will not knead back together.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** Otta seals are usually constructed over an aggregate base course. Since Otta seals do not add structural capacity to the roadway, the base/subbase must be designed to support the anticipated traffic loading. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to Otta seal placement. A prime coat is usually not used above the aggregate base prior to Otta seal application.

**CONSTRUCTION**

**Availability of Experienced Personnel**: Otta seal use in the United States has been very limited, so experienced contractors are generally not available. However, Otta seals are less sensitive to quality of workmanship and materials than other roadway surfacings. Otta seals can be constructed by qualified contractors or agency maintenance crews. Crews familiar with seal coating will be able to apply their equipment and experience.

**Materials**: An Otta seal is constructed of a graded aggregate on top of a thick application of relatively soft bituminous binding agent. The bituminous binding agent can be an emulsified asphalt (e.g. HFMS-2s), cutback asphalt (e.g. MC3000 to MC800), or asphalt cement (e.g. 150/200 penetration grade). Bituminous binder application rates vary from about 1.6 to 2.0 liter/$m^2$ (0.35 to 0.44 gal/$yd^2$) for asphalt cement to about 1.9 to 2.4 liter/$m^2$ (0.45 to 0.56 gal/$yd^2$) for emulsified asphalt, depending on binder type and aggregate gradation. In comparison to other surface treatments, material and construction specifications are not as strict. Local aggregates that would not meet the requirements for high quality paving aggregate are often used in Otta seals. Natural gravels are acceptable. The maximum aggregate size in the graded aggregate is generally 13 to 19 mm (1/2 to 3/4 in.). The graded aggregate can be crushed or uncrushed and contain up to 10% fines. Quantities of aggregate range from 27.1 to 33.6 kg/$m^2$ (50 to 62 lb/$yd^2$). The requirements on aggregate gradation, particle shape and strength are relaxed.

*Paving Grade Asphalt Cement:* Advantages of using paving grade asphalt cement is that it cures quickly, does not require any additives in the asphalt cement, and the material achieves full strength as soon as it cools. Disadvantages of asphalt cement include a high application temperature (121 to 177 °C [250 to 350 °F]) and the need to place the aggregate quickly before that asphalt cement cools.

*Cutback Asphalt*: Advantages of using cutback asphalts include cooler application temperatures (30 to 115 °C [85 to 240 °F]) than paving grade asphalts (130°C [265 °F] or higher) and higher asphalt percentages than emulsified asphalts (approximately 80% compared to approximately 60%). Disadvantages of cutback asphalts include higher cost than emulsified asphalts, 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 a cooler application temperature (20 to 85 °C [70 to 185 °F]) than paving grade or cutback asphalts. In addition, water that evaporates from emulsified asphalt is environmentally safe.

**Equipment**: Equipment required for Otta seal construction includes: asphalt distributor, aggregate spreader, pneumatic-tired roller, and mechanical broom. Equipment is widely available in most areas, but availability may be limited in remote areas.

**Manufacturing/Mixing Process**: The binding agent (either an emulsified or cutback asphalt or asphalt cement) is produced by an asphalt supplier and shipped to the site. Aggregate is processed to remove oversized aggregate and excess fines.

**Placement Process**: The bituminous binding agent is sprayed onto the prepared working surface by the distributor; then, the graded aggregate is spread onto the surface using an aggregate spreader. After the aggregate is placed, the surface is rolled with a pneumatic-tired roller to embed, realign the aggregate chips in the binder, and begin drawing the binder through the aggregate to the surface. Due to the fines in the aggregate, two or three days of compaction, either by rollers or traffic, is required for the binder to coat all the aggregate particles. During the first few weeks, aggregates dislodged from the surfacing by traffic should be swept back into the wheelpaths. After about three weeks, the surface should be swept by a mechanical broom to remove all loose aggregate from the surfacing. Single Otta seals are often overlaid with a sand seal. If a double seal is constructed, the second layer is constructed in a similar manner two to three months after the first layer is constructed. With attention to detail, a second application can be applied 1 day after the first application; however, two to three months is recommended.

**Weather Restrictions**: Do not construct Otta seals if it is raining or there is an imminent risk of rain. The specified minimum air temperature for Otta seal placement varies between different agencies, but is normally 10 °C (50 °F) or above.

**Construction Rate**: Otta seal construction rates are commonly 33,500 $m^2$/day (40,000 $yd^2$/day).

**Lane Closure Requirements**: The roadway lane(s) being constructed is closed during construction, so adequate traffic control is needed. The Otta seal surface can be opened to traffic at lower speeds, commonly 30 km/hr (20 mph), as soon as it is constructed. Normal traffic speeds can be allowed after about three weeks, when the loose aggregate has been swept from the roadway surface. Road surface striping may be performed after the loose aggregate is swept from the surfacing.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Otta seals were developed in Norway in the 1960s. They have been used frequently in Norway, Sweden, Iceland, and Botswana, and to a less extent in several other countries. Otta seal performance has been good in countries that are familiar with this type of surfacing. Otta seal design is empirical in nature and trial sections are often construction to determine the proper material application rates. Experience with Otta seals in the United States is very limited.

**Life Expectancy:** Life expectancy varies depending on construction materials used, environmental conditions, and traffic volumes. Reported serviceable lives for single and double Otta seals range 4 to 8 years and 8 to 15 years, respectively.

**Ride Quality:** Otta seals, similar to other non-structural asphalt surfacings, do not improve ride quality; ride quality is mainly determined by the roughness of the underlying layer. On a proper prepared application surface, a good ride quality can be achieved after construction. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Cracking, raveling, bleeding, potholes, loss of surface friction.

**Preservation Needs:** Only minor preventative maintenance, consisting of localized patching and sealing, is required between reapplications.

**SAFETY**

**Hazards**: Loose aggregate chips can create a windshield hazard. 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**: Skid resistance will vary depending on the quality of materials used during construction.

**Road Striping Possible?**: Yes.

**Other Comments**: Because Otta seals can provide a high-quality road surfacing, there is a tendency for higher road usage and speeding.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) or solvents (for cutback asphalts) are manufactured products. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** Bituminous binding agent must be hauled to the site. Haul distances may be significant for remote sites. Relaxed aggregate specifications often allow for the use of locally available aggregate and reduce or eliminate aggregate hauling costs.

**Potential Short-Term Construction Impacts**: If paving grade asphalt cement or cutback asphalts are used, significant heat is generated during the placement process. Construction processes may impact vegetation adjacent to the roadway. Dust can be a problem during construction and sweeping. Excess loose aggregate can be thrown/brushed/washed from the surface into the surrounding environment. Hydrocarbon emissions into the atmosphere can be a significant impact if cutback asphalts are used. Cutback asphalts can potentially impact water quality and aquatic species due to runoff if heavy rains occur before the cutback asphalt cures. Surface runoff should be properly contained or managed during the curing stage when the project is adjacent to bodies of water.

Asphalt Surfacings (non-structural) Otta Seal: Page 4 of 4

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Otta seals are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by Otta seal surfacings.

*Erosion:* Otta seals are a bound surface and are not particularly susceptible to surface erosion. Some aggregate loss can be expected due to a combination of traffic and erosional processes.

*Water quality*: Otta seals have a minimal impact on water quality. Water quality could be affected by sediment loading from dust or crushed aggregate particles from the Otta seal surface.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Otta seals can be pulverized and reused as an unbound or stabilized material.

**Other Environmental Considerations:** The amount of heat generation associated with Otta seal construction varies significantly with the type of bituminous binding agent used. Paving grade asphalt cement results in the highest level of heat generation, with cutback asphalt seals generating less heat and emulsified asphalt seals generating even less heat. For Otta seals, tire/road noise is typically low to moderate with the same or slightly higher noise level than HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)].

**AESTHETICS**

**Appearance:** Immediately after placement, the Otta seal's appearance is similar to a gravel road and is influenced by the aggregate color. With time and traffic, the black bituminous binding agent works its way up through the aggregate, creating a surface appearance similar to cold mix asphalt concrete.

**Appearance Degradation Over Time:** Over time, the Otta seal will generally maintain its appearance.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$2.00 to \$2.70/$m^2$ (\$1.70 to \$2.30/$yd^2$).

**EXAMPLE PROJECTS**

Cass County Roads 25 & 171, Cass County, MN; MN Highway 74, north of Whitewater State Park, Elba, MN.

**SELECT RESOURCES**

Johnson, Greg (2003). "Minnesota's Experience with Thin Bituminous Treatments for Low-Volume Roads," Transportation Research Record 1819, TRB, National Research Council, Washington, D.C., pp. 333-337.

Norwegian Public Roads Administration (1999). "A Guide to the Use of Otta Seals," PIARC XXIst World Road Congress, Kuala Lumpur, Malaysia.

Thurmann-Moe, T., and Ruistuen, H. (1983). "Graded Gravel Seal (Otta Surfacing)," Transportation Research Record 898, TRB, National Research Council, Washington, D.C., 333-335.

## *SAND SEAL*

### GENERAL INFORMATION

**Generic Name(s):** Sand Seal

**Trade Names:** N/A

**Product Description:** A sand seal is a thin asphalt surface treatment constructed by spraying a bituminous binding agent and immediately spreading and rolling a thin fine aggregate (i.e. sand or screenings) cover. A sand seal is basically the same as a chip seal except that finer aggregate is used in the cover. The bituminous binding agent can be an emulsified asphalt, cutback asphalt, or asphalt cement. The maximum aggregate size is usually smaller than 2 mm (#10 sieve). Sand seals are often used in areas where good sources of aggregate for chip seals are not available.

**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.

### APPLICATION

**Typical Use:** Road surfacing; preventative maintenance treatment for small cracks, oxidation, bleeding, raveling, and loss of surface friction.

**Traffic Range:** Very Low to Low when sand seal is placed over aggregate base, Very Low to High (typically AADT < 2,000) when sand seal is placed over existing HACP.

**Restrictions:**

*Traffic*: Sand seals should generally be limited to traffic mixes with a low percentage of trucks.

*Climate*: None.

*Weather*: None.

*Terrain*: Sand seals are generally not used for roadway gradients steeper than 8%.

*Soil Type*: N/A

*Other*: Sand seals can be damaged by snow plow operations. Sand seals should not be applied to pavements with a majority of ruts greater than 12 mm (0.5 in.) deep.

**Other Comments:** The grade of asphalt cement needs to be selected based on service temperature ranges and traffic volumes. Sand seals are commonly applied to existing asphalt pavements to enrich dry, weathered, or oxidized surfaces, seal small cracks, and improve skid resistance.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** Sand seals can be constructed over an aggregate base course. Since sand seals do not add structural capacity to the roadway, the base/subbase must be designed to support the anticipated traffic loading. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to sand seal placement. A prime coat is sometimes used above the aggregate base prior to sand seal application.

**Other Comments:** Sand seal performance is highly dependent on the quality of workmanship and the component materials used.

**CONSTRUCTION**

**Availability of Experienced Personnel**: Sand seals are a commonly used surfacing in some regions, but not others. Experienced contractors are, in general, available in most areas. Maintenance crews are used by some agencies for sand seal construction.

**Materials**: Sand seals are constructed of a bituminous binding agent (emulsified asphalt, cutback asphalt, or asphalt cement) and fine aggregate; the maximum aggregate size is typically less than 2 mm (#10 sieve). Modified asphalt cements, including rejuvenators, can be used to enhance certain performance characteristics, such as bonding to the road surface.

*Paving Grade Asphalt Cement:* Advantages of using paving grade asphalt cement is that it cures quickly, does not require any additives in the asphalt cement, and the material achieves full strength as soon as it cools. Disadvantages of asphalt cement include a high application temperature (121 to 177 °C [250 to 350 °F]) and the need to place the aggregate quickly before that asphalt cement cools.

*Cutback Asphalt*: Advantages of using cutback asphalts include cooler application temperatures (30 to 115 °C [85 to 240 °F]) than paving grade asphalts and higher asphalt percentages than emulsified asphalts (approximately 80% compared to approximately 60%). Disadvantages of cutback asphalts include higher cost than emulsified asphalts, hydrocarbon emissions into the atmosphere during the evaporation process, and potential fire hazards during storage and 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 a cooler application temperature (20 to 85 °C [70 to 185 °F]) than paving grade or cutback asphalts, and the water that evaporates is environmentally safe.

**Equipment**: Equipment required for sand seal construction includes: asphalt distributor, sand spreader, pneumatic-tired roller, and mechanical broom. The use of a vacuum type sweeper should be considered in areas sensitive to dust. Equipment is widely available in most areas, but availability may be limited in remote areas.

**Manufacturing/Mixing Process**: The binding agent (either an emulsified or cutback asphalt or asphalt cement) is produced by an asphalt supplier and shipped to the site.

**Placement Process**: The bituminous binding agent is sprayed onto the prepared working surface by the distributor; then, the fine aggregate is spread onto the surface using a sand spreader. Typical application rates are 0.70 to 1.25 liter/$m^2$ (0.15 to 0.28 gal/$yd^2$) for emulsified asphalt and 5.5 to 12 kg/$m^2$ (10 to 22 lb/$yd^2$) for fine aggregate. After the fine aggregate is placed, the surface is rolled with a pneumatic-tired roller. The set time for the binder will depend on the type of binding agent, binder temperature when it is placed, air temperature, and wind, but can range from several minutes to several hours or more. Once the binding agent has hardened, the road surface should be swept with a mechanical broom to remove all loose sand from the surface.

**Weather Restrictions**: Do not construct sand seals if it is raining or there is an imminent risk of rain. The specified minimum air temperature for sand seal placement varies between different agencies, but is normally 10 °C (50 °F) or above. When using emulsified asphalt, do not apply when freezing weather is predicted within 24 hours of intended application.

**Construction Rate**: Sand seal construction rates are commonly 25,200 $m^2$/day (30,000 $yd^2$/day).

**Lane Closure Requirements**: The roadway lane(s) being constructed is closed during construction, so adequate traffic control is needed. The sand seal surface can be opened to traffic at lower speeds, typically 30 km/hr (20 mph) maximum speed, as soon as it is constructed. Normal traffic speeds can be allowed once the binder has set and excess sand is swept from the roadway surface. Road surface striping may be performed after the lane is opened.

**Other Comments:** None.

Asphalt Surfacings (non-structural) Sand Seal: Page 3 of 4

**SERVICEABILITY**

**Reliability and Performance History:** Sand seals are not as commonly used as many other thin asphalt surfacings, but are used frequently by some agencies. The amount of design and construction information available is fairly limited; project experience will vary by region.

**Life Expectancy:** Life expectancy varies depending on construction materials used, environmental conditions, and traffic volumes. Typical serviceable lives range from 2 to 6 years (average 3 years). Sand seals placed over aggregate or stabilized bases are generally more susceptible to premature structural failures as opposed to multiple surface treatments placed over an existing paved roadway.

**Ride Quality:** Sand seals, similar to other non-structural asphalt surfacings, do not improve ride quality; ride quality is mainly determined by the roughness of the underlying layer. On a properly prepared application surface, a good to very good ride quality can be achieved after construction. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Cracking, raveling, bleeding, streaking and surface wear due to traffic abrasion, loss of surface friction.

**Preservation Needs:** Other than occasional patching, maintenance is not normally performed on the surfacing between sand seal applications.

**SAFETY**

**Hazards**: Road splash/spray can reduce visibility during periods of higher traffic volume. When cutback asphalts are used, the solvents used can create a health hazard (fumes) and a fire/explosion hazard during storage and construction; proper engineering controls and construction practices should be utilized to minimize safety risks.

**Skid Resistance**: Provided high quality aggregates are used, sand seals provide good to excellent skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: N/A

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) or solvents (for cutback asphalts) are manufactured products. Aggregates are naturally occurring.

**Delivery and Haul Requirements:** Bituminous binding agent and sand, if not available locally, must be hauled to the site. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: If paving grade asphalt cement is used, significant heat is generated during the placement process. Construction processes may impact vegetation adjacent to the roadway. If clean sand is not used, dust can be a problem during construction and sweeping. Excess sand can be thrown/brushed/washed from the surface into the surrounding environment. Hydrocarbon emissions into the atmosphere can be a significant impact if cutback asphalts are used.

Cutback asphalts can potentially impact water quality and aquatic species due to runoff if heavy rains occur before the cutback asphalt cures. Surface runoff should be properly contained or managed during the curing stage when the project is adjacent to bodies of water.

Asphalt Surfacings (non-structural) Sand Seal: Page 4 of 4

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Sand seals are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by sand seal surfacings

*Erosion:* Sand seals are a bound surface and are not particularly susceptible to surface erosion. Some sand loss can be expected due to a combination of traffic and erosional processes.

*Water quality*: Sand seals have a minimal impact on water quality. Water quality could be affected by sediment loading from dust or loose fine aggregate from the sand seal surface.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Sand seals can be pulverized and reused as an unbound or stabilized material.

**Other Environmental Considerations:** The amount of heat generation associated with sand seal construction varies significantly with the type of bituminous binding agent used. Paving grade asphalt cement results in the highest level of heat generation, with cutback asphalt seals generating less heat and emulsified asphalt seals generating even less heat. For sand seals, tire/road noise is typically low to moderate with about the same noise level as HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)].

**AESTHETICS**

**Appearance:** Immediately after placement, the sand seal's appearance is influenced by the black bituminous binder and, to a lesser extent, by the sand color. A sand seal's appearance can be modified by the use of pigments in the asphalt cement, but would not normally be done because of the short service life of the surfacing.

**Appearance Degradation Over Time:** Over time, the sand seal surface will wear, exposing more of the underlying surface. The use of preventative maintenance treatments, such as fog seals, will add a black appearance to the surface.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$0.60 to \$1.50/$m^2$ (\$0.50 to \$1.25/$yd^2$).

**EXAMPLE PROJECTS**

None.

**SELECT RESOURCES**

Asphalt Emulsion Manufacturers Association, (410) 267-0023, www.aema.org
Asphalt Institute. *A Basic Asphalt Emulsion Manual*, Manual Series No. 19 (MS-19), Third Edition, Lexington, Kentucky, 120 pp.
USDA Forest Service (1999a), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center.

## *SCRUB SEAL*

### GENERAL INFORMATION

**Generic Name(s):** Scrub Seal

**Trade Names:** N/A

**Product Description:** A scrub seal is a thin asphalt surface treatment constructed by spraying emulsified asphalt onto an existing pavement, dragging a broom across the surface to scrub the emulsified asphalt into the surface cracks, immediately spreading a thin fine aggregate (i.e. sand or screenings) over the emulsified asphalt, dragging another broom over the surface to scrub the fine aggregate into the surface cracks, and rolling the surface with a pneumatic tire roller. Polymer-modified emulsified asphalt is normally used. Scrub seals can rejuvenate dry, oxidized pavements and fill small cracks up to 6 mm (0.25 in.) wide.

**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.

### APPLICATION

**Typical Use:** Preventative maintenance treatment for small cracks, oxidation, bleeding, raveling, and loss of surface friction.

**Traffic Range:** Very Low to High (typically AADT < 1,500).

**Restrictions:**

*Traffic*: Scrub seals should generally be limited to traffic mixes with a low percentage of trucks.

*Climate*: None.

*Weather*: None.

*Terrain*: Scrub seals are generally not used for roadway gradients steeper than 8%.

*Soil Type*: N/A

*Other*: Scrub seals can be damaged by snow plow operations. Scrub seals should not be applied to pavements with majority of ruts greater than 12 mm (0.5 in.) deep.

**Other Comments:** None.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** N/A

**Other Comments:** Scrub seal performance is highly dependent on the quality of workmanship and the component materials used.

### CONSTRUCTION

**Availability of Experienced Personnel**: Scrub seals are a commonly used surfacing in some regions, but not in others. Availability of experienced contractors may be limited in some areas.

Asphalt Surfacings (non-structural) Scrub Seal: Page 2 of 4

**Materials**: Scrub seals are constructed of emulsified asphalt and fine aggregate; the maximum aggregate size is typically less than 2 mm (#10 sieve). Modified emulsified asphalts, including rejuvenators, can be used to enhance certain performance characteristics.

**Equipment**: Equipment required for scrub seal construction includes: asphalt distributor, sand spreader, pneumatic-tired roller, scrub seal drag brooms, and mechanical broom. The use of a vacuum type sweeper should be considered in areas sensitive to dust. Equipment is widely available in most areas, but availability may be limited in remote areas.

**Manufacturing/Mixing Process**: The binding agent (i.e. emulsified asphalt) is produced by an asphalt supplier and shipped to the site.

**Placement Process**: The emulsified asphalt is sprayed onto the prepared working surface by the asphalt distributor and worked into the existing surface with a drag broom pulled behind the distributor; then, the fine aggregate is spread onto the surface using a sand spreader and worked into the existing surface using a drag broom. Typical application rates are 0.70 to 1.80 liter/$m^2$ (0.15 to 0.40 gal/$yd^2$) for emulsified asphalt and 5.4 to 10.8 kg/$m^2$ (10 to 20 lb/$yd^2$) for fine aggregate. After the fine aggregate is placed, the surface is rolled with a pneumatic-tired roller. The set time for the binder is typically a few hours, but will depend on the type of binding agent, binder temperature when it is placed, air temperature, and wind conditions. Once the binding agent has hardened, the road surface should be swept with a mechanical broom to remove all loose fine aggregate from the surface.

**Weather Restrictions**: Do not construct scrub seals if it is raining or there is an imminent risk of rain or if freezing temperatures are expected within 24 hours. The specified minimum air temperature for scrub seal placement varies between different agencies, but is normally 10 °C (50 °F) or above.

**Construction Rate**: Scrub seal construction rates are commonly 20,000 $m^2$/day (23,800 $yd^2$/day).

**Lane Closure Requirements**: The roadway lane(s) being treated is closed during scrub seal application, so adequate traffic control is needed. The scrub seal surface can be opened to traffic at lower speeds, typically 30 km/hr (20 mph) maximum speed, as soon as it is constructed. Normal traffic speeds can be allowed once the binder has set and excess fine aggregate is swept from the roadway surface. Road surface striping may be performed after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Scrub seals are not as commonly used as many other maintenance treatment surfacings, but are used frequently by some agencies. The amount of design and construction information available is fairly limited. Project experience will vary by region.

**Life Expectancy:** Life expectancy varies depending on construction materials used, environmental conditions, and traffic volumes. Typical serviceable lives range from 2 to 6 years (average 3 years).

**Ride Quality:** Scrub seals have little to no effect on ride quality.

**Main Distress / Failure Modes:** Raveling, bleeding, wear by tire abrasion, loss of surface friction.

**Preservation Needs:** None.

**SAFETY**

**Hazards**: None.

**Skid Resistance**: Provided high quality aggregates are used, scrub seals initially provide good skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: None.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) are manufactured products. Aggregates are naturally occurring.

**Delivery and Haul Requirements:** Emulsified asphalt and fine aggregate, if not available locally, must be hauled to the site. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: Construction processes may impact vegetation adjacent to the roadway. Dust can be a problem during construction and sweeping. Excess fine aggregate can be thrown/brushed/washed from the surface into the surrounding environment.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Scrub seals are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by scrub seal surfacings. In parking areas, oil and other vehicle fluids can be collected by surface runoff, affecting the water quality.

*Erosion:* Scrub seals are a bound surface and are not particularly susceptible to surface erosion. Some aggregate loss can be expected due to a combination of traffic and erosional processes.

*Water quality*: Scrub seals have a minimal impact on water quality. Water quality could be affected by sediment loading from dust or loose fine aggregate from the scrub seal surface.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Scrub seals can be pulverized with underlying pavement layers and reused as an unbound or stabilized material.

**Other Environmental Considerations:** For scrub seals, tire/road noise is typically low to moderate with about the same noise level as HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)].

**AESTHETICS**

**Appearance:** Immediately after placement, the scrub seal's appearance is influenced by the black bituminous binder and the fine aggregate color. A scrub seal's appearance can be modified with the careful selection of colored aggregates and by the use of pigments in the asphalt cement; however, this is not normally done because of the additional cost relative to the life expectancy.

**Appearance Degradation Over Time:** Over time, the scrub seal surface will wear, exposing more of the underlying surface.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$0.60 to \$1.60/$m^2$ (\$0.50 to \$1.30/$yd^2$).

| **EXAMPLE PROJECTS** |
| --- |
| Merced County, CA.<br>U.S. Highway 169, from I-29 to Union Star, MO. |
| **SELECT RESOURCES** |
| Asphalt Emulsion Manufacturers Association, (410) 267-0023, www.aema.org<br>USDA Forest Service (1999), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center. |

## *SLURRY SEAL*

### GENERAL INFORMATION

**Generic Name(s):** Slurry Seal

**Trade Names:** N/A

**Product Description:** Slurry seals are a cold-mixed thin surface treatment constructed of a mixture of emulsified asphalt, dense-graded crushed fine aggregate, mineral filler or other additives, and water. Slurry seals are applied at the thickness of the largest aggregate in the mix; 3 mm (1/8 in.) for Type I slurry, 6 mm (1/4 in.) for Type II slurry, and 9 mm (3/8 in.) for Type III slurry. Type II is the most commonly used slurry seal gradation. Slurry seals are used as a protective or preventive maintenance technique for paved surfaces or thin asphalt surface treatments; slurry seals are applied to existing surfaces to seal small cracks, correct minor surface irregularities, stop raveling, improve ride quality, and improve friction properties.

**Product Suppliers:** Representative list of manufacturers, suppliers, and contractors can be obtained from: International Slurry Surfacing Association, PMB 250, 3 Church Circle, Annapolis, MD 21401, (410) 267-0023, www.slurry.org

### APPLICATION

**Typical Use:** Preventative maintenance treatment for small cracks or raveling.

**Traffic Range:** Very Low for Type I, Very Low to Medium for Type II, and Very Low to High (typically AADT < 5,000) for Type III

**Restrictions:**

*Traffic*: None.

*Climate*: None.

*Weather*: None.

*Terrain*: Slurry seals are generally not used for roadway gradients steeper than 8%.

*Soil Type*: N/A

*Other*: Slurry seals can be damaged by snow plow operations. Slurry seals should not be applied to pavements with majority of ruts greater than 12 mm (0.5 in.) deep.

**Other Comments:** Slurry seals have a smoother texture than chip seals and may be preferred by non-vehicular users (i.e. bicyclists, in-line skaters, etc.) in recreational areas.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** N/A

**Other Comments:** None.

### CONSTRUCTION

**Availability of Experienced Personnel**: Slurry seal construction generally requires experienced specialty contractors. In remote areas, specialty contractors may not be locally available, but they are generally available on a statewide or regional level.

**Materials**: Slurry seals are constructed of a mixture of emulsified asphalt, dense-graded crushed fine aggregate, mineral filler or other additives, and water. The emulsified asphalt is usually cationic and quick-setting. Modified emulsified asphalts can be used to enhance certain performance characteristics.

**Equipment**: Slurry seal construction requires a special slurry seal mixing machine with a spreader box attached. The slurry seal mixing machine can be truck-mounted or self-propelled. Equipment is locally available in large urban areas and regionally available in more remote areas. The slurry seal mixing machine should be calibrated using site-specific materials and mix proportions prior to each construction job.

**Manufacturing/Mixing Process**: The slurry seal mixing machine carries all the unmixed materials and, when construction commences, combines the materials in exact mix proportions in a continuous flow pugmill. For continuous operation, haul vehicles must replenish materials to the mixing machine.

**Placement Process**: Once the slurry is mixed by the slurry seal mixing machine, the mix is automatically fed into a spreader box attached to the rear of the equipment and applied to the roadway. Rolling or compaction is seldom required but may be desirable in low traffic areas such as parking lots and airports.

**Weather Restrictions**: Do not construct slurry seals if it is raining or there is an imminent risk of rain, or there is a danger of freezing within 24 hours. The specified minimum air temperature for slurry seal placement is normally 10 °C (50 °F) or above.

**Construction Rate**: Slurry seal construction rates typically range from 135 to 270 Mg/day (150 to 300 tons/day). This would be equivalent to about 10,000 to 20,000 $m^3$ /day (12,000 to 24,000 $yd^3$/day)

**Lane Closure Requirements**: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. Depending on the type of emulsified asphalt used and weather conditions, roads can be opened to traffic one to twelve hours after placement. Road surface striping may be performed after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Slurry seals are a common roadway maintenance treatment and have been used on roadway projects for more than 50 years; design and construction guidelines and performance data is available.

**Life Expectancy:** Life expectancy varies depending on mix types, traffic volumes, and environmental conditions. Typical serviceable lives range from 3 to 8 years (average 5 years).

**Ride Quality:** Slurry seals may slightly improve the ride quality of a previously paved roadway. However, slurry seals will not mitigate significant defects (rutting, depressions, severe cracking, etc.) in the existing surface. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Flushing, rutting, cracking (from the underlying pavement).

**Preservation Needs:** None.

**SAFETY**

**Hazards**: Road splash/spray can reduce visibility during periods of higher traffic volumes.

**Skid Resistance**: Slurry seals provide excellent initial skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: None.

Asphalt Surfacings (non-structural) Slurry Seal: Page 3 of 3

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Emulsifying agents (for emulsified asphalt) are manufactured products. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** Emulsified asphalt, aggregates, and additives must be hauled to the site. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: None.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Slurry seals help to seal old pavement surfaces, which promotes surface runoff. However, surface runoff water quality is not generally impacted by slurry seals.

*Erosion:* None.

*Water quality*: None.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Slurry seals can be pulverized and reused with the underlying HACP as an unbound or stabilized material.

**Other Environmental Considerations:** Slurry seals are cold-mixed and have much lower energy requirements and heat generation compared to hot mixed and hot-placed road surfacings For slurry seals, tire/road noise is typically low to moderate with the same or slightly higher noise level than HACP [72 to 79.5 dB(A) at a distance of 7.5 m (25 ft)], but with a lower noise level than chip seals.

**AESTHETICS**

**Appearance:** Slurry seals have a black appearance similar to HACP. A slurry seal's color can be modified by the use of pigments in the slurry mix, but this is not normally done because of cost.

**Appearance Degradation Over Time:** Over time, the slurry seal surface will wear, exposing more of the underlying surface and modifying the appearance. Reapplication of the slurry seal will maintain the black surface color.

**COST**

**Supply Price**: N/A

**Supply+Install Price**: \$0.90 to \$1.80/$m^2$ (\$0.75 to \$1.50/$yd^2$).

**EXAMPLE PROJECTS**

City of Las Vegas, NV.

**SELECT RESOURCES**

International Slurry Surfacing Association, (410) 267-0023, www.slurry.org
Asphalt Institute. *A Basic Asphalt Emulsion Manual*, Manual Series No. 19 (MS-19), Third Edition, Lexington, Kentucky, 120 pp.
International Slurry Seal Association (2003). *Recommended Performance Guidelines for Emulsified Asphalt Slurry Seal*, A105, International Slurry Seal Association, 16 pp.
USDA Forest Service (1999), *Asphalt Seal Coat Treatments*, San Dimas Technology and Development Center.

## *ULTRATHIN FRICTION COURSE*

### GENERAL INFORMATION

**Generic Name(s):** Ultrathin Friction Course, Ultrathin Bonded Wearing Course

**Trade Names:** NovaChip

**Product Description:** An ultra-thin friction course is constructed of a thin layer of gap graded, coarse aggregate hot mix asphalt concrete that provides a smooth, durable, and skid-resistant surface. The thin layer, typically 9 to 19 mm (0.375 to 0.75 in.) thick, combines attributes of stone matrix asphalt and open graded friction course asphalt mixes. The hot mix asphalt layer is bound to the existing surface with a polymer modified emulsion that is specifically designed to seal the existing surface and bond the new mix to the existing surface. Ultrathin friction course can be used on asphalt or concrete pavements as a preventative maintenance or surface rehabilitation treatment. Ultrathin friction course provides excellent skid resistance, reduced tire/road noise, and reduced vehicle splash/spray.

**Product Suppliers:** Sunland Asphalt Company, www.sunlandasphalt.com; or

E.J. Breneman, LP, www.ejbreneman.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 are available.

### APPLICATION

**Typical Use:** Road surfacing, preventative maintenance or surface rehabilitation treatment.

**Traffic Range:** Very Low to High. Typically used for AADT>1,000.

**Restrictions:**

*Traffic*: None.

*Climate*: None.

*Weather*: None.

*Terrain*: None.

*Soil Type*: N/A

*Other*: None.

**Other Comments:** Ultrathin friction course should be placed over a structurally sound pavement with rut depths less than 13 mm (0.5 in.), minor to moderate cracking, and/or minor bleeding.

### DESIGN

**SLC:** N/A

**Other Design Values**: N/A

**Base/Subbase Requirements:** N/A

**Other Comments:** None.

### CONSTRUCTION

**Availability of Experienced Personnel**: Ultrathin friction course is a commonly used surfacing and experienced contractors are, in general, widely available. Availability may be limited for projects in remote areas.

**Materials**: Ultrathin friction course is composed of a gap graded aggregate with asphalt cement as a binder and polymer modified emulsified asphalt to bind the overlay with the existing surface.

**Equipment**: Equipment required for ultrathin friction course construction includes: haul vehicles, a special asphalt paver machine, and compaction equipment (static steel wheel roller). Because a specialty paver is required, availability is limited to large or specialty paving contractors.

**Manufacturing/Mixing Process**: Ultrathin friction course is normally hot mixed at an asphalt plant by mixing specified proportions of the heated material components together to form a uniform mixture. Ultrathin friction course mixes are normally mixed at temperatures between 132 to 163 °C (270 to 325 °F). After mixing, the product is placed in haul vehicles to be transported to the project site. The asphalt concrete mix must arrive on-site and be placed before it cools. When transported in insulated vehicles with a tarp cover, the asphalt mixture can remain at an adequate temperature for up to approximately 1.5 hours. Since the quantities of ultrathin friction course are relatively small and the quality requirements are very high, production from a mobile asphalt plant would likely not be economical.

**Placement Process**: Cracks in the surfacing to be covered should be sealed or repaired before ultrathin friction course is placed. The polymer modified emulsified asphalt membrane and thin asphalt layer are placed in one pass using a special asphalt paver (e.g. NovaPaver), specially designed for ultrathin friction course placement. The emulsified asphalt is sprayed onto the prepared surface by the machine and the asphalt concrete layer is placed immediately after the emulsified asphalt. The paving machine has a special combination tamping bar-vibratory screed that compacts and levels the surfacing layer after it has been applied. Once the ultrathin friction course has been placed, a steel drum roller is used to seat the asphalt concrete overlay into the emulsified asphalt membrane layer.

**Weather Restrictions**: Do not place ultrathin friction course if it is raining or there is ponded water on the prepared paving surface. The specified minimum air temperature for ultrathin friction course placement varies between different agencies, but is normally about 15 °C (60 °F).

**Construction Rate**: Ultrathin friction course placement rates are in the range of 7.2 to 14.4 lane-km perday (4.4 to 8.9 lane-miles/day).

**Lane Closure Requirements**: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The ultrathin friction course surface can be opened to traffic within minutes of being placed. Road surface striping may be performed before or after the lane is opened.

**Other Comments**: None.

**SERVICEABILITY**

**Reliability and Performance History:** Ultrathin friction course is a relatively new but very common roadway surfacing. Ultrathin friction course was first developed in France in 1986 and was introduced to the United States in 1992. Since that time, ultrathin friction course has been used by nearly all state transportation agencies. Research, design and construction information, and project experience is available.

**Life Expectancy:** Life expectancy varies depending on mix types, environmental conditions, and traffic volumes. Typical serviceable lives range from 10 to 12 years.

**Ride Quality:** Very good ride quality after construction. Ride quality deteriorates over the serviceable life.

**Main Distress / Failure Modes:** Cracking, rutting, raveling, shoving.

**Preservation Needs:** Preventative maintenance includes periodic crack sealing.

**SAFETY**

**Hazards**: None.

**Skid Resistance**: Ultrathin friction course provides excellent skid resistance.

**Road Striping Possible?**: Yes.

**Other Comments**: Because ultrathin friction course provides a high-quality road surfacing, there is a tendency for road usage to be higher and for drivers to exceed posted speed limits.

**ENVIRONMENTAL CONCERNS**

**Source of Raw Materials:** Asphalt cement is an asphalt product produced by distillation of crude oil. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

**Delivery and Haul Requirements:** Ultrathin friction course must be hauled from an asphalt plant. Haul distances may be significant for remote sites.

**Potential Short-Term Construction Impacts**: Significant heat is generated during the mixing and placement process. The paving operation proceeds quickly with little impact on vegetation adjacent to the roadway.

**Potential Long-Term Environmental Impacts:**

*Leachate:* None.

*Surface Runoff:* Ultrathin friction course is impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by ultrathin friction course overlays.

*Erosion:* Ultrathin friction course is a bound material and is not susceptible to surface erosion. Shoulders and base material should be protected from fast moving water.

*Water quality*: None.

*Aquatic species*: None.

*Plant quality*: None.

*Air Quality*: None.

*Other*: None.

**Ability to Recycle/Reuse:** Ultrathin friction course can be fully recycled as a pavement construction material.

**Other Environmental Considerations:** Ultrathin friction course's characteristic black surface will absorb heat from sunlight; select aggregates can be used to lighten the color and increase heat reflectivity of the surface. For ultrathin friction course, tire/road noise is typically 1.4 to 2.1 decibels lower than conventional HACP and 3.2 to 4.1 decibels lower than conventional PCCP.

**AESTHETICS**

**Appearance:** Immediately after placement, ultrathin friction course is generally black with a very smooth surface.

**Appearance Degradation Over Time:** Over time, ultrathin friction course can change color to a wide range of gray-blacks and occasionally has a brown or red sheen, depending on the predominant aggregate color. With maintenance activities, such as crack sealing, the surface appearance deteriorates further.

**COST**

**Supply Price**: \$4.20 to \$4.80/$m^2$ (\$3.50 to \$4.00/$yd^2$).

**Supply+Install Price**: \$7.25 to \$8.00/$m^2$ (\$6.00 to \$6.70/$yd^2$).

**EXAMPLE PROJECTS**

Garden State Parkway, NJ.
Interstate I-65, Cullman, AL.
U.S. Highway 50, Lake Tahoe, CA.

**SELECT RESOURCES**

Koch Pavement Solutions, http://www.kochpavementsolutions.com/Solutions/novachip.htm.
Kandhal, P.S., and Lockett, L. (1997). *Construction and Performance of Ultrathin Asphalt Friction Course*, NCAT Report No. 97-5, National Center for Asphalt Technology, Auburn, AL, 23 pp.