



ROADWAY SURFACING OPTIONS PHOTO ALBUM

Companion Document to Context Sensitive Roadway Surfacing Selection Guide

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Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228



**FHWA
FLH**

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Roadway Surfacing Selection Guide

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Central Federal Lands Highway Division
12300 West Dakota Avenue
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INTRODUCTION

To address context sensitive concerns, the Federal Lands Highway (FLH) Division of the Federal Highway Administration (FHWA) has developed a selection process that includes consideration of environmental impacts, cultural sensitivity, and aesthetics in the selection of roadway surfacing while also facilitating the public consultation process. As a result, the selection process permits a balanced consideration of engineering and environmental factors and better ensures that the completed roadway enhances, or is, at least, compatible with, the surrounding landscape.

The FLH has developed a “Roadway Surfacing Options Photo Album” as a supplement to the “Context Sensitive Roadway Surfacing Selection Guide” (Guide). This album contains product descriptions, photographs, and presents some advantages and limitations for different roadway surfacing types. Additional information for each surfacing type can be found in the Guide. The Guide includes technical and design information for over 50 roadway surfacing options and a detailed description of the context sensitive surfacing selection process.

INTRODUCTION (cont.)

Several assumptions were made in the summaries presented for each surfacing type. It is assumed that best design practices will be used and that certain common design elements will be part of the design. These design elements include: adequate surface and subsurface drainage provisions, structurally stable slopes and embankments, erosion control and shoulder treatments, provisions for cross-drainage and wildlife/fish passage structures, etc.

An estimate of how long the roadway will last under normal conditions has been provided. The life expectancy will vary depending on traffic volumes, in particular the percentage of heavy vehicles, climatic conditions, subgrade types, and level of preventative maintenance that is used. If the traffic volume exceeds the range provided for a particular surfacing type, the life expectancy may be significantly decreased, the road serviceability level may be reduced, or maintenance costs may be unacceptably high.

A unit price estimate has been provided for each roadway surfacing type. This price range is a “ballpark” number provided for preliminary cost comparisons between different surfacings. Prices can vary significantly with location, product availability, and project size. Local unit price estimates should be obtained during roadway planning and design. Prices included are based on Year 2004 estimates.

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ACRONYMS

AADT	Average Annual Daily Traffic	OGFC	Open Graded Friction Course
CFLHD	Central Federal Lands Highway Division	PCC	Portland Cement Concrete
CIR	Cold In-Place Recycling	PCCP	Portland Cement Concrete Pavement
CMAC	Cold Mix Asphalt Concrete	RAP	Reclaimed Asphalt Product
EFLHD	Eastern Federal Lands Highway Division	RCA	Reclaimed Concrete Aggregate
FDR	Full Depth Reclamation	RCC	Roller Compacted Concrete
FHWA	Federal Highway Administration	RMP	Resin Modified Pavement
FLH	Federal Lands Highway	WFLHD	Western Federal Lands Highway Division
HACP	Hot Asphalt Concrete Pavement		
HIR	Hot In-Place Recycling		

Asphalt Surfacing – Surface Treatments or Layers (non-structural)

**Traffic Range:**

Typical AADT < 1,000 to 5,000. However, there are no traffic limitations for some of the higher quality surface treatments.

Life Expectancy:

Life expectancy is generally shorter than for other paved surfaces.

Unit Price:

Material and installation costs are generally lower than for other types of paved surfaces.

Appearance:

Appearance is generally black or gray, but can be influenced by pigmented binders and aggregate chip color. Surface texture ranges from fine to coarse.

Advantages:

Lower initial cost than other paved surfaces; Provides a relatively durable surfacing with generally good friction properties.

Limitations:

Does not add to the structural capacity of the roadway.

Product Description: When used as a road surfacing on aggregate base, the surface treatments protect the underlying materials from water and erosion and provide a relatively smooth riding surface. Surface treatments may also be used as preventative maintenance treatments for small cracks, bleeding, raveling, and loss of surface friction on existing paved roadways.

Cape Seal



Cape seal construction.

Photo Source: Slurry Pavers, Inc.

Traffic Range:

Typical AADT < 2,000 when placed on aggregate base. No limitations when placed on existing HACP.

Life Expectancy:

7 to 15 years (average 9 years).

Unit Price:

Material & Installation: \$2.70 to \$3.60/m² (\$2.25 to \$3.00/yd²).

Appearance:

Appearance is generally black with a fine texture. The color can be influenced by pigmented binders and aggregate chip color.

Advantages:

Durable; Good skid resistance; Reduces chip loss.

Limitations:

Higher initial cost than some other surface treatments; Limited use in United States.

Product Description: A Cape seal is a thin surface treatment constructed by applying a slurry seal or microsurfacing to a newly constructed chip seal. It is designed to be an integrated system where the primary purpose of the slurry is to fill voids in the chip seal.

Cape Seal



Cape seal surfacing.

Photo Source: Western Emulsions



Cape seal surfacing.

Photo Source: Western Emulsions

Chip Seal



Chip seal surfacing with red aggregate chips.

Photo Source: Golder Associates Inc.

Traffic Range:

Typical AADT < 1,000 when placed on aggregate base. Typical AADT < 2,000 when placed on existing HACP.

Life Expectancy:

3 to 7 years (average 5 years).

Unit Price:

Material & Installation: \$1.00 to \$1.50/m² (\$0.80 to \$1.25/yd²).

Appearance:

Appearance is influenced by the binder and aggregate chip color. Surface texture is influenced by the aggregate size, but is generally coarse.

Advantages:

Lower initial cost than many other surface treatments; Durable; Widely available.

Limitations:

Loose chips can be windshield hazard.

Product Description: A chip seal is a single thin surface treatment constructed by spraying a bituminous binding agent and immediately spreading and rolling a single layer of aggregate cover, typically 6 to 9.5 mm (0.25 to 0.375 in.) thick.

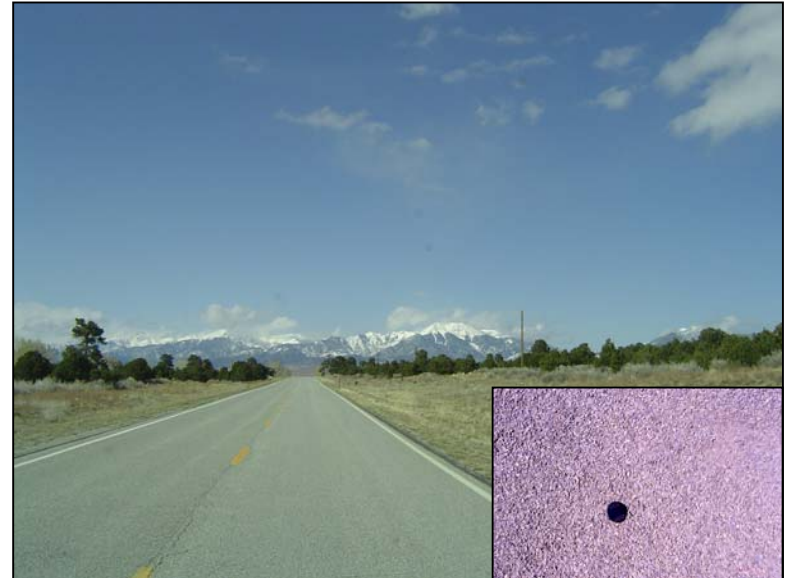
Chip Seal

1.2



Chip seal surfacing.

Photo Source: FHWA-CFLHD



Chip seal surfacing.

Photo Source: FHWA-CFLHD

Chip Seal

1.2



Chip seal construction.

Photo Source: FHWA-WFLHD



Chip seal surfacing.

Photo Source: FHWA-CFLHD

Chip Seal

1.2



Chip seal crack sealing.

Photo Source: Golder Associates Inc.



Worn chip seal surfacing with colored chips.

Photo Source: Golder Associates Inc.



Chip seal over geotextile construction.

Photo Source: FHWA-CFLHD

Traffic Range:

Typical AADT < 1,000 when placed on an existing surface treatment. Typical AADT < 2,000 when placed on existing HACP.

Life Expectancy:

Typically 3 to 7 years (average 5 years).

Unit Price:

Material & Installation: \$2.30 to \$3.40/m² (\$1.90 to \$2.80/yd²).

Appearance:

Appearance is influenced by the binder and aggregate chip color. Surface texture is influenced by the aggregate size, but is generally coarse.

Advantages:

Reduces reflective cracking; Reduces moisture infiltration.

Limitations:

Few experienced contractors; Slippage is possible in applications with high shearing forces at the surface (e.g. tight radius curves, breaking at intersections, etc.).

Product Description: A geotextile-reinforced chip seal is constructed by applying a tack coat to the prepared unbound or bound surfacing, rolling out a geotextile layer onto the prepared surface, applying a scatter coat of aggregate on top of the geotextile and rolling it, and then constructing a traditional chip seal as a final driving surface.

Chip Seal over Geotextile



Geotextile placement.

Photo Source: FHWA-CFLHD



Finished chip seal over geotextile surfacing on left lane

Photo Source: Asphalt Interlayer Association

Fog Seal



Fog seal surfacing.

Photo Source: Golder Associates Inc.

Traffic Range:

No limitations, although a high degree of quality control is required for high volume applications.

Life Expectancy:

1 to 3 years (average 2 years).

Unit Price:

Material & Installation: \$0.25 to \$0.60/m² (\$0.20 to \$0.50/yd²).

Appearance:

Immediately after placement, fog seals are black. Appearance can be modified with the use of pigments in the emulsified asphalt.

Advantages:

Low initial cost; Enriches oxidized asphalt surfaces; Seals small cracks.

Limitations:

No structural value; Short life expectancy; Can reduce skid resistance.

Product Description: A fog seal is a light application of emulsified asphalt diluted with water. Fog seals are predominately used to enrich oxidized asphalt surfaces or to seal very small cracks and surface voids.

Fog Seal



Fog seal on right lane of roadway.

Photo Source: FHWA-CFLHD

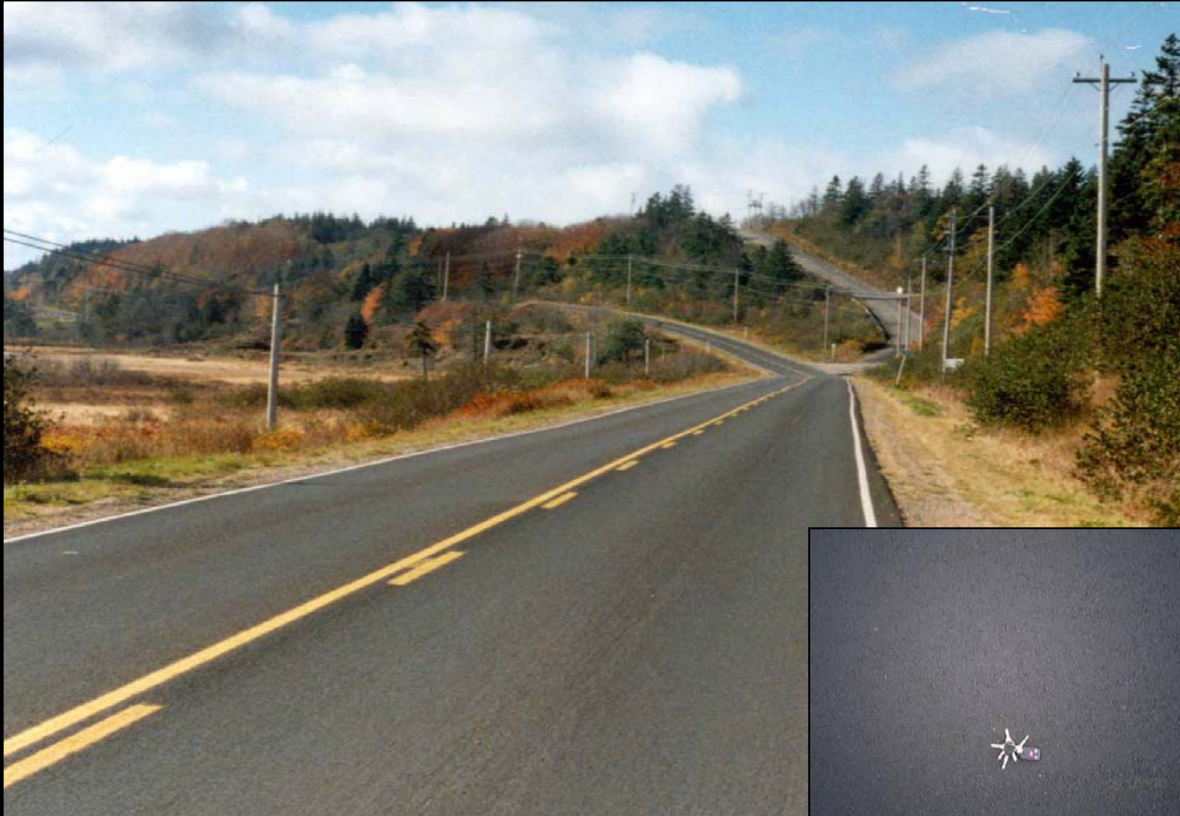


Fog Seal.

Photo Source: Telfer Oil Company

Microsurfacing

1.5



Microsurfacing treatment on roadway.

Photo Source: Miller Group

Traffic Range:

No limitations. Typically used for AADT > 400.

Life Expectancy:

5 to 8 years (average 7 years).

Unit Price:

Material & Installation: \$3.10 to \$3.90/m² (\$2.60 to \$3.30/yd²).

Appearance:

Microsurfacing is usually black with a fine surface texture. Microsurfacing color can be modified by the use of pigments in the microsurfacing mix.

Advantages:

High quality surface treatment; Excellent skid resistance; Can rehabilitate instability rutting.

Limitations:

Higher initial cost than some other surface treatments; Specialty contractors required.

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. Microsurfacing is used as a protective or rehabilitative maintenance technique for paved surfaces or thin asphalt surface treatments.

Microsurfacing



Microsurfacing placement.

Photo Source: Nevada DOT



Microsurfacing treatment on roadway.

Photo Source: Missouri Petroleum



Double chip seal surfacing.

Photo Source: D & D Contracting Inc.

Traffic Range:

Typical AADT <1,000 when placed on aggregate base. Typical AADT < 2,000 when placed on existing HACF.

Life Expectancy:

4 to 8 years (average 6 years).

Unit Price:

Material & Installation: \$1.50 to \$3.00/m² (\$1.25 to \$2.50/yd²).

Appearance:

Appearance is influenced by the binder and aggregate chip color. Surface texture is influenced by the aggregate size, but is generally coarse.

Advantages:

Widely available; Less susceptible to minor construction defects than single chip seals.

Limitations:

Loose chips can be windshield hazard.

Product Description: Multiple surface treatments include double chip seals, triple chip seals, and sandwich seals. Double and triple chip seals consist of two and three layers of chip seal, respectively. A sandwich seal is similar to a double chip seal, except the first layer of asphalt binder is omitted.



Triple chip seal surfacing.

Photo Source: FHWA-WFLHD



Double chip seal surfacing.

Photo Source: Missouri Petroleum

Open Graded Friction Course

1.7



Open graded friction course
surfacing.

Photo Source: FHWA-CFLHD

Traffic Range:

No limitations; however, low traffic volumes allow dust and other materials to clog surface pores.

Life Expectancy:

8 to 12 years.

Unit Price:

Material & Installation: \$11.00 to \$13.40/m² (\$9.20 to \$11.20/yd²) for 19 mm (0.75 in.) layer thickness.

Appearance:

Appearance is generally black with a coarse surface texture.

Advantages:

High quality surface treatment; Excellent skid resistance; Significantly reduces hydroplaning and splash/spray from vehicles.

Limitations:

Higher initial cost than most surface treatments; Requires special maintenance procedures in cold climates where ice and snow are common.

Product Description: Open graded friction course (OGFC) is a porous HACP wearing course, containing little sand and with high air voids content (typically from 15 to 25%). The OGFC 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.

Otta Seal

1.8



Otta seal roadway surfacing.

Photo Source: Minnesota
DOT

Traffic Range:

Typical AADT < 400 for a single Otta seal.
Typical AADT < 2,000 for a double Otta seal.

Life Expectancy:

4 to 8 years for single Otta seal. 8 to 15
years for double Otta seal.

Unit Price:

Material & Installation: \$2.00 to \$2.70/m²
(\$1.70 to \$2.30/yd²) for a double Otta seal.

Appearance:

Initially, appearance is influenced by the
aggregate color. With time and traffic, the
black bituminous binding agent moves up
through the aggregate, creating a look
similar to cold mix asphalt concrete.

Advantages:

Less strict aggregate requirements.

Limitations:

Loose chips can be windshield hazard;
Limited use in United States.

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 binder works its way into the aggregate with rolling and traffic.

Otta Seal



Otta seal construction.

Photo Source: Minnesota DOT



Otta seal surfacing.

Photo Source: Minnesota DOT

Sand Seal

1.9



Sand seal construction.

Photo Source: Telfer Oil Company /
Golder Associates Inc.

Traffic Range:

Typical AADT < 400 when placed on aggregate base. Typical AADT < 2,000 when placed on existing HACP.

Life Expectancy:

2 to 6 years (average 3 years).

Unit Price:

Material & Installation: \$0.60 to \$1.50/m²
(\$0.50 to \$1.25/yd²).

Appearance:

Appearance is influenced by the black bituminous binder and, to a lesser extent, by the sand color.

Advantages:

Can enrich dry, weathered, or oxidized surfaces and seal small cracks, and improve skid resistance; Can be used in aggregate poor areas.

Limitations:

Use and experience varies by region; Not as durable as chip seals.

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.

Scrub Seal



Brooms used to scrub fine aggregate into surface cracks.

Photo Courtesy of: Western Emulsions

Traffic Range:

Typically AADT < 1,500.

Life Expectancy:

2 to 6 years (average 3 years).

Unit Price:

Material & Installation: \$0.60 to \$1.60/m²
(\$0.50 to \$1.30/yd²).

Appearance:

Appearance is influenced by the black bituminous binder and, to a lesser extent, by the sand aggregate color.

Advantages:

Brooming and brushing process more effectively seals cracks than other surface treatments.

Limitations:

Use and experience varies by region.

Product Description: A scrub seal is constructed by spraying emulsified asphalt onto an existing pavement, dragging a broom across the surface to scrub the emulsified asphalt into the surface cracks, spreading sand 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 roller.

Scrub Seal



Scrub seal surfacing.

Photo Source: Western Emulsions



Scrub broom used in construction process.

Photo Source: Western Emulsions

Slurry Seal



Slurry seal surfacing.

Photo Source: FHWA-CFLHD

Traffic Range:

Typical AADT < 200 for Type I, AADT < 1,000 for Type II, and AADT < 5,000 for Type III slurry.

Life Expectancy:

3 to 8 years (average 5 years).

Unit Price:

Material & Installation: \$0.90 to \$1.80/m² (\$0.75 to \$1.50/yd²).

Appearance:

Black color with fine surface texture; appearance is similar to HACP. Color can be modified by the use of pigments in the slurry mix.

Advantages:

Uniform appearance; Smoother surface than chip seals.

Limitations:

Requires special equipment.

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, 6 mm (1/4 in.) for Type II, and 9 mm (3/8 in.) for Type III slurry.

Slurry Seal



Slurry seal surfacing.

Photo Source: FHWA-CFLHD



Slurry seal placement.

Photo Source: FHWA-CFLHD

Ultrathin Friction Course

1.12



Ultrathin friction course
surfacing.

Photo Source: FHWA-CFLHD

Traffic Range:

No limitations. Typically used for AADT > 1,000.

Life Expectancy:

Typically 10 to 12 years.

Unit Price:

Material & Installation: \$7.25 to \$8.00/m²
(\$6.00 to \$6.70/yd²).

Appearance:

Appearance is black with a very fine surface texture.

Advantages:

Provides excellent skid resistance; Reduces tire/road noise and vehicle splash/spray; Provides a very durable riding surface for high volume roads.

Limitations:

Relatively new technology in United States; High initial cost; Specialty paver required.

Product Description: An ultrathin 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 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



Ultrathin friction course.

Photo Source: KOCH



Ultrathin friction course construction.

Photo Source: FHWA-CFLHD

Asphalt Surfacing – Surface Layers (structural)



Traffic Range:

No traffic limitations for most surfacings.

Life Expectancy:

15 to 20 years for most surfacings.

Unit Price:

Material and installation costs are generally higher than for asphalt surface treatments.

Appearance:

Appearance is generally black, but can be influenced by pigments or surface coatings and, in some cases, coarse aggregate color.

Advantages:

Durable; Long life expectancy; Good ride quality; Provides structural capacity to roadway; High quality material.

Limitations:

Higher initial cost than asphalt surface treatments; High energy requirements for construction; Normal black appearance may contrast surrounding environment.

Product Description: Asphalt Concrete Surface Layers (structural) are composed of carefully designed blends of coarse and fine aggregate and mineral filler with asphalt cement as a binder. In general, these surfacings are high quality and durable. More than 90% of the paved roads in the United States are constructed of asphalt concrete surface layers.

Cold Mix Asphalt Concrete Pavement

2.1



Cold mix asphalt concrete pavement.

Photo Source: FHWA-CFLHD

Traffic Range:

No limitations on traffic volumes.

Life Expectancy:

15 to 20 years.

Unit Price:

Material & Installation: \$33 to \$44/Mg
(\$30.00 to \$40.00/ton).

Appearance:

Appearance is generally black, but can be influenced by pigmented binders and aggregate chip color. Surface texture is coarse.

Advantages:

No heating requirements; Plant or road mixing is possible.

Limitations:

Hydrocarbon emissions (if cutback asphalt used); Past experience with CMAC varies from very good to bad, depending on the agency; Generally more reliable as binder course than surface course.

Product Description: Cold Mix Asphalt Concrete (CMAC) is a blend of coarse and fine aggregate with emulsified or cutback asphalt as a binder. CMAC differs from HACP in that no heating is required during the production process.

Exposed Aggregate HACP

2.2



Exposed Aggregate HACP surfacing.

Photo Source: Golder Associates Inc.

Traffic Range:

No limitations on traffic volumes; however, surfacing is typically used for AADT < 1,000.

Life Expectancy:

15 to 20 years.

Unit Price:

Material & Installation: \$7.00 to \$12.50/m² (\$5.90 to \$10.50/yd²) based on a 40 mm (1.5 in.) thick layer of HACP.

Appearance:

Appearance will be influenced by the black asphalt binder and the color of the coarse aggregate in the HACP mixture.

Advantages:

Overall surfacing color can be controlled by careful selection of the aggregate used.

Limitations:

Not a common surfacing, so product information and experienced contractors are limited.

Product Description: For exposed aggregate HACP, the asphalt coating of the aggregate at the surface is removed by sandblasting, shotblasting, or other methods. This process results in improved texture and a modified appearance, especially if colored aggregate are used in the HACP mixture.

Hot Asphalt Concrete Pavement

2.3



Hot Asphalt Concrete Pavement.

Photo Source: FHWA-WFLHD

Traffic Range:

No limitations on traffic volumes.

Life Expectancy:

15 to 20 years.

Unit Price:

Material & Installation: \$33 to \$44/Mg (\$30 to \$40/ton).

Appearance:

Conventional HACP is generally black with a fine surface texture. Appearance can be modified with the careful selection of colored aggregates or by the use of pigments in the asphalt cement.

Advantages:

Durable; Excellent ride quality; Very common surfacing.

Limitations:

Asphalt concrete plant is needed in the area; Quality aggregate source is required.

Product Description: Hot Asphalt Concrete Pavement (HACP) is a high quality pavement material that is hot-mixed at a plant and then hot-laid. It is the most common surfacing for paved roads in the U.S., accounting for more than 90% of paved roads. HACP is composed of a carefully designed blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder.



HACP highway.

Photo Source: FHWA-CFLHD



HACP with red aggregate.

Photo Source: Golder Associates Inc.



Imprinted HACP street surfacing.

Photo Courtesy of: Golder Associates Inc.

Traffic Range:

Typical AADT < 1,300. For higher traffic volumes, color and imprint wear will increase.

Life Expectancy:

15 to 20 years.

Unit Price:

Material & Installation: \$60 to \$95/m² (\$50 to \$80/yd²) based on a 40 mm (1.5 in.) thick HACP layer.

Appearance:

Imprinted asphalt concrete can be a highly decorative surfacing. More than 15 different textures (e.g. brick, cobble, herringbone, etc.) and nearly 50 colors are available to choose from.

Advantages:

Durable; Aesthetically pleasing appearance; Can simulate some more expensive surfacings.

Limitations:

High initial cost; Imprinted pattern can cause rough surface.

Product Description: Imprinted asphalt concrete is a decorative paving system that is created by stamping a design into asphalt concrete when it is hot, using a special woven wire cable pattern template. The imprinted asphalt concrete surface is covered with a coating product consisting of cement-modified acrylic resins, epoxy-based polymers, and a blend of aggregates.



Imprinted HACP surfacing.

Photo Source: StreetPrint



Imprinted HACP surfacing.

Photo Source: StreetPrint



Imprinted HACP parking spaces.

Photo Source: Streetprint



Imprinted HACP surfacing.

Photo Source: Streetprint



Pigmented HACP surfacing.

Photo Source: Iterchimica

Traffic Range:

No limitations on traffic volumes. High traffic volumes will cause any surface coatings to wear away faster.

Life Expectancy:

15 to 20 years. Surface applied coatings commonly last 1 to 6 years.

Unit Price:

Material & Installation: \$4.00 to \$6.70/m² (\$3.30 to \$5.60/yd²) for spray coating.
\$18.00 to \$24.00/m² (\$15.00 to \$20.00/yd²) for pigment for 25 mm (1 in.) thick HACP layer.

Appearance:

Numerous pigment colors are available; Earth tones are most common.

Advantages:

Surfacing color can be selected to fit the application and surrounding environment.

Limitations:

High cost for the pigments or surfacing coating.

Product Description: Pigmented HACP is constructed by one of two methods: (1) the color is incorporated into the HACP surface mixture during mixing at the batch plant, or (2) a colored surface coating can be applied to the HACP surface after construction. Surface color can be achieved by applying a cement-modified acrylic, thermoplastic, or epoxy based coating.



Blue pigmented HACP.

Photo Source: Iterchimica



Red pigmented HACP.

Photo Source: Iterchimica



Porous HACP parking lot.

Photo Source: Cahill Associates

Traffic Range:

Typical AADT < 400.

Life Expectancy:

10 to 15 years.

Unit Price:

Material & Installation: \$5.00 to \$11.00/m² (\$4.20 to \$9.20/yd²) for a 50 mm (2 in.) thick lift of porous asphalt concrete.

Appearance:

Appearance is generally gray/black with a coarse surface texture.

Advantages:

Significantly reduces stormwater runoff.

Limitations:

Not suitable for high traffic volumes or heavy truck traffic; Shorter life expectancy than conventional HACP; Frequent maintenance required to clean porous asphalt pores.

Product Description: Porous Asphalt Concrete is a paved surface and subbase comprised of asphalt concrete and gravel or crushed aggregate, formed in a manner that results in a permeable surface. Stormwater that passes through the pavement may partially or completely infiltrate the underlying soil; the excess is collected and routed through underdrain pipes.



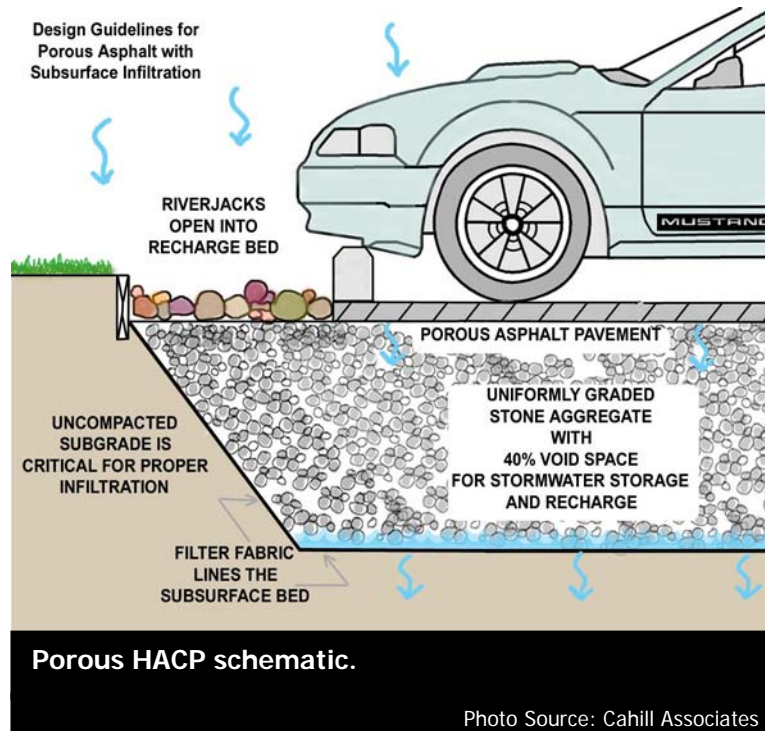
Porous HACP parking lot.

Photo Source: Cahill Associates



Porous HACP roadway.

Photo Source: City of Portland, OR





Resin Modified Pavement
surfacing.

Photo Source: Alyan Corp.

Traffic Range:

No limitations on traffic volumes; however, RMP is limited to low speed applications (less than 65 km/hr [40 mph]) due to low skid resistance.

Life Expectancy:

15 to 25 years.

Unit Price:

Material & Installation: \$12.00/m²
(\$10.00/yd²) for 50 mm (2 in.) thick RMP.

Appearance:

RMP has a relatively coarse texture and appearance, similar to coarse textured PCC. RMP typically has a light to dark gray color.

Advantages:

Low cost alternative to PCC when resistance to heavy loads, tracked vehicle equipment, or fuel spillage is required.

Limitations:

Limited to low speed applications due to low skid resistance; Limited use in United States.

Product Description: Resin Modified Pavement (RMP) is an open-graded asphalt concrete mixture with 25% to 35% voids that are filled with a latex-rubber modified cement grout. RMP provides many of the performance characteristics of Portland cement concrete with the economy and ease of construction of an asphalt concrete pavement .



Synthetic binder concrete pavement roadway surfacing.

Photo Source: FHWA-EFLHD

Traffic Range:

No limitations on traffic volume.

Life Expectancy:

15 to 20 years expected.

Unit Price:

Material & Installation: New product in United States; pricing is estimated to be about 4 times the price of HACP.

Appearance:

The synthetic binder is amber-colored. The appearance of the pavement will be dominated by the color of the coarse aggregate used. If colored pavements are required, pigments can be mixed with the synthetic binder.

Advantages:

Color can be controlled with careful aggregate selection; Properties similar to hot-mix asphalt concrete.

Limitations:

Very new technology in United States; Cost will be more than HACP.

Product Description: Synthetic binder concrete pavement is composed of a carefully designed blend of coarse and fine aggregate and mineral filler with polymer modified synthetic binder. The synthetic binder is composed of a petroleum hydrocarbon resin that can replace asphalt cement in traditional HACP.



Synthetic binder concrete pavement surfacing.

Photo Source: FHWA-EFLHD



Synthetic binder concrete pavement surfacing

Photo Source: FHWA-EFLHD

Portland Cement Concrete Surfacings

3.0



Traffic Range:

No limitations on traffic volumes for most surfacings.

Life Expectancy:

30 years or more for most surfacings.

Unit Price:

Material and installation costs are typically higher than for asphalt surfacings.

Appearance:

PCC surfacings typically has a smooth surface texture and light gray color. Surface appearance can be modified by using pigments or stains or finishing techniques.

Advantages:

Long life; Very good ride quality; Low maintenance requirements.

Limitations:

High initial cost; Initial construction is time and labor intensive.

Product Description: Portland cement concrete (PCC) is a mixture of aggregate, cementitious material (portland cement, fly ash, silica fume, ground blast furnace slag, etc.), and water that forms a rigid, paved surfacing. Portland cement concrete pavements (PCCP) have very good performance characteristics with respect to strength, durability, and ride quality.

Cellular Portland Cement Concrete

3.1



Cellular PCC concrete placement.

Photo Source: Presto Products Company

Traffic Range:

Typical AADT < 1,000.

Life Expectancy:

20 years.

Unit Price:

Material & Installation: \$16.00 to \$20.00/m²
(\$13.40 to \$16.70/yd²).

Appearance:

Cellular PCC typically has a fine surface texture and light gray color. The geosynthetic cellular support system is not visible in the completed surface.

Advantages:

Supports heavy loads; Does not require steel reinforcement.

Limitations:

Initial cost is higher than for aggregate filled system; Requires cellular confinement system setup prior to concrete placement.

Product Description: Cellular Portland cement concrete consists of a geosynthetic, honeycomb-like, cellular confinement system (geocells) that is filled with Portland cement concrete (PCC). Once constructed, the cellular mat is composed of numerous individual concrete blocks. The resulting product is a flexible surfacing that can support heavy loads.

Exposed Aggregate PCCP

3.2



Exposed aggregate PCCP
entranceway.

Photo Source: Golder
Associates Inc.

Traffic Range:

No limitations on traffic volumes.

Life Expectancy:

30 to 40 years.

Unit Price:

Material & Installation: \$145 to \$200/m³
(\$110 to \$150/yd³).

Appearance:

Appearance is influenced by the coarse aggregate color. Surface texture is coarse.

Advantages:

Appearance can be controlled by careful selection of coarse aggregate; Tire/road noise may be less than conventional PCCP.

Limitations:

Higher initial cost than conventional PCCP.

Product Description: Exposed Aggregate PCCP is constructed of Portland cement concrete (PCC). At the end of PCCP construction, a thin layer of cement paste is removed from the surface to expose the coarse aggregate in the PCC mixture.

Pigmented PCCP

3.3



Portland cement concrete pavement roadway.

Photo Source: Golder Associates Inc.

Traffic Range:

No Limitations on traffic volumes. Surface applied pigments and coatings will wear away faster with high traffic volumes.

Life Expectancy:

30 to 40 years for PCCP. 3 to 6 years for surface applied pigments or coatings.

Unit Price:

Material & Installation: \$6.50 to \$105/m³ (\$5 to \$80/yd³) for pigments, depending on color and intensity required.

Appearance:

Pigmented PCCP typically has a smooth surface texture. Surface color and intensity can be controlled by the pigment color and amount of pigment used.

Advantages:

Surface color can be selected to match the surrounding environment.

Limitations:

High initial cost than conventional PCCP.

Product Description: Pigmented PCCP is constructed of Portland cement concrete (PCC). The pigment can be incorporated in the concrete mixture during mixing or sprinkled onto a freshly poured PCC surface and mixed in during the finishing process, or pigmented sealers or stains can be applied to the hardened concrete surface.

Pigmented PCCP

3.3



Pigmented PCCP surfacing.

Photo Source: Concretenetwork.com



Pigmented PCCP surfacing.

Photo Source: Concretenetwork.com

Portland Cement Concrete Pavement

3.4



Portland cement concrete pavement roadway.

Photo Source: Golder Associates Inc.

Traffic Range:

Very Low to High.

Life Expectancy:

30 to 40 years.

Unit Price:

Material & Installation: \$130 to \$180/m³ (\$100 to \$135/yd³). The use of pigments, stains, or finishing techniques will increase the unit price.

Appearance:

PCCP typically has a fine surface texture and light gray color. Surface appearance can be modified by using pigments or stains or finishing techniques.

Advantages:

Long life; Very good ride quality; Low maintenance requirements.

Limitations:

High initial cost; Potential for increased road noise.

Product Description: Portland cement concrete (PCC) is a mixture of aggregate, cementitious material, and water that forms a rigid, paved surfacing. Portland cement concrete pavements (PCCP) have very good performance characteristics with respect to strength, durability, and ride quality.

Portland Cement Concrete Pavement

3.4



PCCP highway.

Photo Source: Golder Associates Inc.



PCCP surfacing.

Photo Source: Golder Associates Inc.

Portland Cement Concrete Pavement

3.4



PCCP construction: dowel bar placement.

Photo Source: Golder Associates Inc.

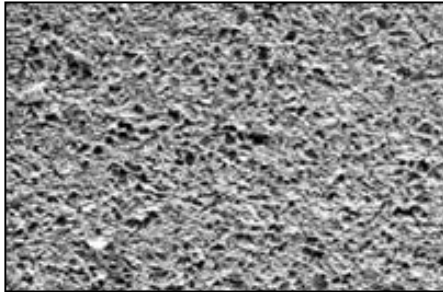


PCCP construction: concrete paving.

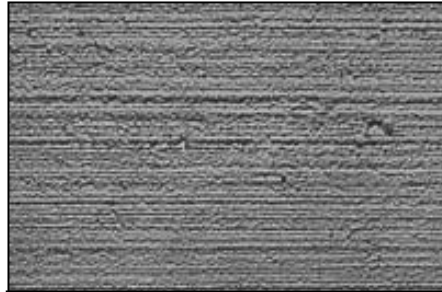
Photo Source: American Concrete Pavement Association

Portland Cement Concrete Pavement

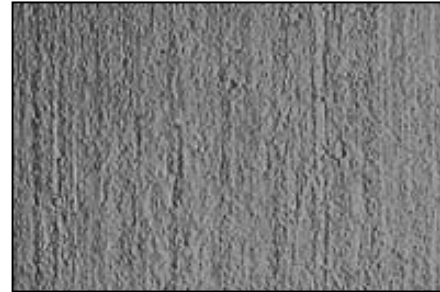
3.4



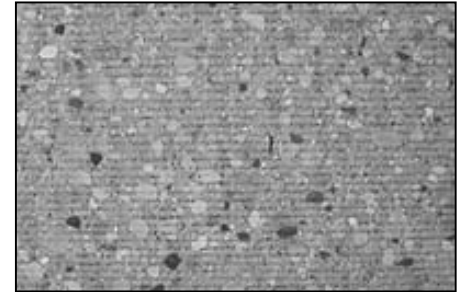
Abraded Finish.



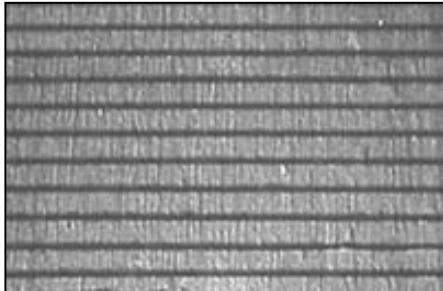
Broom Finish.



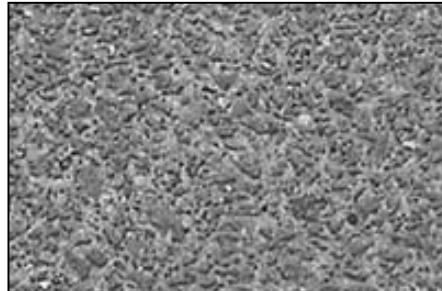
Burlap Finish.



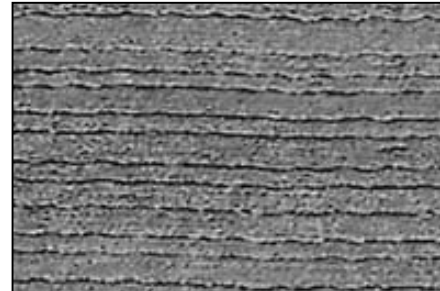
Diamond Grind Finish.



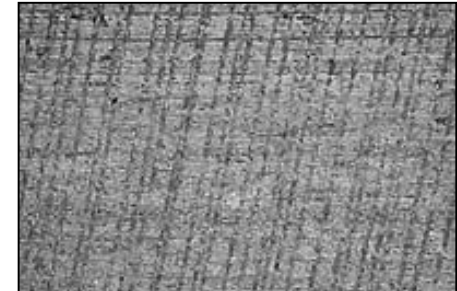
Diamond Groove Finish.



Exposed Aggregate Finish.



Longitudinal Tine Finish.



Transverse Tine Finish.

PCCP surfacing textures.

Photo Source: American Concrete Pavement Association

Porous PCCP

3.5



Porous PCCP parking lot.

Photo Source: Southeast
Cement Association

Traffic Range:

Typical AADT < 1,000.

Life Expectancy:

Typically 20 years.

Unit Price:

Material & Installation: \$44 to \$70/m² (\$37 to \$59/yd²) for 100 mm (4 in.) thick PCC layer.

Appearance:

PCCP typically has a coarse surface texture and light gray color. Surface color can be modified by using pigments or stains.

Advantages:

Allows surface water infiltration and reduces surface runoff compared to conventional PCCP.

Limitations:

Not recommended for high traffic volumes or heavy truck traffic; Frequent maintenance required.

Product Description: Porous PCCP is a paved surface and subbase comprised of PCC and gravel or crushed aggregate, formed in a manner that results in a permeable surface. Stormwater that passes through the pavement may completely or partially infiltrate the underlying soil with the excess being collected and routed to an overflow facility.

Porous PCCP

3.5



Porous PCCP parking lot.

Photo Source: Cahill Associates

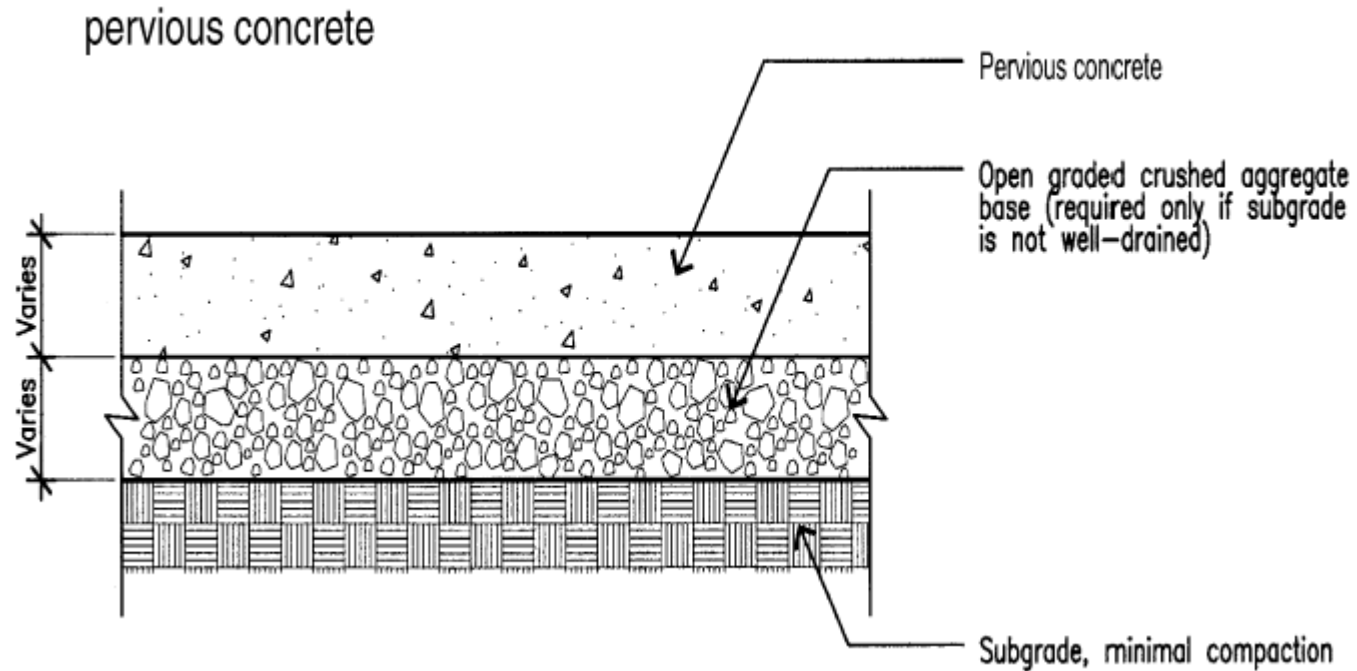


Porous PCCP construction.

Photo Source: City of Portland, OR

Porous PCCP

3.5



Porous PCCP schematic.

Photo Source: City of Portland, OR

Roller Compacted Concrete

3.6



Roller compacted concrete roadway surfacing.

Photo Source: Southeast Cement Association

Traffic Range:

No limitations on traffic volume. RCC is normally limited to low speed traffic applications (less than 60 km/hr [37 mph]).

Life Expectancy:

20 to 30 years.

Unit Price:

Material & Installation: \$55 to \$70/m³ (\$46 to \$59/yd³).

Appearance:

RCC has a relatively rough texture and light gray color. The surface color can be modified using pigments or stains.

Advantages:

Does not require steel reinforcement, joints, dowel bars, or forms; Lower cost and shorter construction time than conventional PCCP.

Limitations:

Traditionally, limited to low speed applications due to poor ride quality and poor to marginal skid resistance. Improvements have been achieved by using high density paving machines.

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Product Description: Roller compacted concrete (RCC) is constructed by compacting zero-slump Portland cement concrete that has been placed using traditional asphalt paving equipment. RCC does not require steel reinforcing, joints, dowel bars, or forms. RCC possesses most of the benefits of conventional Portland cement concrete, but has a lower cost and shorter construction time.

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Roller Compacted Concrete

3.6



RCC surfacing.

Photo Source: Southeast Cement Association



RCC construction.

Photo Source: Southeast Cement Association

Stamped PCCP

3.7



Stamped PCCP entranceway.

Photo Source: Golder Associates Inc.

Traffic Range:

Typical AADT < 1,200.

Life Expectancy:

30 to 40 years for PCCP. 3 to 5 years for color coating.

Unit Price:

Material & Installation: \$70 to \$86/m² (\$58.50 to \$72/yd²).

Appearance:

Stamped PCCP can be imprinted with various different patterns (e.g. brick, slate, flagstone, tile, stone, etc.) and numerous colors are available to choose from.

Pros:

Appearance can be selected to fit surrounding environment; Surface can be constructed to resemble expensive and decorative surface types at a lower cost.

Cons:

Higher initial cost than conventional PCCP; Imprint pattern can reduce ride quality and, in some cases, may reduce skid resistance.

Product Description: For stamped portland cement concrete (PCC), the surface of freshly poured PCC is patterned to resemble brick, slate, flagstone, tile, stone, or other traditional materials. The stamped concrete surface is covered with a coating product consisting of cement-modified acrylic resins and/or epoxy-based polymers and a blend of aggregates.

Stamped PCCP

3.7



Various Stamped PCCP textures and colors.

Photo Source: Decorative-Concrete.net



Stamped PCCP surfacing.

Photo Source: Increte Systems Inc.

Stamped PCCP

3.7



Stamped PCCP surfacing.

Photo Source: Increte Systems Inc.



Stamped PCCP surfacing.

Photo Source: FHWA-CFLHD

Whitetopping

3.8



Whitetopping roadway surface.

Photo Source: Golder Associates Inc.

Traffic Range:

No limitations on traffic volumes.

Life Expectancy:

20 to 30 years for conventional whitetopping. 5 to 15 years for UTW.

Unit Price:

Material & Installation: \$15.50 to \$19.10/m² (\$13.00 to \$16.00/yd²) for UTW; \$24.00 to \$32.30/m² (\$20.00 to \$27.00/yd²) for thin whitetopping.

Appearance:

Whitetopping typically has a smooth surface texture and light gray color. Appearance of UTW is characterized by fairly closely spaced joints.

Advantages:

Durable; Good ride quality; Excellent skid resistance.

Limitations:

High initial cost; UTW is relatively new technology.

Product Description: Whitetopping is a pavement rehabilitation technique that involves construction of a portland cement concrete (PCC) overlay on top of hot asphalt concrete pavement (HACP). Three different types of whitetopping are commonly used in construction: conventional whitetopping, thin whitetopping, and ultrathin whitetopping (UTW).

Unbound and Mechanically Stabilized Surfacing

4.0



Traffic Range:

Typical AADT < 200 to 1,000 when used as a road surfacing. No limitations on traffic volumes when used as an engineered base or subbase.

Life Expectancy:

Many unbound roadway surfacings must be reconstructed every 4 to 10 years, although some will last much longer with regular maintenance.

Unit Price:

Material and installation cost are generally less than for paved or sealed surfacings.

Appearance:

Appearance is influenced by the aggregate color and gradation.

Pros:

Low initial cost; Rustic appearance; Material is widely available.

Cons:

Dust generation; Material losses into surrounding environment; Vehicle damage from loose particles; Frequent regrading required.

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Product Description: Unbound and mechanically stabilized surfacings make up a significant portion of the rural low volume road system in the United States. Unbound surfacings typically have the lowest initial cost and can provide a durable riding surface when constructed with quality materials and adequately maintained.

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Cellular Confinement

4.1



Cellular confined aggregate surfacing.

Photo Source: Presto Products Company

Traffic Range:

Typical AADT < 1,000 when used as a road surfacing. No traffic limitations when used as a reinforced base.

Life Expectancy:

15 to 20 years, assuming the aggregate surface course is maintained.

Unit Price:

Material & Installation: \$36 to \$42/m² (\$30 to \$35/yd²) for a 150 mm (6 in.) thick layer.

Appearance:

The geocells are normally covered by a wearing surface, so they do not affect the aggregate surface appearance.

Pros:

Increases aggregate layer strength; Can reduce surface erosion; Does not affect appearance of gravel fill; Soil/aggregate mix can be used to support grass growth.

Cons:

Initial cost is higher than gravel surfacing alone.

Product Description: Cellular confinement systems, sometimes referred to as geocells, are constructed with a geosynthetic product that forms a honeycomb-like cellular structure that is infilled with aggregate to create a stabilized aggregate layer. Some aggregate cover is required to protect the geocells from traffic abrasion.

Cellular Confinement

4.1



Geocell framework.

Photo Source: FHWA-CFLHD



Cellular confined sand surfacing.

Photo Source: FHWA-CFLHD

Fiber Reinforcement

4.2



Fiber reinforced soil.

Photo Source: Fiber Reinforced Soils LLC

Traffic Range:

Typical AADT < 200 when used as a roadway surfacing.

Life Expectancy:

4 to 6 years; afterwards, another treatment of fiber reinforcement is typically required.

Unit Price:

Material & Installation: \$10.00 to \$16.00/m² (\$7.70 to \$12.30/yd²) for 200 mm (8 in.) layer. Unit price does not include soil.

Appearance:

The fibers will be visible in the surfacing material, with strands of fiber protruding from the soil mixture.

Pros:

Increases soil strength.

Cons:

Initial cost is higher than for untreated material; Relatively new technology.

Product Description: Materials that have been used for fiber reinforcement include metallic, polypropylene, glass, wire, cellophane, straw, and hemp fibers. The fibers are mixed with the soil to create a uniformly reinforced soil mix with discrete, randomly oriented fibers. The soil is then placed and compacted.

Geotextile/Geogrid Reinforcement

4.3



Spreading aggregate base over geogrid layer.

Photo Source: Tensar Earth Technologies

Traffic Range:

Typical AADT < 400 for roadway surfacing applications. No limitations on traffic volumes for base reinforcement applications.

Life Expectancy:

6 to 10 years or more until the aggregate surfacing is reconstructed, when used for surface reinforcement. When properly covered with aggregate, the geotextile/geogrid will last indefinitely.

Unit Price:

Material & Installation: \$2.80 to \$5.00/m² (\$2.30 to \$4.20/yd²). Unit price does not include aggregate material cost.

Appearance:

Does not significantly alter the appearance of soil/aggregate materials since it is covered.

Pros:

Increases layer strength or reduces required layer thickness; Reduces aggregate/subgrade mixing.

Cons:

Does not improve the roadway surface characteristics.

Product Description: Geotextiles and geogrids belong to a group of synthetic products collectively referred to as geosynthetics. Geosynthetic products can be used to reinforce soils and to act as filter or separation layers in pavement construction.

Geotextile/Geogrid Reinforcement

4.3



Geogrid placement for base reinforcement.

Photo Source: Mirafi Construction Products



Geotextile for subgrade stabilization.

Photo Source: Missouri Petroleum

Gravel (Crushed and Uncrushed)

4.4



Unbound gravel surfacing.

Photo Source: Golder Associates Inc.

Traffic Range:

Best suited for AADT < 250.

Life Expectancy:

Many gravel roads will last indefinitely with regular regrading and reapplication of gravel. Some require reconstruction after 6 to 10 years, even with regular maintenance.

Unit Price:

Material & Installation: \$22.20 to \$32.70/m³ (\$17.00 to \$25.00/yd³).

Appearance:

The color will depend on the material type and source. Texture depends on aggregate gradation and maximum particle size.

Pros:

Low initial cost; Widely available; Rustic appearance.

Cons:

Requires more frequent maintenance than if material was stabilized.

Product Description: Unbound gravel/crushed aggregate surfaced roads make up a significant portion of the rural low volume road system in the United States. Unbound surfaces typically have the lowest initial cost and can provide an acceptable riding surface when constructed with quality materials and adequately maintained.

Gravel (Crushed and Uncrushed)

4.4



Unbound crushed gravel surfacing.

Photo Source: Golder Associates Inc.



Unbound crushed gravel surfacing.

Photo Source: FHWA-CFLHD

Gravel (Crushed and Uncrushed)

4.4



Rutting of gravel road.

Photo Source: FHWA-WFLHD



Gravel loss in wheel paths.

Photo Source: FHWA-WFLHD

Sand

4.5



Sand roadway surfacing.

Photo Source: FHWA-CFLHD

Traffic Range:

Typically AADT < 200 when used as a roadway surfacing.

Life Expectancy:

4 to 6 years.

Unit Price:

Material & Installation: \$7.30 to \$10.90/Mg (\$6.60 to \$9.90/ton).

Appearance:

Color and texture will be determined by sand type and source.

Pros:

Low initial cost and readily available, in some regions.

Cons:

Lower quality material and performance than gravel; Lacks stability; Frequent regrading required.

Product Description: When used as a subgrade or subbase material, dense sand can provide good support for a pavement system, although not as good as a well graded gravel and sand mixture. When used as a road surfacing, clean, dry sands are subject to severe rutting, shoving, and erosion.



Sand roadway surfacing.

Photo Source: Golder Associates Inc.



Sand roadway surfacing.

Photo Source: Golder Associates Inc.

Other Stabilized Surfacing

5.0



Traffic Range:

Typical AADT < 200 or 400. When used for higher traffic volumes, more frequent applications are required.

Life Expectancy:

3 months to 1 year for dust palliative applications. 2 to 10 years for soil stabilization applications.

Unit Price:

Material and installation costs vary widely based on the product and application rate.

Appearance:

Chlorides do not significantly alter the appearance of soil/aggregate materials.

Pros:

Reduces dust generation by 50% or more;
May reduce surface erosion and required maintenance intervals.

Cons:

Many stabilizers are proprietary in nature and performance varies among products;
Performance may vary with soil type and climate.

Product Description: Soil stabilizers and dust palliatives are often used to increase the strength of unbound materials, extend the life expectancy, reduce maintenance requirements, and/or reduce dust generation. Many of the products are proprietary in nature and the exact composition and stabilization mechanisms are not publicly available. Performance and applicability can vary from product to product.



Gravel surfacing treated with CaCl.

Photo Source: Golder Associates Inc.

Traffic Range:

Typical AADT < 200. When used for higher traffic volumes, more frequent applications are required.

Life Expectancy:

3 months to 1 year before an additional topical treatment is required.

Unit Price:

Material & Installation: \$0.30 to \$0.60/m² (\$0.25 to \$0.50/yd²) for surface treatment. Unit price does not include aggregate.

Appearance:

Chlorides do not significantly alter the appearance of soil/aggregate materials.

Pros:

Reduces dust generation by 50% or more;
Widely available.

Cons:

Not effective in very arid or very wet climates; Slippery when wet; Can impact water and plant quality.

Product Description: Chlorides are commonly used for dust suppression in unbound road surfacings. Chlorides draw moisture from the air to keep the road surface moist (i.e. hygroscopic) and help resist evaporation of road surface moisture (i.e. deliquescent). By keeping the road surface moist, chlorides reduce the amount of dust generated.



Gravel surfacing treated with MgCl.

Photo Source: FHWA-CFLHD



Application of chloride treatment.

Photo Source: U.S. Forest Service

Clay Additives

5.2



Gravel road stabilized with clay additives.

Photo Source: FHWA-WFLHD

Traffic Range:

Typical AADT < 250. When used for higher traffic volumes, more frequent mixing and grading are required.

Life Expectancy:

2 to 4 years before additional clay additives treatments are needed on the roadway surface.

Unit Price:

Material & Installation: \$10.60 to \$14.10/m³ (\$8.10 to \$10.80/yd³) for an aggregate stabilized with clay additives.

Appearance:

Clay additives do not significantly alter the appearance of soil/aggregate materials.

Pros:

Helps stabilize non-plastic aggregates;
Reduces surface erosion and aggregate loss.

Cons:

Susceptible to wet weather; Not as effective as a dust suppressant as some other products.

Product Description: Clay additives are naturally occurring soils composed of the mineral montmorillonite. Clay additives are typically used to stabilize nonplastic crushed aggregates; they help to bind the aggregate particles and prevent raveling and washboarding. The clay additives will also attach to fines in the aggregate mix to reduce fugitive dust.

Electrolyte Emulsions

5.3



Electrolyte emulsion stabilized surfacing.

Photo Source: CBR Plus Inc.

Traffic Range:

Typical AADT < 250 AADT. When used for higher traffic volumes, more frequent applications are required.

Life Expectancy:

Typically 3 to 5 years between treatments for stabilization applications, with some stabilized surfaces in service after 15 years.

Unit Price:

Material & Installation: \$0.40 to \$0.80/m² (\$0.35 to \$0.70/yd²) for surface treatment. Unit price does not include aggregate/soil price.

Appearance:

Electrolyte emulsions do not significantly alter the appearance of soil/aggregate materials.

Pros:

Does not leach from soil; Increases soil strength; effective on clay soils.

Cons:

Softened by heavy rains; Requires clay particles in soil/aggregate.

Product Description: Electrolyte emulsions contain chemicals that affect the electro-chemical bonding characteristics of soils and replace water molecules within the soil structure. At low application rates, electrolyte emulsions are used for dust suppression. At higher application rates, electrolyte emulsions can be used to stabilize soils.

Enzymatic Emulsions

5.4



Enzymatic emulsion stabilized
surfacing.

Photo Source: FHWA-CFLHD

Traffic Range:

Typical AADT < 250. When used for higher traffic volumes, more frequent applications are required.

Life Expectancy:

Typically 5 to 7 years before additional stabilization treatments are needed, for stabilization applications. Some stabilized surfaces are in service after 12 years.

Unit Price:

Material & Installation: \$2.40 to \$4.80/m² (\$2.00 to \$4.00/yd²) for mixing depth of 150 mm (6 in.). Unit price does not include aggregate/soil price.

Appearance:

Enzymatic emulsions do not significantly alter the appearance of soil/aggregate materials.

Pros:

Increases soil strength; effective on clay soils.

Cons:

Softened by heavy rains; Requires clay particles in soil/aggregate; Relatively new technology.

Product Description: Enzymatic emulsions contain enzymes (protein molecules) that react with soil molecules to form a cementing bond that stabilizes the soil structure and reduces the soil's affinity for water. At low application rates, enzymatic emulsions are used for dust suppression. At higher application rates, enzymatic emulsions can be used to stabilize soils.

Lignosulfonates

5.5



Gravel surfacing treated with lignosulfonates.

Photo Source: FHWA-CFLHD

Traffic Range:

Typical AADT < 250. When used for higher traffic volumes, more frequent applications are required.

Life Expectancy:

3 months to 1 year before additional treatments are needed for dust suppression. 3 to 5 years for soil stabilization applications.

Unit Price:

Material & Installation: \$0.30 to \$0.60/m² (\$0.25 to \$0.50/yd²) for surface application. Unit price does not include aggregate/soil price.

Appearance:

Lignosulfonates do not significantly alter the appearance of aggregate/soil price.

Pros:

Increases soil strength; Effective on clay soils.

Cons:

Slippery when wet; Leaches from soil, especially during heavy or sustained periods of rain; Leaches more quickly from sandy soils.

Page 1 of 1

Product Description: Lignosulfonates are derived from the lignin that naturally binds cellulose fibers together to give trees firmness. At low application rates, lignosulfonates are used for dust suppression. At higher application rates, lignosulfonates can be used to stabilize soils.

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Organic Petroleum Emulsions

5.6



Organic petroleum emulsion stabilized surfacing.

Photo Source: Tricor Refining LLC

Traffic Range:

Typical AADT < 400.

Life Expectancy:

6 to 9 months before additional treatments are needed for dust suppression. 5 to 9 years for soil stabilization applications.

Unit Price:

Material & Installation: \$3.00 to \$4.00/m² (\$2.50 to \$3.30/yd²) for mixing depth of 150 mm (6 in.). Unit price does not include aggregate/soil price.

Appearance:

Turns the aggregate material black.

Pros:

Widely available.

Cons:

Hydrocarbon emissions for cutback asphalts; Increased potential for potholes; Regrading is more difficult than with some other soil stabilization products.

Product Description: Organic petroleum products include cutback asphalts, asphalt emulsions, modified asphalt emulsions, and emulsified oils. These products can be used for dust suppression or to stabilize soils. These products bind soil particles together due to the adhesive properties of the asphalt component of the products .



Synthetic polymer emulsion stabilized roadway.

Photo Source: Golder Associates Inc.

Traffic Range:

Typical AADT < 250. When used for higher traffic volumes, more frequent applications are required.

Life Expectancy:

6 months to 1 year between treatments for dust suppression. 5 to 10 years for soil stabilization applications.

Unit Price:

Material & Installation: \$2.40 to \$14.30/m² (\$2.00 to \$12.00/yd²) for mixing depth of 150 mm (6 in.). Unit price varies widely between different products. Unit price does not include aggregate/soil price.

Appearance:

Synthetic polymer emulsions do not significantly alter the appearance of soil/aggregate materials.

Pros:

Significantly reduces dust generation;
Increases soil/aggregate strength.

Cons:

High initial cost; Softens under extended wet weather conditions.

Product Description: Synthetic polymer emulsions primarily consist of acrylic or acetate polymers. The polymers cause a chemical bond to form between soil particles. At low application rates, synthetic polymer emulsions are used for dust suppression. At higher application rates, synthetic polymer emulsions can be used to stabilize soils.

Tree Resin Emulsions

5.8



Tree resin emulsion stabilized gravel.

Photo Source: Golder Associates Inc.

Traffic Range:

Typical AADT < 250. When used for higher traffic volumes, more frequent applications are required.

Life Expectancy:

6 months between treatments for dust suppression. 5 to 10 years for soil stabilization applications.

Unit Price:

Material & Installation: \$21.40 to \$53.60/m² (\$18.00 to \$45.00/yd²) for 50 mm (2 in.) thick stabilized layer. Unit price does not include aggregate/soil price.

Appearance:

Tree resin emulsions do not significantly alter the appearance of soil/aggregate materials.

Pros:

Reduces dust generation and surface material loss; Increases soil/aggregate strength.

Cons:

High initial cost; Softens under extended wet weather conditions; Slippery when wet.

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Product Description: Tree resin emulsions are derived from tree resins (mainly pine, fir, and spruce) combined with other additives to produce an emulsion. At low application rates, tree resin emulsions are used for dust suppression. At higher application rates, tree resin emulsions can be used to stabilize soils.

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Stabilized Aggregate and Soil (other than surfacing)

6.0

soil/
gravel
stabilizers



Traffic Range:

No limitations on traffic when used for base or subgrade stabilization. These stabilized soils/aggregates are not used as a surfacing material.

Life Expectancy:

Typically more than 20 years and may last for the lifetime of the roadway.

Unit Price:

Material and installation costs can vary by region due to the relative availability of the stabilizer.

Appearance:

Does not significantly alter the appearance of soil/aggregate materials.

Pros:

Increases soil strength; Reduces shrink/swell; Construction expedient for wet soil conditions.

Cons:

Not used as roadway surfacing.

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Product Description: Fly ash, lime, and Portland cement are commonly used to stabilize subgrade, subbase, or base materials. These stabilizers can be used to lower the water content of soils, reduce shrink-swell potential, increase workability, and increase soil strength and stiffness.

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Spreading fly ash for soil treatment.

Photo Source: Lafarge North America

Traffic Range:

No limitations on traffic when used for subgrade or subbase stabilization. Fly ash-stabilized soils/aggregates are not used as a surfacing material.

Life Expectancy:

Fly ash-stabilized subgrades and base materials will generally last for the lifetime of the roadway.

Unit Price:

Material & Installation: \$2.50 to \$4.50/m² (\$2.10 to \$3.80/yd²) for 200 mm (8 in.) treatment depth. Unit price does not include aggregate/soil cost.

Appearance:

Fly ash does not significantly alter the appearance of soil/aggregate materials.

Pros:

Effective use of a waste byproduct of the coal combustion power industry.

Cons:

Potential leaching of heavy metals; Limited availability in some areas.

Product Description: Fly ash is a residue of coal combustion that occurs at power generation plants throughout the United States. Fly ash can be used to lower the water content of soils, reduce shrink-swell potential, increase workability, and increase soil strength and stiffness.



Lime stabilized subgrade material.

Photo Source: FHWA-CFLHD

Traffic Range:

No limitations on traffic when used for subgrade or subbase stabilization. Lime-stabilized soils/aggregates are not used as a surfacing material.

Life Expectancy:

5 to 12 years for low application rates. More than 20 years for higher application rates.

Unit Price:

Material & Installation: \$1.60 to \$2.40/m² (\$1.30 to \$2.00/yd²) for mixing depth of 200 mm (8 in.). Unit price does not include aggregate/soil price.

Appearance:

Lime treatment does not significantly alter the appearance of soil/aggregate materials.

Pros:

Increases soil strength, workability;
Construction expedient for wet soil conditions; Widely available.

Cons:

Clay particles required in soil/aggregate;
Quicklime is highly reactive.

Product Description: Lime can be obtained in the form of quicklime or hydrated lime. Lime can be used to stabilize clay soils and submarginal base materials. Lime stabilization will increase soil workability and can increase the soil strength and stiffness.



Spreading lime treatment on subgrade.

Photo Source: Slurry Pavers Inc.



Mixing lime into subgrade material.

Photo Source: Slurry Pavers Inc.

Portland Cement

6.3



Portland cement stabilized base material.

Photo Courtesy of: Golder Associates Inc.

Traffic Range:

No limitations on traffic when used for subgrade or subbase stabilization. Portland cement-stabilized soils/aggregates are not used as a surfacing material.

Life Expectancy:

More than 20 years when used for subgrade or base stabilization.

Unit Price:

Material & Installation: \$3.30 to \$4.10/m² (\$2.80 to \$3.40/yd²) for mixing depth of 150 mm (6 in.).

Appearance:

Cement stabilization does not significantly alter the appearance of soil/aggregate materials.

Pros:

Increases strength of soil/aggregate layer;
Widely available.

Cons:

Higher initial cost; Cracking.

Product Description: Portland cement stabilization creates a hard, bound, impermeable layer. Cement-stabilized materials are rarely used as a surfacing material because they can become brittle and crack under traffic loads. Cement-treated soils are most frequently used as a stabilized subgrade or road base.

**Traffic Range:**

No limitation on traffic volume, except for porous unit pavers. Unit surfacings are normally limited to low speed traffic applications.

Life Expectancy:

Life expectancy is similar to or longer than other paved surfaces.

Unit Price:

Material and installation costs for unit surfacings are generally higher than for other paved surfaces.

Appearance:

Unit surfacing products are available in numerous shapes and natural colors (brown, red, gray, etc.), and can be placed in various patterns to create a decorative surface or pattern.

Advantages:

Long lasting under moderate traffic;
Decorative or historic appearance possible.

Limitations:

High initial cost; Poor to fair ride quality;
Easily damaged by snow plow activity.

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Product Description: Unit surfacings are composed of individual blocks, made from natural or manufactured materials, that are fit snugly together to form a road surfacing. Unit surfaces are typically supported on a layer of bedding sand or lean concrete, which is also used to fill the spaces between the individual blocks.

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Brick paver surfacing.

Photo Courtesy of: Golder Associates Inc.

Traffic Range:

Typical AADT < 500 due to concerns with excessive wear. Brick pavers are normally limited to low speed traffic applications with speeds less than about 60 km/hr (37 mph).

Life Expectancy:

20 to 25 years or more under light traffic.

Unit Price:

Material & Installation: \$145 to \$185/m² (\$120 to \$155/yd²), including the bedding sand layer.

Appearance:

Brick pavers are available in numerous shapes and natural colors (brown, red, gray, etc.), and can be placed in various patterns.

Advantages:

Can accommodate heavy traffic loads; Historic and/or decorative appearance.

Limitations:

Price is typically higher than for PCC unit pavers; Typically limited to lower traffic speeds than unit pavers.

Product Description: Brick pavers are accurately dimensioned blocks constructed of kiln-fired clay, shale, or other similar earthy substance. The bricks are fit snugly together to form a road surfacing. Brick pavers are supported on a layer of bedding sand, which is also used to fill the spaces between the pavers.



Brick paver surfacing.

Photo Source: Golder Associates Inc.

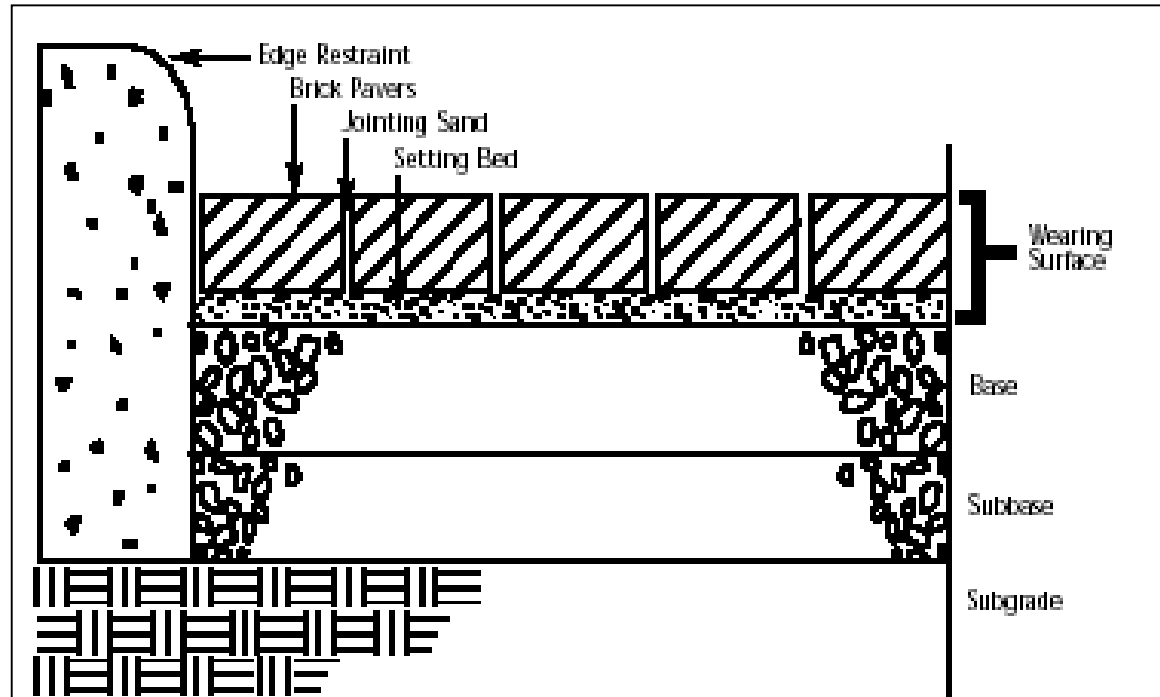


Brick paver surfacing.

Photo Source: Golder Associates Inc.

Brick Pavers

7.1



Typical brick paver detail.

Photo Source: Brick Industry Association



Natural stone paver surfacing.

Photo Source: Golder Associates Inc.

Traffic Range:

Typical AADT < 200. Natural stone pavers are normally limited to low speed traffic applications with speeds less than about 24 km/hr (15 mph).

Life Expectancy:

100 years.

Unit Price:

Material & Installation: \$300 to \$360/m² (\$250 to \$300/yd²).

Appearance:

Natural stone pavers can be produced in numerous shapes and natural colors (brown, red, gray, etc.), and can be placed in various patterns.

Advantages:

Long Lasting; Appearance compatible with historic settings.

Limitations:

Initial cost is higher than for other unit surfacings; Poor ride quality; Limited to lower traffic speeds than other unit surfacings; May pose a trip hazard for pedestrians.

Product Description: Natural stone pavers consist of irregularly sized, smooth natural stones or rock that is cut and shaped into regular sizes. Natural stone pavers fit together to form a road surfacing. They are supported on a layer of bedding sand or on a layer of lean concrete mix.

Natural Stone Pavers

7.2



Natural stone paver (setts) surfacing.

Photo Source: Golder Associates Inc.



Natural stone paver (cobblestone) surfacing.

Photo Source: Golder Associates Inc.



Porous unit paver surfacing.

Photo Source: City of
Portland, OR

Traffic Range:

Typical AADT < 200. Porous unit pavers are normally limited to low speed traffic applications with speeds less than about 30 km/hr (20 mph). They are frequently used for overflow or temporary parking applications.

Life Expectancy:

20 to 25 years.

Unit Price:

Material & Installation: \$36 to \$48/m² (\$30 to \$40/yd²) for porous unit pavers. Unit price does not include permeable base layer.

Appearance:

Porous unit pavers are available in numerous shapes and natural colors and can be placed in various patterns.

Advantages:

Allows surface water infiltration; Decorative surface pattern possible; Supports grass growth.

Limitations:

Limited to low volume, low speed applications. Not typically used for heavy traffic loads except for emergency vehicle access.

Product Description: Porous unit pavers are accurately dimensioned dense concrete or high strength plastic products that fit together to form a road surfacing. They have an interlocking geometry that results in regular void spacing. When the voids are filled with sand, they allow good stormwater infiltration while maintaining a driveable surface.



Porous concrete unit paver placement.

Photo Source: City of Portland, OR



Porous unit paver surfacing.

Photo Source: UNIGROUP-U.S.A.



Concrete unit paver surfacing.

Photo Courtesy of: Golder Associates Inc.

Traffic Range:

No limitations on traffic volume. Unit pavers are normally limited to traffic applications with speeds less than about 80 km/hr (50 mph).

Life Expectancy:

20 to 40 years.

Unit Price:

Material & Installation: \$36 to \$48/m² (\$30 to \$40/yd²), including leveling sand.

Appearance:

Unit pavers are available in numerous shapes and natural colors and can be placed in various patterns.

Advantages:

Can accommodate heavy traffic loads; Applicable to higher speed applications than other unit surfacings; Durable in all climatic conditions.

Limitations:

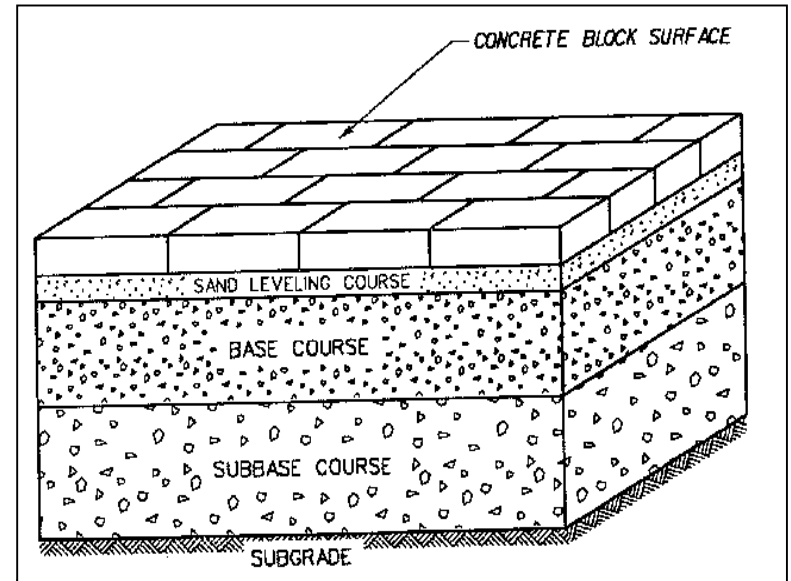
Can become unsightly if not properly maintained.

Product Description: Unit pavers are accurately dimensioned dense and durable concrete products that fit together to form a road surfacing. Unit pavers are typically supported on a layer of bedding sand, which is also used to fill the spaces between the pavers. Concrete pavers are available in a range of sizes and colors.



PCC paver surfacing.

Photo Source: Golder Associates Inc.



PCC paver surfacing schematic.

Photo Source: UNIGROUP-USA

Recycling Alternatives



Traffic Range:

Varies from AADT < 400 to no limitations, depending on the recycling alternative and application.

Life Expectancy:

Varies with recycling alternative.

Unit Price:

Material and installation costs vary widely with recycling alternative.

Appearance:

Many recycling products are not used as surfacings. HACP recycled surfacings generally appear black with fine to medium coarse surface texture. PCCP recycled materials generally have an appearance similar to crushed aggregate with a coarse texture.

Advantages:

Most alternatives are in situ processes; Allows materials to be reused; Reduces construction energy requirements; Reduces trucking requirements.

Limitations:

Surfacing quality may be lower than if virgin materials were used; Product quality may be more difficult to control.

Product Description: These recycling alternatives are methods developed to recycle/reuse PCC and HACP materials in roadway construction. By reusing the materials, disposal costs and environmental impacts are reduced and the energy requirements for roadway construction are often reduced. Many of these alternatives are in situ processes that require specialized equipment or paving trains.

Cold In-Place Recycling

8.1



Cold in-place recycled material.

Photo Courtesy of: FHWA-CFLHD

Traffic Range:

Typical AADT < 1,000. Usually overlain by HACP or surface treatment.

Life Expectancy:

6 to 8 years (12 to 20 years with HACP overlay).

Unit Price:

Material & Installation: \$4.20 to \$4.80/m² (\$3.50 to \$4.00/yd²) for 75 mm (3 in.) recycling depth.

Appearance:

Appearance is generally black with a medium coarse texture.

Advantages:

In situ process; Recycles existing HACP; Reduces energy requirements.

Limitations:

Not typically used as surface course; Experienced personnel and equipment required; Construction weather limitations; Will not remove full depth cracking in original HACP.

Product Description: Cold in-place recycling (CIR) is an in situ process used to recycle up to 100 mm (4 in.) of an existing asphalt concrete layer to construct a rejuvenated cold mix asphalt concrete layer. CIR is the rehabilitation of asphalt pavements without the application of heat during the recycling process.

Cold In-Place Recycling

8.1



CIR equipment train.

Photo Source: Nevada DOT



CIR construction.

Photo Source: Nevada DOT

Cold In-Place Recycling

8.1

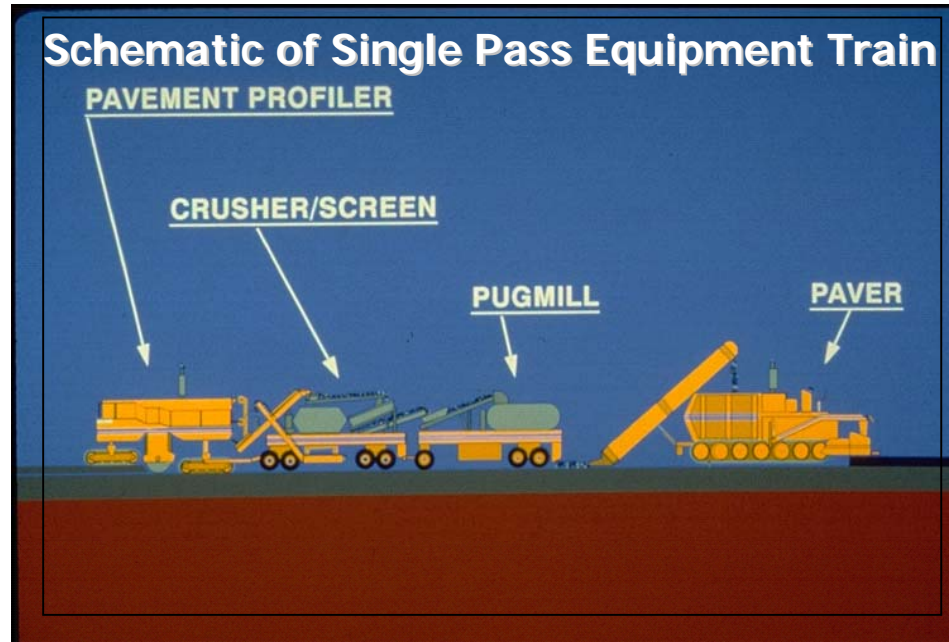


Photo Source: National Highway Institute

Hot In-Place Recycling

8.2



Hot in-place recycled pavement on right.

Product Description: Hot in-place recycling involves (1) milling and softening the existing asphalt concrete to a specified depth, (2) mixing the loosened asphalt concrete with a recycling agent and possibly virgin asphalt and (3) placing and compacting the mixture with conventional asphalt paving equipment.

Traffic Range:

Typical AADT < 400 for heater-scarification process. No limitations on traffic volume for remixing or repaving process.

Life Expectancy:

2 to 4 years for heater-scarification process. 6 to 10 years for heater-scarification with surface treatment. 7 to 14 years for remixing process. 6 to 15 years for repaving process.

Unit Price:

Material & Installation: \$0.90 to \$1.60/m² (\$0.75 to \$1.35/yd²) for heater-scarification. \$1.50 to \$2.40/m² (\$1.25 to \$2.00/yd²) for remixing. \$2.40 to \$3.90/m² (\$2.00 to \$3.25/yd²) for repaving. Unit prices are for 25 mm (1 in.) recycling depth.

Appearance:

Appearance is black with fine surface texture.

Advantages:

In situ process; Recycles in-place HACCP; Reduces energy requirements.

Limitations:

Specialized equipment required; Only recycles a maximum of 50 mm (2 in.) of existing HACCP.

Hot In-Place Recycling

8.2





PCCP rubblization.

Photo Source: Golder Associates Inc.

Traffic Range:

No limitation on traffic volumes when used as a base or subbase layer.

Life Expectancy:

Typically lasts for the life of the pavement when used as a base or subbase layer.

Unit Price:

Material & Installation: \$15.00 to \$30.00/m³ (\$12.50 to \$25.00/yd³) for reclaimed concrete aggregate, depending on location and availability.

Appearance:

Appearance is similar to unbound crushed aggregate.

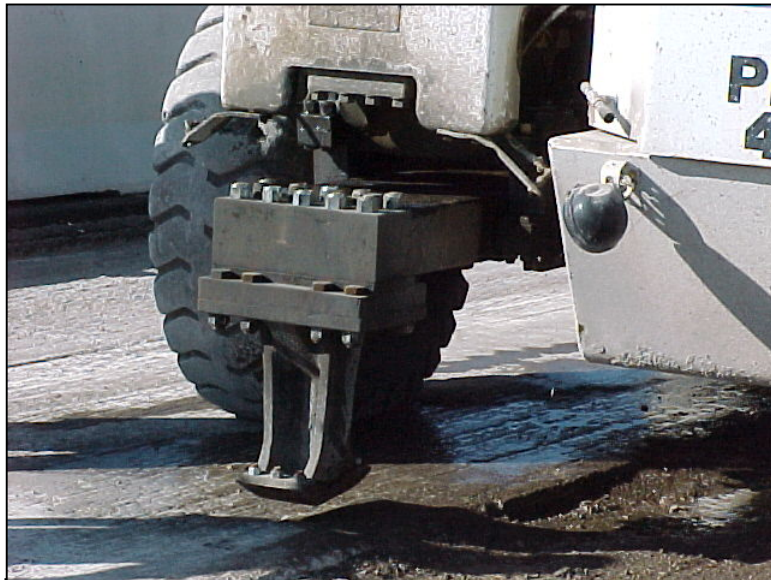
Advantages:

In situ process; Recycles in-place PCCP.

Limitations:

Specialized equipment required; Reflective cracking when concrete is not sufficiently broken into pieces.

Product Description: Reclaimed concrete aggregate (RCA) is a high quality aggregate produced by crushing old PCC. It can be used as an unbound base or subbase layer. Rubblization and crack-and-seat are two methods for fracturing concrete slabs in-place, using specialized equipment, for use as a base or subbase layer.



PCCP rubblizing equipment.

Photo Source: Golder Associates Inc.



Concrete aggregate reclamation process.

Photo Source: American Concrete Pavement Association

Recycled HACP

8.4



Recycled HACP.

Photo Source: FHWA-WFLHD

Traffic Range:

No limitations on traffic volumes.

Life Expectancy:

15 to 20 years, similar to HACP.

Unit Price:

Material & Installation: \$28 to \$39/Mg (\$25 to \$35/ton).

Appearance:

Appearance is black with fine surface texture, similar to HACP.

Advantages:

Recycles old HACP; Provides a use for cold milling product; High quality surfacing.

Limitations:

Adversely affects the quality of HACP when used in too high a proportion. Many agencies prohibit the use of RAP in wearing course mixes and strictly limit the proportion allowed in base course layers. Mix quality becomes more difficult to control as the RAP content increases.

Product Description: Recycled hot asphalt concrete pavement is HACP that contains a mixture of virgin asphalt binder and aggregate combined with cold milled HACP from old pavement structures. This cold milled product is generally referred to as reclaimed asphalt product (RAP).

Full Depth Reclamation



Traffic Range:

No limitations on traffic volumes for base stabilization applications.

Life Expectancy:

Typically 8 to 12 years when covered by thin surface treatment. 15 to 20 years or longer when covered by HACP.

Unit Price:

Material and installation costs vary from \$2.00 to \$8.50/m² (\$1.70 to \$7.20/yd²).

Appearance:

Appearance is generally dark brown/dark gray/black depending on the stabilization additives used.

Advantages:

Cost-effective; In situ process; Reuses existing asphalt concrete and base materials; Removes existing HACP distresses.

Limitations:

Not used as a roadway surfacing, except as a temporary surfacing; Specialized equipment required; Existing aggregate base must be of sufficient thickness.

Product Description: Full depth reclamation (FDR) is a rehabilitation technique in which the full thickness of the asphalt pavement and predetermined portion of the underlying materials (base, and sometimes, subbase) are uniformly pulverized and blended to provide an upgraded, homogeneous base material. The blended base material can be compacted as is, or can be stabilized by the addition of emulsified asphalt, cementitious stabilizers, or foamed asphalt.



FDR with cementitious stabilization additive.

Photo Source: FHWA-CFLHD

Traffic Range:

No limitations on traffic volumes when used for stabilized base applications.

Life Expectancy:

7 to 10 years when covered by thin surface treatment. 15 to 20 years or longer when covered by HACP.

Unit Price:

Material & Installation: \$4.00 to \$7.00/m² (\$3.30 to \$5.90/yd²) for a 150 to 200 mm (6 to 8 in.) mixing depth.

Appearance:

Appearance is similar to a stabilized aggregate base material, with the appearance influenced by the presence of asphalt-coated particles and the original aggregate base material.

Advantages:

In situ process; Reuses existing asphalt concrete and base materials.

Limitations:

With excessive dosages of cementitious additive, layer may become brittle and incompatible with flexible surfacing.

Product Description: Full depth reclamation (FDR) is a rehabilitation technique in which the full thickness of the asphalt pavement and predetermined portion of the underlying materials (base, and sometimes, subbase) are uniformly pulverized and blended to provide an upgraded, homogeneous base material. A cementitious additive is used to stabilize the reclaimed material.



Spreading of cement prior to reclamation process.

Photo Source: FHWA-CFLHD



FDR reclamation process.

Photo Source: Slurry Pavers Inc.



Compacted FDR-emulsified asphalt material.

Photo Source: EJ Breneman LP

Traffic Range:

No limitations on traffic volumes for stabilized base applications.

Life Expectancy:

7 to 10 years when covered by thin surface treatment. 15 to 20 years or longer when covered by HACP.

Unit Price:

Material & Installation: \$5.00 to \$8.00/m² (\$4.20 to \$6.70/yd²) for 150 to 200 mm (6 to 8 in.) mixing depth.

Appearance:

Appearance is similar to a dark aggregate base material, with the asphalt coated particles visible on close examination. Surface texture is coarse.

Advantages:

In situ process; Reuses existing asphalt concrete and base materials.

Limitations:

Difficult to achieve a smooth finish.

Product Description: Full depth reclamation (FDR) is a rehabilitation technique in which the full thickness of the asphalt pavement and predetermined portion of the underlying materials (base, and sometimes, subbase) are uniformly pulverized and blended to provide an upgraded, homogeneous base material. An emulsified asphalt is used to stabilize the reclaimed material.



FDR-emulsified asphalt construction.

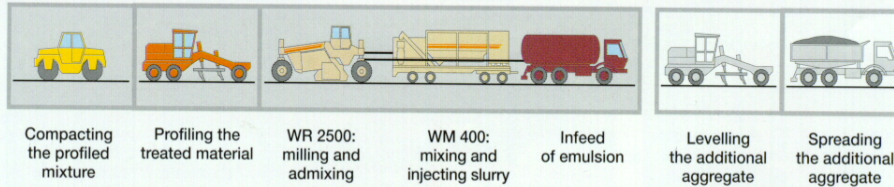
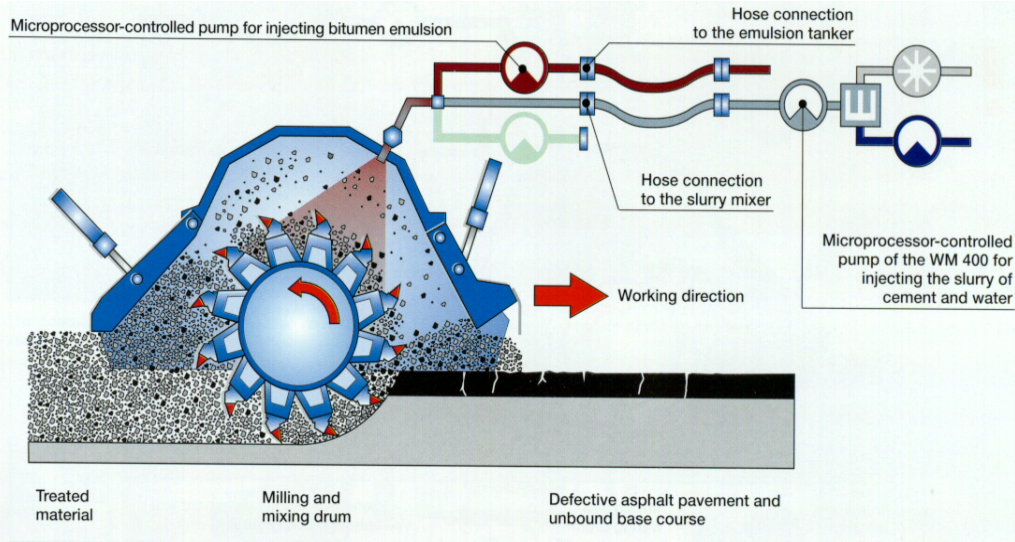
Photo Source: EJ Breneman LP



Compaction of FDR-emulsified asphalt material.

Photo Source: FHWA-CFLHD

FDR-Emulsified Asphalt



FDR-emulsified asphalt construction process.

Photo Source: Wirtgen Group



Foamed asphalt base layer.

Photo Source: Golder Associates Inc.

Traffic Range:

No limitations on traffic volumes for base stabilization applications.

Life Expectancy:

8 to 12 years when covered by thin surface treatment. 15 to 20 years or longer when covered by hot-mix asphalt concrete.

Unit Price:

Material & Installation: \$4.80 to \$8.40/m² (\$4.00 to \$7.00/yd²) for 150 mm (6 in.) mixing depth.

Appearance:

Foamed asphalt generally is dark brown to dark gray in color.

Advantages:

Cost-effective; Suitable for use with marginal materials containing large amounts of fines; Small quantity of asphalt cement needed.

Limitations:

Not used as a roadway surfacing, except as a temporary surfacing; Relatively new technology.

Product Description: Foamed asphalt is a technique where asphalt cement is used to bind granular material. When hot asphalt cement comes in contact with cold water, the mixture expands and is separated into very fine droplets. The foamed material is mixed with the aggregate/RAP blend and coats the fines in the mixture to form a mortar that binds the coarse particles.



Foamed asphalt material in right lane.

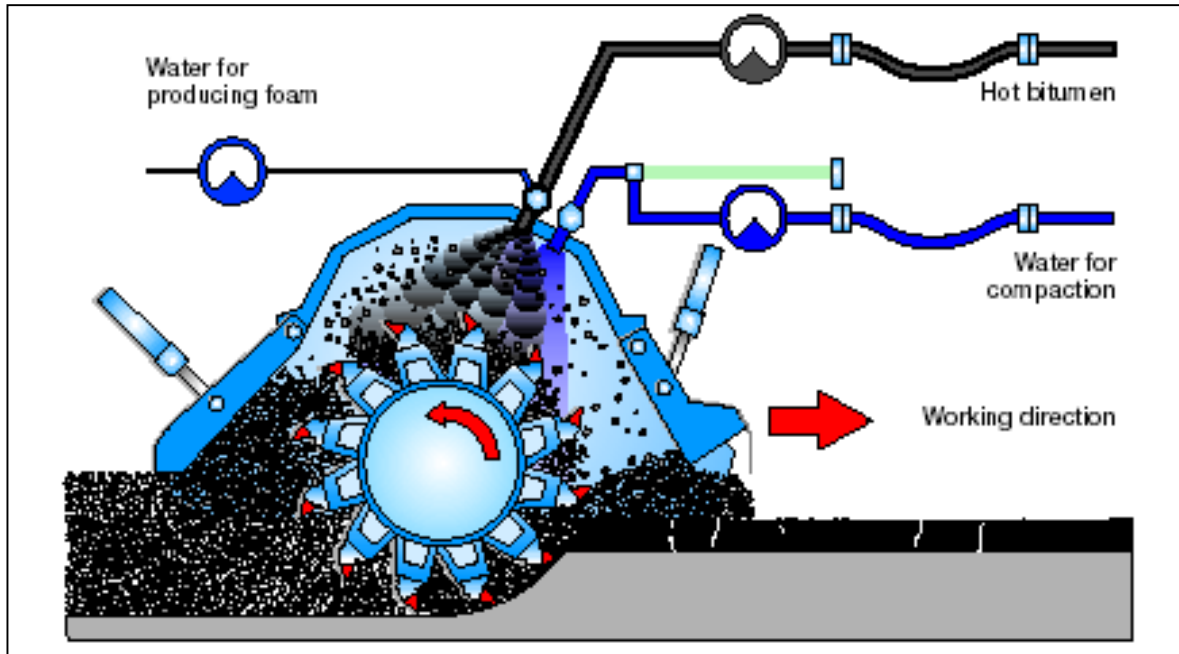
Photo Source: FHWA-CFLHD



Foamed asphalt equipment train.

Photo Source: Golder Associates Inc.

Foamed Asphalt



Foamed asphalt schematic.

Photo Source: Wirtgen Group



Pulverized roadway material.

Photo Source: FHWA-CFLHD

Traffic Range:

No limitations on traffic volumes for base applications.

Life Expectancy:

7 to 10 years with surface treatment; 15 to 20 years with HACP overlay.

Unit Price:

Material & Installation: \$2.00 to \$4.00/m² (\$1.70 to \$3.30/yd²) for 200 mm (8 in.) mixing depth.

Appearance:

Appearance is similar to a dark aggregate base material, with the asphalt coated particles visible on close examination.

Advantages:

In situ process; Reuses existing asphalt concrete and base material; Less expensive than other FDR alternatives because no additive is used.

Limitations:

Lower quality material than stabilized FDR materials; Some virgin aggregate base is generally needed to permit fine grading prior to paving.

Product Description: Full depth reclamation (FDR) or pulverization is a rehabilitation technique in which the full thickness of the asphalt pavement and predetermined portion of the underlying materials (base, and sometimes, subbase) are uniformly pulverized and blended to provide an upgraded, homogeneous base material.



Pulverization process.

Photo Source: FHWA-CFLHD



Pulverized material prior to compaction.

Photo Source: FHWA-CFLHD