ASPHALT SURFACING – SURFACE LAYERS (STRUCTURAL)

COLD MIX ASPHALT CONCRETE PAVEMENT

GENERAL INFORMATION

Generic Name(s): Cold Mix Asphalt Concrete (CMAC)

Trade Names: N/A

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; this reduces energy requirements as well as emissions. Cold mixes can be placed immediately after mixing or stockpiled for later use. CMAC can be an economical alternative when there is a long haul distance to the nearest hot mix plant.

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, binder course.

Traffic Range: Very Low to High.

Restrictions:

Traffic: CMAC is prone to damage from heavy wheel loadings and excessive turning movements. Therefore, CMAC is not recommended for heavy industrial loading conditions (i.e. slow moving trucks, frequent braking, etc.).

Climate: None.

Weather: None.

Terrain: None.

Soil Type: N/A

Other: None.

Other Comments: The grade of asphalt cement needs to be selected based on service temperature ranges and traffic volumes. Cold mixes typically utilize slow or medium setting emulsified or cutback asphalts and are more pliable than typical HACP. This pliability aids in compaction and reduces cracking potential and is useful in applications where distortion due to frost or poor subgrade conditions may be a problem. CMAC is considered to be "self-healing" under solar heat and traffic. CMAC is also commonly used as roadway patching material.

DESIGN

SLC: 0.28 to 0.39.

Other Design Values: None.

Base/Subbase Requirements: CMAC is usually constructed over an aggregate base course, but may be placed directly over a prepared subgrade of native materials. The required CMAC thickness depends on the level of base/subgrade support provided. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to CMAC placement. A prime coat is sometimes used above the aggregate base prior to paving. CMAC pavements have the ability to handle subgrade weaknesses better than most surfacing alternatives.

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

CONSTRUCTION

Availability of Experienced Personnel: CMAC is a commonly used surfacing in some regions of the United States, particularly in the western states. In these areas, experienced contractors are, in general, widely available. For other regions, availability of experienced contractors may be limited.

Materials: Cold Mix Asphalt Concrete (CMAC) is a blend of coarse and fine aggregate with emulsified or cutback asphalt as a binder. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics. Emulsified asphalt grades used for CMAC are: MS-1, MS-2, MS-2h, HFMS-1, HFMS-2, HFMS-2h, HFMS-2s, SS-1, SS-1h, CMS-2, CMS-2s, CMS-2h, CSS-1, and CSS-1h. The medium setting emulsified asphalts are designed for mixing with coarse aggregates. High-float medium setting emulsified asphalt gives better aggregate coating under extreme temperature conditions. Slow setting emulsified asphalts are designed for maximum mixing stability and are used for dense graded aggregates with high fines content. Cutback asphalts used for CMAC include: MC-70, MC-250, MC-800, MC-3000, SC-250, SC-800, and SC-3000.

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

Emulsified Asphalt: Advantages of emulsified asphalt include a cooler application temperature (10 to 70 °C [50 to 160 °F]) than cutback asphalts, and the water that evaporates is environmentally safe.

Equipment: Equipment required for CMAC construction include: haul vehicles, asphalt distributor, stationary or rotary mixer or motor grader, and compaction equipment (static steel wheel roller, pneumatic tire roller, or vibratory roller). Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: CMAC can be plant mixed or road mixed. Plant mixed CMAC can be stockpiled for later use. For road mixing, emulsified or cutback asphalts are produced by an asphalt supplier and shipped to the site.

Placement Process: For road mixing with a rotary mixer, the aggregate is spread to a uniform thickness over the entire roadway. The aggregate is then sprayed with the asphalt and mixed using multiple passes of the rotary mixer. Asphalt should be added in increments of about 2.25 L/m^2 (0.50 gal/yd^2) with each pass of the rotary mixer. Additional passes of the rotary mixer are made between asphalt applications, as necessary, to achieve uniform mixing. Once the total amount of asphalt has been added and mixed, the material must be allowed to aerate (i.e. allow the emulsion diluents to evaporate) if adequate aeration did not occur during the mixing process. Once aeration is completed, the CMAC is graded and compacted. CMAC should be placed and compacted with a maximum lift thickness of 75 mm (3 in.).

For road blade mixing with a motor grader, the aggregate is piled in windrows and asphalt is applied using an asphalt distributor at a rate of 3.5 L/m^2 (0.75 gal/yd^2) per pass. Between asphalt applications, the asphalt and aggregate are mixed together using multiple passes of the motor grader. The motor grader makes as many passes as necessary to obtain a uniform mix. Once the total amount of asphalt has been added and mixed, the material must be allowed to aerate (i.e. allow the emulsion diluents to evaporate off) if adequate aeration did not occur during the mixing process. Once aeration is completed, the CMAC is compacted and graded.

For plant mix CMAC, the cold mix is transported to the site and placed in windrows if aeration is still required. Once aeration is complete, the cold mix is spread, graded, and compacted. Better product quality control can be achieved with the plant mixed CMAC.

Weather Restrictions: Do not place CMAC if it is raining or there is ponded water on the prepared paving surface. The specified minimum air temperature for CMAC placement varies between different agencies, but is normally about 10 °C (50 °F).

Construction Rate: Typical production rates are 900 to 1,360 Mg/day (1,000 to 1,500 tons/day).

Lane Closure Requirements: The roadway lane being constructed is closed during construction, so adequate traffic control is needed. The CMAC surface can be opened to traffic as soon as construction is completed. Road surface striping may be performed before or after the lane is opened.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: CMAC is a common roadway surfacing in some areas of the United States; research, design and construction information, and project experience is available. Agencies have had mixed results with regard to CMAC performance, some agencies have experienced very good performance while other have not. Poor mix design or construction can lead to rutting, raveling, and premature failure. CMAC is more reliable as a binder course than as a wearing course.

Life Expectancy: Life expectancy varies depending on mix types, environmental conditions, traffic volumes and degree of routine maintenance. Typical serviceable lives range from 15 to 20 years.

Ride Quality: CMAC provides good ride quality after construction. Ride quality deteriorates over the serviceable life.

Main Distress / Failure Modes: Rutting, raveling, cracking.

Preservation Needs: Preventative maintenance includes periodic crack sealing and localized patching. Thin surface treatments can be applied to extend the serviceable life of CMAC.

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 construction; proper engineering controls and construction practices should be utilized to minimize safety risks.

Skid Resistance: Provided high quality aggregates are used in the cold mix, CMAC provides good skid resistance.

Road Striping Possible?: Yes.

Other Comments: Because CMAC provides a good-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: For plant mix CMAC, the cold mix must be hauled from an asphalt plant unless a mobile asphalt plant is assembled. For road mix CMAC, emulsified or cutback asphalts 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, especially where road mixing is used. If clean aggregate is not used, dust can be a problem during mixing. 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: CMAC is impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by CMAC roadways.

Erosion: None.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

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

Other Environmental Considerations: CMAC'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. For CMAC, tire/road noise is similar to HACP and typically in the range of 66.5 to 77.5 dB(A) inside a car (80 km/hr [50 mph]) and 72 to 79.5 dB(A) at a distance 7.5 m (25 ft) from the vehicle.

AESTHETICS

Appearance: Immediately after placement, CMAC is generally black with a smooth surface. CMAC's appearance can be modified with the careful selection of colored aggregates, by the use of pigments in the asphalt cement, and by inclusion of a coarser aggregate in the CMAC.

Appearance Degradation Over Time: Over time, the cold mix may wear, exposing more of the aggregate in the wheel paths. Short or medium term improvements in appearance can be achieved by the use of thin surface treatments, such as fog seals and slurry seals.

COST

Supply Price: N/A

Supply+Install Price: $33 to $44/Mg ($30 to $40/ton).

EXAMPLE PROJECTS

SR 230, Elko County, NV.

SELECT RESOURCES

Asphalt Institute, (859) 288-4960, www.asphaltinstitute.org
Asphalt Institute (1989). *Asphalt Cold Mix Manual*, Manual Series No. 14 (MS-14), Third Edition, Asphalt Institute, Lexington, KY, 185 pp.

HOT ASPHALT CONCRETE PAVEMENT (HACP)

GENERAL INFORMATION

Generic Name(s): Hot Asphalt Concrete Pavement (HACP), Hot Asphalt Concrete Pavement, Hot Mix Asphalt Concrete (HMAC), Bituminous Concrete

Trade Names: N/A

Product Description: 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. The asphalt mix proportions need to be designed to suit the particular application. The asphalt cement grade needs to be selected based on service temperature ranges and traffic volumes. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics.

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, binder course, base course.

Traffic Range: Very Low to High.

Restrictions:

Traffic: A high stability mix should be used for heavy industrial loading conditions (i.e. slow moving trucks, frequent braking, etc.). Mixture criteria should be tailored for the conditions of use.

Climate: None.

Weather: None.

Terrain: None.

Soil Type: N/A

Other: None.

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 penetration grade (60/70, 85/100, etc.) or by viscosity grades (AC-20, AC-30, AR-4000, AR-8000, 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 modifiers to expand the serviceable temperature range of an asphalt will improve rutting resistance at high temperatures and reduce thermal cracking at low temperatures.

For very low to low traffic applications, HACP mixes should be designed so that additional compaction from traffic is not relied upon to help achieve the target HACP air void content as is commonly done for high volume applications. Inadequately compacted HACP will have a higher air void content, making it more permeable and susceptible to oxidation. When HACP oxidizes, it becomes brittle, which leads to cracking. Polymers can be used in the asphalt cement to improve ductility and reduce the effects of oxidation.

DESIGN

SLC: 0.30 to 0.46. Typical default values: 0.44 for Superpave, Marshall, and Hveem, 0.40 for minor asphalt mixes, 0.35 for HACP binder course.

Other Design Values: None.

Base/Subbase Requirements: HACP is usually constructed over an aggregate base course, but may be placed directly over a prepared subgrade of native materials. The required HACP thickness depends on the level of base/subgrade support provided. Subgrade and base materials should be graded and compacted to provide a stable working surface prior to HACP placement. A prime coat is normally used above the aggregate base prior to paving. Tack coats can be used to improve the bond between hot mix layers.

Other Comments: As a general guideline, the minimum HACP lift thickness should be three times the nominal maximum aggregate size. For coarse-graded mixtures, the minimum lift thickness should be four times the nominal maximum aggregate size.

CONSTRUCTION

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

Materials: HACP is composed of a blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics.

Equipment: Equipment required for HACP construction includes: haul vehicles, asphalt distributor (if prime or tack coats are applied), asphalt paver machine, and compaction equipment (static steel wheel roller, pneumatic tire roller, or vibratory roller). Equipment is widely available in urban areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: HACP is hot mixed at an asphalt plant by mixing specified proportions of the heated material components together to form a uniform mixture. HACP 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 2 or 3 hours. When the project site is far from an asphalt plant, a portable asphalt plant can be assembled near the project site. When selecting a site for a portable asphalt plant, impacts to the environment and local residents and businesses must be considered.

Placement Process: Upon arrival at the site, the asphalt concrete 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 HACP is then rolled with compaction equipment to achieve the required density. The compaction process should be completed before the asphalt binder stiffens to the point where additional compactive effort will damage the pavement mat, which generally occurs between a temperature of about 85 °C (185 °F) and 150 °C (300 °F), depending on the asphalt binder. 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 HACP 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 HACP placement varies between different agencies, but is normally about 7 °C (45 °F).

Construction Rate: HACP 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. Compactor speeds are normally limited to 4.8 km/hr (3 mph), so overall construction rates are often dictated by the number of compactors on site. Typical production rates are 900 to 4,500 Mg/day (1,000 to 5,000 tons/day). Coordination of asphalt concrete delivery, paving speed, and compaction is necessary due to the limited time asphalt concrete is workable.

Lane Closure Requirements: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The HACP surface can be opened to traffic as soon as the HACP 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: HACP is a very common roadway surfacing and has been used on roadway projects for more than 100 years; an extensive amount of research, design and construction information, and project experience is available. The Superpave mix design method is relatively new, with most research and project experience occurring since 1990.

Life Expectancy: Life expectancy varies depending on mix types, environmental conditions, traffic volumes and degree of routine maintenance. Typical serviceable lives range from 15 to 20 years.

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

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

Preservation Needs: Preventative maintenance includes periodic crack sealing and localized patching every 7 to 9 years. Thin surface treatments can be applied to extend the serviceable life of HACP.

SAFETY

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

Skid Resistance: Provided high quality aggregates are used in the asphalt concrete mix, HACP provides good to excellent skid resistance.

Road Striping Possible?: Yes.

Other Comments: Because HACP 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. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

Delivery and Haul Requirements: Hot mix asphalt concrete must be hauled from a stationary asphalt plant unless a mobile asphalt plant is assembled, in which case the materials for the concrete mix must be hauled to the mobile plant. Haul distances may be significant for remote sites.

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

Potential Long-Term Environmental Impacts:

Leachate: None

Surface Runoff: HACP is impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by HACP roadways. In parking areas, oil and other vehicle fluids can be collected by surface runoff, affecting the water quality.

Erosion: HACP 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: HACP can be fully recycled as a pavement construction material.

Other Environmental Considerations: HACP'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. For HACP, tire/road noise is typically in the range of 66.5 to 77.5 dB(A) inside a car (80 km/hr [50 mph]) and 72 to 79.5 dB(A) at a distance 7.5 m (25 ft) from the vehicle. Mixtures such as Stone Matrix Asphalt and Porous Friction Courses result in reduced tire/road noise levels compared to conventional dense-graded mixtures. The reduction in sound level is typically about 3 dB(A) for Porous Friction Courses and 2 dB(A) for Stone Matrix Asphalt.

AESTHETICS

Appearance: Immediately after placement, HACP is generally black with a very smooth surface. Conventional HACP's appearance can be modified with the careful selection of colored aggregates, by the use of pigments in the asphalt cement, and by inclusion of a coarser aggregate in the HACP.

Appearance Degradation Over Time: Over time, HACP 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 and patching, the surface appearance is further altered. Where special mixes are used, the future availability of similar mixes should be assured for maintenance purposes to ensure a uniform surface appearance. Surface appearance may be altered by the use of surface treatments, such as fog seals and slurry seals.

COST

Supply Price: N/A

Supply+Install Price: $33 to $44/Mg ($30 to $40/ton).

EXAMPLE PROJECTS

HACP is used extensively throughout the United States.

SELECT RESOURCES

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

EXPOSED AGGREGATE HACP

GENERAL INFORMATION

Generic Name(s): Exposed Aggregate Hot Asphalt Concrete Pavement, Exposed Aggregate Asphalt Concrete

Trade Names: N/A

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. The asphalt mix proportions need to be designed to suit the particular application. The asphalt cement grade needs to be selected based on service temperature ranges and traffic volumes. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics.

In the exposed aggregate asphalt concrete, the coating of the aggregate at the surface is removed by sandblasting, shotblasting or other methods. This results in improved texture and an attractive appearance, particularly if a colorful aggregate is used. The techniques and equipment used for the removal of rubber build-up on airport runways can also be used to produce exposed aggregate asphalt concrete.

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. The most common equipment for surface removal of asphalt are the 'Skidabrader' (Ruston, LA, Tel: 318-251-1935, www.skidabrader.com) and the 'Blastrac' (International Surface Preparation, Bellaire, TX, Tel: 800-374-4043, www.surfacepreparation.com).

APPLICATION

Typical Use: Road surfacing.

Traffic Range: Low to Medium.

Restrictions:

Traffic: Exposed aggregate HACP is not recommended for applications with significant heavy truck traffic.

Climate: None.

Weather: None.

Terrain: None.

Soil Type: N/A

Other: Because of the increased cost to expose the aggregate, this surfacing is mainly used for low to medium volume and low traffic speed applications, such as short access roads and driveways.

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 penetration grade (60/70, 85/100, etc.) or by viscosity grades (AC-20, AC-30, AR-4000, AR-8000, 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 modifiers to expand the serviceable temperature range of asphalt will improve rutting resistance at high temperatures and reduce thermal cracking at low temperatures.

DESIGN

SLC: 0.30 to 0.46, Typical default values: 0.44 for Superpave, Marshall, and Hveem, 0.40 for minor asphalt mixes.

Other Design Values: None.

Base/Subbase Requirements: HACP is usually constructed over an aggregate base course, but may be placed directly over a prepared subgrade of native materials. The required HACP thickness depends on the level of base/subgrade support provided. Subgrade and base materials should be graded and compacted to provide a stable working surface prior to HACP placement. A prime coat is normally used above the aggregate base prior to paving. Tack coats can be used to improve the bond between hot mix layers.

Other Comments: None.

CONSTRUCTION

Availability of Experienced Personnel: HACP is a commonly used surfacing and experienced contractors are, in general, widely available. However, exposed aggregate HACP is not a common surfacing and the availability of experienced contractors is limited. Specialty contractors who supply and operate the 'Skidabrader' and the 'Blastrac', especially for runway maintenance and road skid resistance restoration are available in major cities. A specialty contractor with experience with exposed aggregate HACP construction is recommended.

Materials: HACP is composed of a blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics. Care should be exercised in aggregate selection, especially where specific color effects are desired. In all cases only high quality and durable aggregates should be used.

Equipment: Equipment required for HACP construction includes: haul vehicles, asphalt distributor (if prime or tack coats are applied), asphalt paver machine, and compaction equipment (static steel wheel roller, pneumatic tire roller, or vibratory roller). Equipment is widely available in urban areas, but availability may be limited in remote areas. In addition to regular equipment required for HACP construction, sand and shot blasting equipment (e.g. Skidabrader, Blastrac) are required to remove the asphalt coating from the coarse aggregate at the pavement surface.

Manufacturing/Mixing Process: HACP is hot mixed at an asphalt plant by mixing specified proportions of the heated material components together to form a uniform mixture. HACP 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 2 or 3 hours. When the project site is far from an asphalt plant, a portable asphalt plant can be assembled near the project site. When selecting a site for a portable asphalt plant, impacts to the environment and local residents and businesses must be considered.

Placement Process: Upon arrival at the site, the asphalt concrete 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 HACP is then rolled with compaction equipment to achieve the required density.

The aggregate can be exposed by one of two methods: (1) sand or shot blasting or (2) terrazzo buffers. Once the asphalt concrete is constructed, the asphalt coating covering the aggregate at the pavement surface can be removed by sand or shot blasting. This is a fairly quick and easy process carried out using self-propelled specialty equipment. Where steel shot is used the steel shot is separated from the asphalt and aggregate debris using magnets. This allows the shot to be recovered and reused. Alternatively, the surface asphalt coating can be removed by grinding/buffing with terrazzo grinders/buffers typically used in finishing terrazzo floors. This technique is suitable for small areas (less than 93 m^2 [1,000 ft^2]). Care must be taken not to remove too much of the asphalt cement; removing too much could result in coarse aggregate pop outs, especially in colder climates where snow plowing is required. The asphalt cement coating should be removed just enough to expose the coarse aggregate, typically about 3 mm (0.13 in.). A trial section should be completed before extensive surface removal is undertaken.

Weather Restrictions: Do not place HACP 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 HACP placement varies between different agencies, but is normally about 7 °C (45 °F).

Construction Rate: HACP 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. Compactor speeds are normally limited to 4.8 km/hr (3 mph), so overall construction rates are often dictated by the number of compactors on site. Typical production rates are 900 to 4,500 Mg/day (1,000 to 5,000 tons/day). Coordination of asphalt concrete delivery, paving speed, and compaction is necessary due to the limited time asphalt concrete is workable. The production rate for removing the surface asphalt coating to expose the aggregate ranges from about 4,500 to 18,000 m^2 /day (5,400 to 21,500 yd^2 /day) using dedicated shot blasting equipment.

Lane Closure Requirements: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The HACP surface can be opened to traffic as soon as the HACP aggregate is exposed 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: HACP is a very common roadway surfacing and has been used on roadway projects for more than 100 years; an extensive amount of research, design and construction information, and project experience is available. However, exposed aggregate HACP is not a common surface and available information is limited. Exposed aggregate HACP should perform very similar to conventional HACP, providing only the thin surface asphalt cement is removed.

Life Expectancy: Life expectancy varies depending on mix types, environmental conditions, traffic volumes and degree of routine maintenance. Typical serviceable lives range from 15 to 20 years.

Ride Quality: Good ride quality after construction. Ride quality deteriorates over the serviceable life.

Main Distress / Failure Modes: Cracking, rutting, raveling, popouts.

Preservation Needs: Preventative maintenance includes periodic crack sealing and localized patching every 7 to 9 years. Thin surface treatments can be applied to extend the serviceable life of HACP, but will cover the exposed aggregate. To maintain the exposed aggregate surfacing, a conventional HACP overlay would be needed followed by the shot blasting treatment to again expose the aggregate.

SAFETY

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

Skid Resistance: Provided high quality aggregates are used in the asphalt concrete mix, exposed aggregate HACP provides good to excellent skid resistance. Exposed aggregate asphalt concrete has better frictional characteristics than conventional HACP, however, the improvement in skid resistance will only be maintained if the HACP contains a high quality aggregate.

Road Striping Possible?: Yes.

Other Comments: Because exposed aggregate HACP 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. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

Delivery and Haul Requirements: HACP 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 mixing and placement process. Construction processes may impact vegetation adjacent to the roadway. Dust can be generated during grinding/sandblasting. A system needs to be implemented during construction to contain and collect the sand following sand blasting. Modern dedicated shot blasting equipment is designed to contain and control all the abraded product inside an enclosure so essentially there are no fugitive particles.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: The surface is relatively impermeable, so surface runoff from the road should be managed properly to minimize erosion adjacent to road.

Erosion: None.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: Exposed aggregate HACP can be fully recycled as a pavement construction material.

Other Environmental Considerations: HACP'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. The exposed aggregate further lightens the overall color of the surfacing. For exposed aggregate asphalt concrete, tire/road noise can range from slightly lower to slightly higher than the level for HACP, which is typically in the range of 66.5 to 77.5 dB(A) inside a car (80 km/hr [50 mph]) and 72 to 79.5 dB(A) at a distance 7.5 m (25 ft) from the vehicle.

AESTHETICS

Appearance: The surface appearance will not be as black as conventional asphalt pavements because it will be influenced by the color of the coarse aggregate in the HACP mix. The overall color can be controlled by careful selection of the source aggregate.

Appearance Degradation Over Time: Some surface wearing is possible with time, as well as some aggregate loss. However, with the use of high quality aggregates, the loss in serviceability with time should be similar to a high quality wearing course HACP.

COST

Supply Price: N/A

Supply+Install Price: \$80 to \$140/Mg (\$70 to \$130/ton); or \$7.00 to \$12.50/m^2 (\$5.90 to \$10.50/yd^2), based on a 40 mm (1.5 inch) thick lift. The cost of the asphalt cement coating removal by shot blasting on its own ranges from \$3.00 to \$5.50/m^2 (\$2.50 to \$4.60/ yd^2).

EXAMPLE PROJECTS

Rideau Hall access driveway (residence of the Governor General of Canada), Ottawa, Canada.

SELECT RESOURCES

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

IMPRINTED/EMBOSSED HACP

GENERAL INFORMATION

Generic Name(s): Imprinted Hot Asphalt Concrete Pavement, Stamped Asphalt Concrete, Embossed Colored Asphalt Concrete

Trade Names: StreetPrint

Product Description: Imprinted HACP is a decorative paving system that is created by stamping a design into HACP when it is hot, using a special woven wire cable pattern template. The imprinted depressions are less than 10 mm (0.375 in.) deep. 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. The coating system can be designed to provide a wide range of colors and textures.

Hot mix asphalt concrete 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.

Hot mix asphalt concrete is composed of a carefully designed blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder. The asphalt mix proportions need to be designed to suit the particular application. The asphalt cement grade needs to be selected based on service temperature ranges and traffic volumes. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics.

Product Suppliers: Integrated Paving Concepts, PMB 48, 936 Peace Portal Drive, Blaine, WA 98230-4040, (800) 688-5652, www.streetprint.com.

APPLICATION

Typical Use: Road surfacing, typically on short road sections, crosswalks, pathways, plazas, or parking areas, where decorative treatment is desired.

Traffic Range: Very Low to High (typically less than 1,300 AADT), depending on climate. At higher traffic volumes, the coating system will wear away faster.

Restrictions:

Traffic: Imprinted asphalt concrete is not recommended for heavy industrial loading applications (i.e. high volume of heavy commercial vehicles, frequent braking and turning, etc.).

Climate: Where winter conditions require regularly applied aggregate/salt on the roads, the resulting abrasion accelerates the wearing away of the coating system.

Weather: None.

Terrain: None.

Soil Type: N/A

Other: None.

Other Comments: Imprinted asphalt concrete is mainly used for decorative purposes, since it simulates a wide range of other, more expensive, pavement types, such as cobblestone, brick pavers, etc. Imprinted asphalt concrete has been used most frequently in areas with high pedestrian traffic. The cement modified acrylic coloring is frequently used to delineate crosswalks and bus stops.

DESIGN

SLC: 0.30 to 0.46. Typical default values: 0.44 for Superpave and Hveem, 0.40 for minor asphalt mixes.

Other Design Values: None.

Base/Subbase Requirements: Imprinted asphalt concrete is usually constructed over an aggregate base course. The required asphalt concrete thickness depends on the level of base/subgrade support provided. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to HACP placement. A prime coat is normally used above the aggregate base prior to paving. Tack coats can be used to improve the bond between hot mix layers.

Other Comments: As a general guideline, the minimum asphalt concrete lift thickness should be three times the nominal maximum aggregate size. 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. With the use of polymers, the serviceable temperature range is extended so rutting can be avoided at high temperatures and transverse cracking can be avoided at low temperatures.

CONSTRUCTION

Availability of Experienced Personnel: HACP is a commonly used surfacing and experienced contractors are, in general, widely available. Certified imprinted asphalt concrete installers are available locally in most large urban areas and regionally in more remote areas. Therefore, availability may be limited for projects in remote areas.

Materials: Hot mix asphalt concrete is composed of a blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics. The surface coating applied to the imprinted asphalt surface is composed of cement-modified acrylic resins, epoxy-based polymers, and a blend of aggregates.

Equipment: Equipment required for imprinted HACP construction include: haul vehicles, asphalt distributor (if prime or tack coats are applied), asphalt paver machine, compaction equipment (static steel wheel roller, pneumatic tire roller, or vibratory roller), imprinting templates, and infrared or hot air heaters (if the HACP is existing instead of freshly placed). Equipment is widely available in urban areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Hot mix asphalt concrete is normally 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 2 or 3 hours.

Placement Process: Upon arrival at the site, the asphalt concrete mixture is transferred from the trucks 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 asphalt concrete is then rolled with compaction equipment to achieve the required density.

For freshly placed HACP, imprinting is performed while the asphalt concrete is still warm to hot. For existing HACP, the surface must be heated to a depth of at least 12.5 mm (0.5 in.) using infrared or hot air heaters, until the asphalt concrete is pliable enough to accept the imprinting template. When the surface is hot, the imprinting templates, constructed of specially woven wire cable welded to a desired pattern, are placed on the asphalt concrete surface and pressed into the asphalt concrete using standard compaction equipment. The imprint depth is typically 10 mm (0.375 in.). The template is then removed from the asphalt concrete surface and the process is repeated for the next area. Once the asphalt concrete is imprinted and allowed to cool, a surface coating, consisting of cement-modified acrylic resins, epoxy-based polymers, and a blend of fine aggregates, is applied to the surface to seal the surface, add coloring, and improve surface performance characteristics.

Weather Restrictions: Do not place HACP 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 7 °C (45 °F). The surface coating should not be applied if it is raining or if rain is expected within 2 hours of coat application. Air temperatures should be above 10 ºC (50 ºF) at the time the surface coating is applied and for at least 8 hours after the coating is applied.

Construction Rate: HACP 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 4.4 lane-km per day (2.7 lane-miles per day). Imprinting of the asphalt concrete surface will dictate the placement rate; imprinting can be performed at a rate of 480 to 720 m^2/day (400 to 600 yd^2/day).

Lane Closure Requirements: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The imprinted HACP surface can be opened to traffic as soon as the asphalt concrete 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: Imprinted asphalt concrete is a relatively new surfacing; emerging as a surfacing alternative within the past 10 years. Design and construction information and extensive project experience over the past 10 years, is available.

Life Expectancy: Life expectancy varies depending on mix types, environmental conditions, traffic volumes and degree of routine maintenance. Typical serviceable lives for asphalt pavements range from 15 to 20 years. Depending on traffic volumes, reapplication of the polymer or resin color coating and restamping will be needed during that period, as discussed below.

Ride Quality: Ride quality can vary from poor to good after construction, depending on the type of texture and embossing utilized. Ride quality will decrease with increased surface texture. Ride quality deteriorates over the serviceable life.

Main Distress / Failure Modes: Cracking, rutting, raveling, and wearing of the color coating.

Preservation Needs: Preventative maintenance includes periodic crack sealing and localized patching every 7 to 9 years. Color coating needs to be reapplied every 3 to 5 years and restamping may be needed every 6 to 10 years.

SAFETY

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

Skid Resistance: The imprinted HACP surface coating is designed to provide good skid resistance.

Road Striping Possible?: Yes.

Other Comments: Because HACP 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. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used. The color coating is a manufactured product composed of cement modified acrylic coloring.

Delivery and Haul Requirements: HACP must be hauled from an asphalt plant unless a mobile asphalt plant is assembled, in which case the required hot mix asphalt concrete mix components must be hauled to the mobile plant. Haul distances may be significant for remote sites.

Potential Short-Term Construction Impacts: Significant heat is generated during the asphalt concrete mixing and placement process. If the asphalt concrete is already in-place, significant heat is required to heat the asphalt concrete surfacing for stamping. Construction processes may impact vegetation adjacent to the roadway.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Imprinted HACP is impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by imprinted asphalt concrete.

Erosion: None.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: Imprinted HACP can be reused as recycled aggregate base. The color coating may restrict the use of imprinted HACP as RAP for recycled HACP.

Other Environmental Considerations: Light surface colors can be selected to increase heat reflectivity of the surface. For HACP, tire/road noise is typically in the range of 66.5 to 77.5 dB(A) inside a car (80 km/hr [50 mph]) and 72 to 79.5 dB(A) at a distance 7.5 m (25 ft) from the vehicle. For imprinted HACP, tire/road noise is typically the same or slightly higher than conventional HACP.

AESTHETICS

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. Imprinted HACP can be used to blend in with the surrounding environment (e.g. slate or rock pattern, colored in earth tones, in a wilderness area) or to contrast the surrounding environment (e.g. pedestrian crosswalk, fire lane, or handicap parking area colored in bright, contrasting colors), depending on the application and designer's intent.

Appearance Degradation Over Time: Over time, some color and imprint wear is possible. Additional applications of color coating and restamping can be used to maintain the appearance of the surface. Surfaces can also become discolored by tire marks and oil leakage. If not maintained, the imprinted asphalt concrete will eventually begin to look like conventional asphalt concrete.

COST

Supply Price: N/A

Supply+Install Price: \$60 to \$95/m^2 (\$50 to \$80/yd^2) based on a 40 mm (1.5 inch) HACP wearing course. For the application of the pattern and color excluding the cost of the HACP, the cost would be in the range of \$55 to \$85/m^2 (\$45 to \$70/yd^2).

EXAMPLE PROJECTS

Downtown Historic District, City of Portsmouth, VA.
Birkdale Village, Huntersville, NC.

SELECT RESOURCES

Integrated Paving Concepts, (800) 688-5652, www.streetprint.com.

PIGMENTED HACP

GENERAL INFORMATION

Generic Name(s): Pigmented Asphalt Concrete Pavement, Colored Asphalt Concrete, Colored Asphalt

Trade Names: N/A

Product Description: Hot asphalt concrete pavement (HACP) is a high quality pavement material that is hot mixed at a plant and then hot laid. Pigmented, or colored, HACP can be used to blend in with the surrounding environment (pavement colored in earth tones in a wilderness area, for example) or to contrast the surrounding environment (e.g. pedestrian crosswalk, fire lane, or handicap parking area colored in bright, contrasting colors), depending on the application and designer's intent.

HACP is composed of a carefully designed blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder. The asphalt mix proportions need to be designed to suit the particular application. The asphalt cement grade needs to be selected based on service temperature ranges and traffic volumes. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics.

There are two basic methods for obtaining a colored finish with an asphalt surfacing: (1) the color is incorporated into the surface course mix at the time of manufacture or (2) an overall decorative surface treatment can be applied to the surface after HACP construction. The majority of colored asphalt concrete mixes are produced using the first method.

Decorative surface treatments include emulsified asphalt surfacings and various chemical coatings. For emulsified asphalt treatments (e.g. chip seals, slurry seals, microsurfacing), color can be obtained by mixing pigments with the emulsified asphalt. Surface color can also be achieved by applying a cement-modified acrylic, thermoplastic, or epoxy based coating. Information regarding emulsified asphalt surfacings can be found on the corresponding product summary sheets and will not be covered in this product summary.

Product Suppliers: Asphacolor Corporation, (800) 258-7679, www.asphacolor.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.

Traffic Range: Very Low to High.

Restrictions:

Traffic: None.

Climate: None.

Weather: None.

Terrain: None.

Soil Type: N/A

Other: None.

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 viscosity 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. With the use of polymers, the serviceable temperature range is extended so rutting can be avoided at high temperatures and transverse cracking can be avoided at low temperatures.

Any light-colored surface finish can be disfigured by stains, such as from oil spills, that are not evident on traditional black asphalt concrete surfacings. Also, the asphalt concrete color can rarely be matched when future patching is required over utility cuts, etc.

DESIGN

SLC: 0.30 to 0.46. Typical default values: 0.44 for Superpave, Marshall, and Hveem, 0.40 for minor asphalt mixes.

Other Design Values: None.

Base/Subbase Requirements: HACP is usually constructed over an aggregate base course, but may be placed directly over a prepared subgrade of native materials. The required HACP thickness depends on the level of base/subgrade support provided. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to HACP placement. A prime coat is normally used above the aggregate base prior to paving. Tack coats can be used to improve the bond between hot mix layers.

Other Comments: The effect of color pigments on HACP performance is generally none to minimal. Color pigments are typically only added to the surface course layer, since it is the only visible layer.

CONSTRUCTION

Availability of Experienced Personnel: Pigmented HACP construction is identical to conventional HACP construction. HCAP is a commonly used surfacing and experienced contractors are, in general, widely available. Availability may be limited for projects in remote areas. For colored surface coatings, experienced specialty contractors are required; they are widely available near large urban areas and regionally available in other areas.

Materials: HACP is composed of a blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder. Modified asphalt cement and/or additives can be used to enhance certain performance characteristics. Pigments are generally nontoxic, nonhazardous, dry materials manufactured specifically for use as color additives. Iron oxide is the most common pigment and is widely available; some other pigments can be very expensive and have limited availability.

Equipment: Equipment required for HACP construction includes: haul vehicles, asphalt distributor (if prime or tack coats are applied), asphalt paver machine, and compaction equipment (static steel wheel roller, pneumatic tire roller, or vibratory roller). Equipment is widely available in urban areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: HACP is normally hot mixed at a stationary asphalt plant by mixing specified proportions of the heated material components together to form a uniform mixture. When the color is added during HACP mixing, pigments are added to the heated aggregates and mixed prior to adding the asphalt cement binder. HACP 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 2 or 3 hours. When the project site is far from an asphalt plant, a portable asphalt plant can be assembled near the project site. When selecting a site for a portable asphalt plant, impacts to the environment and local residents and businesses must be considered.

Placement Process: Upon arrival at the site, the asphalt concrete 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 HACP is then rolled with compaction equipment to achieve the required density. When a pigmented surfacing is applied as opposed to adding the pigment during the mixing process, colored chemical surface coatings are typically sprayed onto the finished HACP surface.

Weather Restrictions: Do not place HACP 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 HACP placement varies between different agencies, but is normally about 7 °C (45 °F).

Construction Rate: HACP 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. Compactor speeds are normally limited to 4.8 km/hr (3 mph), so overall construction rates are often dictated by the number of compactors on site. Typical production rates are 900 to 4,500 Mg/day (1,000 to 5,000 tons/day).

Lane Closure Requirements: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The HACP surface can be opened to traffic as soon as the HACP has cooled and construction equipment is cleared from the roadway. Road surface striping may be performed before or after the lane is opened. Chemical surface coatings have varying cure times, but typically range from a few minutes to an hour.

Other Comments: Asphalt concrete producers must dedicate their plant to pigmented asphalt concrete production for the entire production duration, creating logistical problems and increasing cost. Also, asphalt concrete suppliers will not want to dedicate their plant to pigmented asphalt concrete for small asphalt concrete order quantities.

SERVICEABILITY

Reliability and Performance History: Pigmented HACP performs identically to conventional HACP. HACP is a very common roadway surfacing and has been used on roadway projects for more than 100 years; an extensive amount of research, design and construction information, and project experience is available. The Superpave mix design method is relatively new, with most research and project experience occurring since 1990.

For chemical surface coatings, product specific information should be collected regarding performance and durability.

Life Expectancy: Life expectancy varies depending on mix types, environmental conditions, traffic volumes and degree of routine maintenance. Typical serviceable lives range from 15 to 20 years. Surface applied color coatings will commonly last 1 to 2 years for light spray applications and 3 to 6 years or more for thicker and more durable surface coatings.

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

Main Distress / Failure Modes: Cracking, rutting, raveling, loss of surface friction, color fading or wearing (for surface applied coatings).

Preservation Needs: Preventative maintenance includes crack sealing every 2 to 5 years and localized patching every 7 to 9 years. Pigmented crack sealer or asphalt concrete is preferred for preventative and corrective maintenance. However, the asphalt concrete color can rarely be matched exactly since the original surface color fades with time. Thin surface treatments can be applied to extend the serviceable life of pigmented HACP, but they will hide the original pigmented surface.

SAFETY

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

Skid Resistance: Provided high quality aggregates are used in the asphalt concrete mix, pigmented HACP provides good to excellent skid resistance. Colored surface coatings can obscure the natural aggregate texture and can create slippery surface conditions; however, some coatings include skid resistant materials that provide good to excellent skid resistance.

Road Striping Possible?: Yes.

Other Comments: Because HACP 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. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used. Pigments and surface coatings are products manufactured specifically for road coloring applications.

Delivery and Haul Requirements: Hot mix asphalt concrete must be hauled from a stationary asphalt plant unless a mobile asphalt plant is assembled, in which case the required hot mix asphalt concrete mix components must be hauled to the mobile plant. Haul distances may be significant for remote sites.

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

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Pigmented HACP and colored surface coatings are impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by pigmented HACP roadways.

Erosion: None.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: Pigmented HACP can be fully recycled as a pavement construction material. The color coating may restrict the use of pigmented asphalt concrete as RAP for recycled HACP.

Other Environmental Considerations: Select aggregates and pigments can be used to lighten the color and increase heat reflectivity of the surface. For HACP, tire/road noise is typically in the range of 66.5 to 77.5 dB(A) inside a car (80 km/hr [50 mph]) and 72 to 79.5 dB(A) at a distance 7.5 m (25 ft) from the vehicle.

Colored surface coatings are generally safe and environmentally friendly products. Nonetheless, product specific information should be reviewed before using a colored surface coating.

AESTHETICS

Appearance: Pigmented asphalt concrete can be a highly decorative surfacing. Numerous colors are available; earth tones such as red, brown, green, and tan (and numerous variations) are most common. Pigmented asphalt concrete can be used to blend in with the surrounding environment (earth tone colors in a wilderness area, for example) or to contrast the surrounding environment (e.g. pedestrian crosswalk, fire lane, or handicap parking area colored in bright, contrasting colors), depending on the application and designer's intent.

Appearance Degradation Over Time: Over time, some color wear and fading is possible. For surface coatings, non-uniform wear is possible and will expose the underlying asphalt concrete color. Additional applications of colored surface coating can be used to maintain the appearance of the surface. When the entire asphalt concrete surfacing layer is colored, surface wear will not affect the color. Surfaces can also become discolored by tire marks and oil leakage. Pigmented crack sealants and asphalt concrete must be used for preventative and corrective maintenance to maintain the uniform appearance of the surfacing.

COST

Supply Price: \$2.10 to 4.30/m^2 (\$1.80 to \$3.60/yd^2) for spray coating; \$16.10 to 21.40/m^2 (\$13.50 to \$18.00/yd^2) for pigment for 25 mm (1 in.) thick asphalt concrete surface layer.

Supply+Install Price: \$4.00 to 6.70/m^2 (\$3.30 to \$5.60/yd^2) for spray coating; \$18.00 to 24.00/m^2 (\$15.00 to \$20.00/yd^2) for pigment for 25 mm (1 in.) thick asphalt concrete surface layer.

EXAMPLE PROJECTS

San Francisco Mission Bay Park, San Francisco, CA.
Crosswalks, City of Burlington, VT.

SELECT RESOURCES

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

POROUS HACP

GENERAL INFORMATION

Generic Name(s): Porous Asphalt Pavement, Porous Asphalt Concrete, Pervious Asphalt Pavement, Permeable Asphalt Pavement

Trade Names: N/A

Product Description: Porous asphalt pavement 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. The various layers have the potential for stormwater detention. Stormwater that passes through the pavement may completely or partially infiltrate the underlying soil, the excess being collected and routed to an overflow facility through perforated underdrain pipes.

A typical porous asphalt pavement consists of a top porous asphalt concrete course, a filter course, a reservoir course (designed to temporarily retain infiltrated water and for frost protection), and existing soil or subbase material. The top porous asphalt concrete layer is an open graded asphalt concrete surface course (having about 16% air voids), approximately 50 to 100 mm (2 to 4 in.) thick. The filter course is a 25 to 50 mm (1 to 2 in.) thick layer of 12.5 mm (0.5 in.) crushed stone aggregate designed to provide filtration and stability for the reservoir course during paving of the asphalt concrete layer. The reservoir course is a base of 37.5 to 75 mm (1.5 to 3 in.) stone with a depth determined by the storage volume needed. In addition to transmitting mechanical loads, the reservoir course stores infiltrated stormwater until it can infiltrate into the soil.

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 Low. Porous asphalt, because of its high voids content, is not sufficiently durable to sustain medium or high traffic volumes. Further, to achieve adequate permeability the asphalt layer thickness is generally restricted to 100 mm (4 in.) thick.

Restrictions:

Traffic: Porous asphalt is not recommended for applications with significant heavy truck traffic.

Climate: The use of porous asphalt in areas requiring intensive winter maintenance is limited, because of a risk of the pores clogging with winter road sanding material. Porous asphalt is not recommended for windy climates where wind erosion would provide windblown sediment that can clog the asphalt pores.

Weather: None.

Terrain: Porous asphalt is not recommended for roadway gradients steeper than 5%; roadway gradients as flat as possible are desired.

Soil Type: Porous asphalt is mainly used in areas with permeable soils with an infiltration rate greater than 1.3 cm/hr (0.5 in./hr). Where soils have low permeability, the reservoir thickness should be increased to provide additional storage. With soils composed of clay or silt, additional drainage may be required.

Other: Depth to seasonal high groundwater levels and bedrock should be greater than 1.2 m (4 ft.).

Other Comments: Porous asphalt use is usually limited to applications with drainage areas less than 6.1 hectares (15 acres). Porous asphalt has mainly been used for low volume parking lots and roads and recreational areas.

DESIGN

SLC: 0.35 to 0.40.

Other Design Values: None.

Base/Subbase Requirements: The reservoir course (base) should be deep enough to provide sufficient water storage volume and provide frost protection if the soils are frost susceptible and in a climatic zone subject to freezing temperatures. Additional granular thicknesses over and above that needed for structural design may be required.

Other Comments: The depth of the stone reservoir should be such that it drains completely within 72 hours. This allows the underlying soils to dry out between storms and also provides capacity for the next storm. If frost penetrates deeper than the thickness of the pavement and reservoir course, and the subgrade has potential for frost heaving, additional material should be added to the reservoir course to below the frost zone. The reservoir (base) course should be deep enough to provide sufficient water storage volume. A minimum residence time of 12 hours should be a target for the design storm to provide exfiltration for pollutants removal.

When fine-grained natural soils are present, a geosynthetic separation/filtration layer is typically placed at the bottom of the reservoir layer.

CONSTRUCTION

Availability of Experienced Personnel: Porous asphalt pavement construction requires experienced contractors, particularly for placing the porous asphalt layers. Porous asphalt is not a commonly used surfacing and experienced contractors are, in general, not widely available.

Materials: The top porous asphalt concrete course consists of porous hot mix asphalt concrete, containing little sand or dust and with high air voids content (typically 16%). Hot mix asphalt concrete is composed of a blend of coarse and fine aggregate with asphalt cement as a binder. Modified asphalt cements and fibers are frequently used to control draindown, improve adhesion, and improve resistance to raveling and oxidation. The filter course is constructed of 13 mm (0.5 in) crushed stone aggregate. The reservoir course is constructed of 40 to 75 mm (1.5 to 3 in.) crushed stone aggregate.

Equipment: Equipment required for porous asphalt construction includes: haul vehicles, asphalt paver machine, grading equipment, and compaction equipment (i.e. static steel wheel roller). This equipment is widely available.

Manufacturing/Mixing Process: Porous asphalt concrete is hot mixed at a stationary asphalt plant by mixing specified proportions of the heated material components together to form a uniform mixture. Porous asphalt concrete 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. When the project site is far from an asphalt plant, a portable asphalt plant can be assembled near the project site. When selecting a site for a portable asphalt plant, impacts to the environment and local residents and businesses must be considered.

Placement Process: If needed, the site is excavated to design subgrade depth and graded using light equipment to minimize compaction of the subgrade surface. If the subgrade soils are fine-grained, a geosynthetic separation/filtration layer is placed on the subgrade prior to construction of the reservoir layer. Then, the base reservoir and filtration layers are placed and compacted. After the base is constructed, the porous asphalt concrete surface layer can be placed. Upon arrival at the site, the asphalt concrete 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 asphalt concrete is then rolled with compaction equipment to seat the material before the asphalt binder solidifies, which generally occurs between a temperature of about 85 °C (185 °F) and 150 °C (300 °F), depending on the asphalt binder. 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 porous asphalt concrete 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 porous asphalt concrete placement varies between different agencies, but is normally about 10 °C (50 °F). The aggregate base materials should not be constructed on wet or frozen soils.

Construction Rate: Typical porous asphalt concrete pavement construction rates are on the order of 500 to 1,000 Mg/day (550 to 1,100 tons/day). The relatively low production rates reflect the specialty nature of porous asphalt concrete pavement and the typically small project size.

Lane Closure Requirements: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The porous asphalt concrete surface can be opened to traffic 2 days after construction is completed. Road surface striping may be performed before or after the lane is opened.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: In the past, performance reliability of porous asphalt concrete pavements has been very low, with failure rates on the order of 75%. Failure has been caused by poor design, poor construction, heavy vehicle traffic, low permeability soils, and resurfacing with impermeable materials. There is now a better understanding of the construction and design features and reliability is improving.

Life Expectancy: Porous asphalt concrete pavement life expectancy will be less than for conventional HACP. Depending on traffic and environmental conditions, life expectancy will be 10 to 15 years or longer for low traffic volumes. However, premature failure has been common due to poor design, construction, or inappropriate application.

Ride Quality: Ride quality is very good. Ride quality deteriorates over the service life.

Main Distress / Failure Modes: Raveling, cracking, rutting, pore clogging.

Preservation Needs: Vacuum sweeping, followed by high pressure jet hosing to clean pores, should be performed periodically. Periodic filling of potholes, sealing cracks, and filling ruts is required. Porous asphalt should be used for repairs. Rehabilitation requires removal and replacement of the porous surface layer.

SAFETY

Hazards: None.

Skid Resistance: Due to their good frictional characteristics and rapid surface water removal, porous pavements reduce the potential for wet skidding and hydroplaning accidents.

Road Striping Possible?: Yes.

Other Comments: Because HACP provides a high-quality road surfacing, there is a tendency for higher road usage and speeding. Because porous asphalt has an open structure, it can freeze sooner than conventional HACP. Porous asphalt 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: Porous asphalt concrete must be hauled from a stationary asphalt plant unless a mobile asphalt plant is assembled, in which case the required hot mix asphalt concrete mix components must be hauled to the mobile plant. Haul distances may be significant for remote sites. Significant haul distances may also be required for the aggregates, if not locally available.

Potential Short-Term Construction Impacts: Significant heat is generated during the porous asphalt mixing and placement process. Construction processes may impact vegetation adjacent to the roadway. Significant excavation and disposal of existing soils may be required to install the reservoir and filter layers.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: The pavement surface is permeable, allowing infiltration of stormwater, which is temporarily stored in the reservoir course until it can infiltrate into the ground. Contaminants in the surface runoff that are not easily trapped or reduced can flow through the pavement structure and become a potential source of groundwater contamination. Therefore, porous asphalt pavements are not recommended for areas near groundwater drinking supplies or other sensitive bodies of water. However, local infiltration of storm water is generally preferable to large stormwater collection and disposal systems.

Erosion: None.

Water quality: The filter layer below porous asphalt removes particulate matter and so improves stormwater quality. However, if the surface water infiltrating the pavement surface contains contaminants that are not easily trapped or reduced, the contaminants will flow through the pavement structure and be introduced into the surrounding soil.

Aquatic species: None. However, porous asphalt can be a vehicle for contaminates to be introduced into nearby bodies of water. Therefore, porous asphalt pavements are not recommended for areas near groundwater drinking supplies or other sensitive bodies of water.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: Porous asphalt concrete can be fully recycled as a pavement construction material.

Other Environmental Considerations: Pre-treatment of stormwater is recommended where oil and grease or other potential groundwater contaminants are expected. The possible environmental benefits of porous asphalt pavement include: removal of fine particulates and soluble pollutants through soil infiltration, attenuation of peak flows, reduction in the volume of runoff leaving the site and entering storm sewers, reduction in soil erosion, and groundwater recharge.

Porous asphalt concrete pavement'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. Porous asphalt concrete pavements typically reduce tire/road noise by 3 decibels compared to conventional HACP and 5 decibels compared to PCCP.

AESTHETICS

Appearance: Immediately after placement, porous asphalt is generally black with a coarse surface texture.

Appearance Degradation Over Time: Over time, Porous asphalt concrete 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 and patching, the surface appearance is further altered.

COST

Supply Price: N/A

Supply+Install Price: \$5.00 to \$11.00/m^2 (\$4.20 to \$9.20/yd^2) for a 50 mm (2 in.) thick lift.

EXAMPLE PROJECTS

Fort Necessity National Battlefield, Farmington, PA.

SELECT RESOURCES

U.S. Environmental Protection Agency (1999). *Stormwater Technology Fact Sheet: Porous Pavement*, EPA 832-F-99-023, U.S. EPA, Office of Water, Washington, D.C., 6 pp.

RESIN MODIFIED PAVEMENT

GENERAL INFORMATION

Generic Name(s): Resin Modified Pavement (RMP)

Trade Names: Resin Modified Pavement, SALVIACIM

Product Description: Resin Modified Pavement (RMP) is a surfacing alternative that provides many of the performance characteristics of PCCP with the economy and ease of construction of HACP. RMP is a low cost alternative to PCC when resistance to heavy loads, tracked vehicle equipment, or fuel spillage is required, with a cost savings of 30% to 50% compared to PCCP. RMP is an open graded asphalt concrete mixture with 25% to 35% voids that are filled with a latex-rubber modified cement grout. The composite surface is generally 40 to 65 mm (1.5 to 2.5 in.) thick.

Product Suppliers: Alyan Corporation, P.O. Box 788, Vienna, VA 22183, (703) 255-1381, www.alyancorp.com.

APPLICATION

Typical Use: Road surfacing, parking areas.

Traffic Range: Very Low to High.

Restrictions:

Traffic: RMP is limited to low speed traffic applications (less than 65 km/hr [40 mph]) due to possibility of low skid resistance during early stages of performance life and in icy conditions.

Climate: None.

Weather: None.

Terrain: RMP is not recommended for roadway gradients greater than 5%. Gradients are generally limited to less than 2%; for gradients of 2% to 5%, excessive hand work is required during construction.

Soil Type: N/A

Other: None.

Other Comments: None.

DESIGN

SLC: 0.44 (assumed same as HACP).

Other Design Values: None.

Base/Subbase Requirements: RMP must be placed over a minimum of 50 mm (2 in.) of HACP.

Other Comments: None.

CONSTRUCTION

Availability of Experienced Personnel: RMP use in the United States has been limited, so experienced contractors are generally not locally available. However, local contractors with asphalt concrete construction experience teamed with experienced grout installers should be able to successfully construct a RMP pavement.

Materials: RMP is composed of an open graded asphalt concrete and a resin modified grout. The open graded asphalt concrete, composed of a blend of coarse and fine aggregate and mineral filler with asphalt cement as a binder, should have 25% to 35% voids when compacted and a maximum particle size of 19 mm (0.75 in.). The resin modified grout is composed of portland cement, sand, fly ash, water, and a resin additive. The resin additive is a proprietary product, named Prosalvia 7, and is composed of water, a cross polymer resin of styrene and butadiene, and a water reducing agent.

Equipment: Equipment required for RMP construction includes: Trucks for hauling asphalt concrete and grout, asphalt concrete paving machine, small (5-ton maximum) steel wheel vibratory roller, lumber or other product to contain grout within a particular application area, and hand squeegees. Equipment is widely available in most areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: The asphalt concrete component of RMP is mixed at a plant and hauled to the site. The asphalt concrete is usually mixed at temperatures of 121 to 135 °C (250 to 275 °F). The resin modified grout is typically mixed at a plant and hauled to the site, although a portable mixer can be used for small jobs to mix the grout at the site. The resin is added to the grout mix at the plant if the site is located within 20 minutes of the batch plant. If the haul distance from the plant to the site requires more than 20 minutes, the resin is added to the grout at the site.

Placement Process: The open graded asphalt concrete is placed using an asphalt concrete paving machine utilizing standard asphalt concrete construction procedures. Compaction of the asphalt concrete is not required; a small steel wheel roller is used just to smooth the asphalt concrete surface after placement. Typically, one roller pass when the asphalt concrete temperature is about 71 °C (160 °F) and another when the temperature is around 55 °C (130 °F) is adequate. The resin modified grout is then applied to the asphalt concrete surface from the rear of the mix truck. Pieces of lumber are often placed on the asphalt concrete surface to isolate the application area and prevent the grout from spreading outside of the application area or into areas where the grout has already been placed. Workers use hand squeegees to adequately distribute the grout within the application area. The steel wheel roller is used to roll and vibrate the application area to ensure that the grout penetrates all the voids in the asphalt concrete. Once the voids in the asphalt concrete are filled, workers use hand squeegees to remove the remaining excess grout. Curing compounds can then be applied to the RMP surface.

Weather Restrictions: Do not place RMP open graded asphalt concrete if it is raining or the air temperature is below 10 °C (50 °F). Grout should not be applied when the surface temperature is above 38 °C (100 °F).

Construction Rate: Typical RMP construction rates can be on the order of 1,700 to 2,500 m^3/day (2,000 to 3,000 yd^3/day).

Lane Closure Requirements: The roadway lane(s) being constructed is closed during construction, so adequate traffic control is needed. RMP can be opened to pedestrian traffic 24 hours after construction and light vehicle traffic after 3 days. Normal traffic loads can be allowed on the RMP surface once an adequate RMP strength is reached, typically 7 to 14 days. Road surface striping may be performed after the lane is opened.

Other Comments: None.

SERVICEABILITY

Reliability and Performance History: RMP was developed in France in the 1960s, under the trade name Salviacim, as a fuel and abrasion resistant surfacing material. Today, RMP is an accepted standard surfacing in France and has been used on projects in at least 25 other countries. RMP has been used on at least 30 projects in the United States since the late 1980s; projects have mainly been for airfields or military bases. RMP for road surfacing applications is still relatively new in the United States and research, design and construction information, and project experience is limited.

Life Expectancy: Life expectancy varies depending on construction materials used, environmental conditions, and traffic volumes. Typical serviceable lives range from 15 to 25 years (typical design life is 20 years).

Ride Quality: RMP ride quality is inferior to most paved surfaces. RMP generally has a rough surface finish, leading to a fair ride quality. This smoothness level is usually adequate for low-speed applications. Ride quality deteriorates over the serviceable life.

Main Distress / Failure Modes: Cracking, raveling.

Preservation Needs: In general, RMP requires relatively little preventative maintenance. Cracking has little impact on RMP performance. For cracks greater than 6 mm (0.25 in.) wide, periodic crack sealing may be required. Patching of localized failure areas may be required after 5 to 10 years. Patching will require the use of the same modified cement grout used in the original construction.

SAFETY

Hazards: None.

Skid Resistance: RMP has an irregular surface after construction, leading to poor to marginal skid resistance and limiting RMP use to low-speed applications. Skid resistance can improve with time as surface grout is worn away.

Road Striping Possible?: Yes.

Other Comments: None.

ENVIRONMENTAL CONCERNS

Source of Raw Materials: The open graded asphalt concrete is composed of a blend of coarse and fine aggregate and mineral filler with asphalt cement. Asphalt cement is 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. The resin modified grout is composed of portland cement, sand, fly ash, water, and a resin additive. Portland cement is manufactured from limestone. The resin additive is a manufactured chemical. Fly ash is an industrial by-product of coal combustion.

Delivery and Haul Requirements: Asphalt concrete and grout must be hauled from mixing plants to the site. Haul distances can be significant for remote sites; in these cases, a portable mixing plant can be set up on site assembled, in which case the required mix components must be hauled to the site.

Potential Short-Term Construction Impacts: Significant heat is generated during the asphalt concrete mixing and placement process. Construction processes may impact vegetation adjacent to the roadway. The application area should be contained to prevent excessive grout runoff into the surrounding environment.

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: RMP is impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by RMP roadways.

Erosion: None.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: RMP can be milled or crushed for use as an unbound or stabilized material.

Other Environmental Considerations: Light-colored RMP can be used to reduce surface heat reflectivity. For RMP, tire/road noise is typically moderate to high with a higher noise level than HACP.

AESTHETICS

Appearance: RMP typically has a light to dark gray color and a relatively rough texture, similar to rough textured PCCP. The surface color can be modified using pigments or stains to color the grout.

Appearance Degradation Over Time: RMP will maintain its general appearance throughout its serviceable life. Surface grout will wear to some extent with time, exposing more of the asphalt concrete.

COST

Supply Price: N/A

Supply+Install Price: $\$12/m^2$ ($\$10/yd^2$) (typical average price for 50 mm [2 in.] thick RMP).

EXAMPLE PROJECTS

Travis Air Force Base, Fairfield, CA.
Hill Air Force Base, UT.
Miami International Airport, Miami, FL.

SELECT RESOURCES

Alyan Corporation, (703) 255-1381, www.alyancorp.com.
Anderton, G.L. (1996). *User's Guide: Resin Modified Pavement*, FEAP-UG-96/01, U.S. Army Center for Public Works, Alexandria, VA, 58 pp.

SYNTHETIC BINDER CONCRETE PAVEMENT

GENERAL INFORMATION

Generic Name(s): Synthetic Binder Concrete Pavement

Trade Names: PAVEBRITE

Product Description: Synthetic binder concrete pavement is a high quality pavement material that is hot mixed at a plant and then hot laid. 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 completely replaces asphalt cement in traditional HACP. Synthetic binder concrete pavement meets or exceeds specifications for HACP.

Product Suppliers: Neville Chemical Company, 2800 Neville Road, Pittsburgh, PA 15225-1496, (877) 704-4200, www.nevchem.com.

APPLICATION

Typical Use: Road surfacing.

Traffic Range: Very Low to High.

Restrictions:

Traffic: A high stability mix should be used for heavy industrial loading conditions (i.e. slow moving trucks, frequent braking, etc.).

Climate: None.

Weather: None.

Terrain: None.

Soil Type: N/A

Other: None.

Other Comments: The synthetic binder is typically classified as PG 64-22, but can be modified to meet different performance grade specifications.

DESIGN

SLC: 0.44.

Other Design Values: None.

Base/Subbase Requirements: Synthetic binder concrete pavement is usually constructed over an aggregate base course, but may be placed directly over a prepared subgrade of native materials. The required synthetic binder concrete pavement thickness depends on the level of base/subgrade support provided. Subgrade and base materials should be compacted and graded to provide a stable working surface prior to synthetic binder concrete placement.

Other Comments: As a general guideline, the minimum synthetic binder concrete lift thickness should be three times the nominal maximum aggregate size.

CONSTRUCTION

Availability of Experienced Personnel: Synthetic binder concrete pavement is a new surfacing and experienced contractors are, in general, not available. However, the construction process is nearly identical to HACP construction, for which experienced contractors are widely available. Experienced HACP contractors can be advised by the manufacturer to ensure that the synthetic concrete pavement is constructed properly.

Materials: 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.

Equipment: Equipment required for synthetic concrete construction include: haul vehicles, asphalt paver machine, and compaction equipment (static steel wheel roller, pneumatic tire roller, or vibratory roller). Equipment is widely available in urban areas, but availability may be limited in remote areas.

Manufacturing/Mixing Process: Synthetic binder concrete is normally hot mixed at an asphalt plant by mixing specified proportions of the heated material components together to form a uniform mixture. If colored pavements are desired, the coloring pigments must be mixed with the synthetic binder prior to adding the aggregate to the mix. Synthetic binder concrete mixes are normally mixed at temperatures between 127 to 141 °C (260 to 285 °F). After mixing, the product is placed in haul vehicles to be transported to the project site. The synthetic concrete mix must arrive on-site and be placed before it cools. When transported in insulated vehicles with a tarp cover, the synthetic concrete mixture can remain at an adequate temperature for up to 2 or 3 hours. When the project site is far from an asphalt plant, a portable mixing plant can be assembled near the project site. When selecting a site for a portable mixing plant, impacts to the environment and local residents and businesses must be considered.

Placement Process: Upon arrival at the site, the synthetic concrete 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 synthetic concrete is then rolled with compaction equipment to achieve the required density. The synthetic concrete should be adequately compacted before it reaches a minimum specified temperature, typically 85 °C (185 °F). 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 synthetic binder concrete if it is raining or there is ponded water on the prepared paving surface. The specified minimum air temperature for synthetic binder concrete placement can vary, but is normally about 7 °C (45 °F).

Construction Rate: Synthetic binder concrete pavement placement rates will depend on the speed that the synthetic concrete mixture is delivered, layer thickness, and paving width. Placement rates can be 0.2 m/sec (40 ft/min) or higher. Compactor speeds are normally limited to 4.8 km/hr (3 mph), so overall construction rates are often dictated by the number of compactors on site. Typical production rates are 900 to 4,500 Mg/day (1,000 to 5,000 tons/day).

Lane Closure Requirements: The roadway lane(s) being constructed are closed during construction, so adequate traffic control is needed. The synthetic binder concrete surface can be opened to traffic as soon as the synthetic concrete 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: During synthetic binder concrete production, the plant needs to be dedicated exclusively to that mix. Prior cleaning of all plant equipment is needed to prevent contamination from previous asphalt binder. Similar prior cleaning would also be needed for the paver. These requirements impose logistical constraints on the scheduling of the work as well as limit the number of paving contractors who would be prepared to perform the work.

SERVICEABILITY

Reliability and Performance History: Synthetic binder concrete pavement is a new roadway surfacing and available research, design and construction, and performance history information is extremely limited at this time. Preliminary testing has shown that synthetic binder concrete meets or exceeds the specifications for hot mix asphalt concrete. It is expected that the performance of synthetic binder concrete pavements will meet or exceed that of conventional hot mix asphalt concrete, however this can only be determined over time.

Life Expectancy: Life expectancy varies depending on mix types, environmental conditions, traffic volumes and degree of routine maintenance. No long-term performance information is available. Typical serviceable lives are expected to range from 15 to 20 years.

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

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

Preservation Needs: Preventative maintenance includes periodic crack sealing and localized patching every 7 to 9 years. In most circumstances, preventative maintenance measures will not match the original color of the pavement. Thin surface treatments can be applied to extend the serviceable life of synthetic binder concrete pavements.

SAFETY

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

Skid Resistance: Provided high quality aggregates are used in the synthetic binder concrete mix, synthetic binder concrete should provides good to excellent skid resistance.

Road Striping Possible?: Yes.

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

ENVIRONMENTAL CONCERNS

Source of Raw Materials: The synthetic binder used is composed of a specially formulated proprietary petroleum hydrocarbon resin. Aggregates may be naturally occurring or quarried, but either requires mechanical processing (crushing, sizing) before they can be used.

Delivery and Haul Requirements: Synthetic binder concrete must be hauled from a mixing plant unless a mobile mixing plant is assembled, in which case the required concrete mix components must be hauled to the mobile plant. Haul distances may be significant for remote sites.

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

Potential Long-Term Environmental Impacts:

Leachate: None.

Surface Runoff: Synthetic binder concrete is impermeable, which promotes surface runoff. However, surface runoff water quality is not generally impacted by synthetic concrete roadways.

Erosion: None.

Water quality: None.

Aquatic species: None.

Plant quality: None.

Air Quality: None.

Other: None.

Ability to Recycle/Reuse: Synthetic binder concrete can be crushed or pulverized and reused as an unbound construction material.

Other Environmental Considerations: Light-colored aggregates and pigments can be used to lighten the pavement color and increase heat reflectivity of the surface. For HACP, tire/road noise is typically in the range of 66.5 to 77.5 dB(A) inside a car (80 km/hr [50 mph]) and 72 to 79.5 dB(A) at a distance 7.5 m (25 ft) from the vehicle. For synthetic binder concrete pavements, tire/road noise is expected to be similar to HACP.

AESTHETICS

Appearance: The synthetic binder is amber-colored. Therefore, the appearance of synthetic binder concrete pavement will be dominated by the color of the coarse aggregate used. If colored pavements are required, coloring pigments can be mixed with synthetic binder. Smaller quantities of pigment are required, compared to HACP, because the pigment does not have to mask the black color of the asphalt cement.

Appearance Degradation Over Time: Over time, synthetic binder concrete pavement is expected to maintain its general appearance. With maintenance activities, such as crack sealing and patching, the surface appearance can be further altered. Where special mixes or colors are used, the future availability of similar materials should be assured for maintenance purposes to lessen the aesthetic degradation.

COST

Supply Price: N/A

Supply+Install Price: N/A. Synthetic binder concrete pavement is a new product in the United States, so pricing has not been well established. The price is estimated to be on the order of four times greater than the price of HACP.

EXAMPLE PROJECTS

Richmond National Battlefield Park, Richmond, VA.
Pennsylvania Avenue, Washington, D.C.

SELECT RESOURCES

None.