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STRATEGIES FOR DESIGN AND CONSTRUCTION OF HIGH-REFLECTANCE ASPHALT PAVEMENTS

By

Nam Tran
Buzz Powell

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National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

277 Technology Parkway ■ Auburn, AL 36830

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Nam Tran
Research Assistant Professor

Buzz Powell
Assistant Director

National Center for Asphalt Technology
277 Technology Parkway
Auburn, AL 36830

Sponsored by

Asphalt Pavement Alliance
5100 Forbes Blvd
Lanham, MD 20706

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Abstract

The occurrence of higher air and surface temperatures in urban areas is known as the urban heat island (UHI) effect. Reducing the UHI effect in urban areas may decrease summer time energy use and improve human and ecological health. The Leadership in Energy and Environmental Design (LEED®) certification system, for some programs, awards up to three points for construction projects that provide any combination of the following cool pavement strategies for up to 75 percent of the site landscape: (1) shading hard surfaces on the site with landscape features; (2) using high-reflectance materials with a minimum Solar Reflectance Index (SRI) of 29; and (3) utilizing an open grid pavement system. While a guide to the design and construction of porous asphalt pavements has been around for some time, such a guide is not readily available for high-reflective asphalt pavements. The objective of this project is to identify and validate high-reflectance asphalt materials and pavement surface treatments that (1) are suitable for use in parking lots and other large paved surfaces; (2) have a minimum SRI of 29; and (3) are economically viable. In this study, six technologies exhibited SRI values of 29 or greater. They include E-Krete® micro-surfacing, StreetBond™ coating, synthetic binder, Densiphalt®, and chip and sand seals using light-colored aggregates. Another technology, surface gritting using light-colored aggregate, most likely would have exhibited SRI values of at least 29 if the aggregate had adhered properly to the asphalt mat. Except for surface gritting, as well as chip and sand seals, all other technologies appeared durable for parking lot applications after a durability test.

1. BACKGROUND

Many U.S. cities have air temperatures up to 10 °F (5.6 °C) warmer than the surrounding rural areas (*1*). The occurrence of higher air and surface temperatures in urban areas is known as the urban heat island (UHI) effect. UHI forms as cities replace natural vegetation with pavements, buildings, and other structures necessary for development. The non-reflective surfaces of these structures absorb solar heat, causing pavement surface temperatures and potentially overall ambient temperatures to rise. The displacement of trees and shrubs eliminates the natural cooling effects of shading and evapotranspiration. Further, urban geometry and man-made sources of heat contribute to UHI formation. Measures to reduce the UHI effect include increasing vegetative cover as well as installing reflective roofs and pavements (*1*).

Reflective asphalt pavements can be achieved with existing paving materials and engineering design. The use of reflective pavements is meant to reduce the absorption, retention and emittance of solar heat by increasing solar reflectivity of pavement surfaces and through increased air filtration and evaporation (*2*). Potential pavement technologies and strategies for reducing UHI include: (1) use of urban landscape and vegetation to reduce direct sunlight on pavement surfaces; or (2) use of high-reflective, porous paving materials or thinner pavements to reduce absorption and retention of heat (*3*).

The Leadership in Energy and Environmental Design (LEED®) certification system for new construction developed and administered by the United States Green Building Council (USGBC) (*4*) has awarded one credit for “new construction” and “school” projects that utilize any combination of the following cool pavement strategies for 50 percent of the landscape. For “retail” projects, the LEED certification system is offering one credit for 25 percent, two credits for 50 percent and three credits for 75 percent coverage of the site using any combination of the following cool pavement strategies.

1. Shading hard surfaces on the site with landscape features
2. Using high-reflectance materials with a Solar Reflectance Index (SRI) of at least 29 (percent)
3. Utilizing an open grid pavement system.

Government agencies and private businesses are increasingly focused on “green” construction practices and plan to achieve LEED certification for new government building construction (*5*). In order to qualify for a higher LEED certification, e.g. Gold or Platinum, each point is extremely important. Architects and designers have been asking for guidance in the design and construction of cool asphalt pavements. While a guide to the design, construction and maintenance of porous asphalt pavements (*6*) has been around for some time, such a guide is not readily available for high-reflective asphalt pavements.

Research is needed to develop guidelines for the design and construction of high-reflective asphalt pavements that meet the SRI requirement in the LEED rating system for use in parking lots and other large paved surfaces.

2. OBJECTIVE

The objective of this project is to identify and validate high-reflectance asphalt materials and pavement surface treatments that (1) are suitable for use in parking lots and other large paved surfaces (20,000 - 50,000 square feet); (2) have a SRI value of at least 29 (the LEED minimum requirement); and (3) are economically viable (up to approximately $3 per square foot placed).

This study will be a starting point for developing a guide for design, construction and maintenance of a high-reflectance asphalt pavement for land use and site development.

3. SOLAR REFLECTANCE INDEX

Several material properties and pavement characteristics influence the temperatures of a pavement surface and near-surface ambient air. These include solar reflectance (also referred to as albedo) and roughness of the surface, as well as permeability, conductivity, emissivity, and thickness of the top bound layers (*3*). Among these factors, two parameters—solar reflectance and thermal emittance—are used to determine the Solar Reflectance Index (SRI) of a pavement surface. The SRI represents the surface temperature relative to those of the standard white (SRI = 100) and black (SRI = 0) surfaces, as shown in Equation 1.

$$SRI = 100\frac{T_b - T_s}{T_b - T_w} \tag{1}$$

where:

SRI = Solar Reflectance Index, percent
T_s = steady-state surface temperature
T_b = steady-state temperature of black surface
T_w = steady-state temperature of white surface

An iterative approach for determining the three steady-state temperatures in Equation 1 based on solar reflectance and thermal emissivity is presented in ASTM E 1980, *Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces*. This procedure has been developed in a spreadsheet by the Heat Island Group of the Lawrence Berkeley National Laboratory (LBNL) (*7*).

Solar reflectance or albedo measures the ability of the pavement surface to reflect sunlight and is expressed as the ratio of incoming and reflected sunlight. Generally, albedo is correlated with color; lighter colors have higher reflectance. Emissivity of a pavement material refers to its ability to radiate absorbed heat. Higher albedos and/or higher emissivities correspond to higher SRI values, and under equivalent conditions, the higher the SRI of a pavement surface the lower its surface temperature.

Albedo of a pavement surface can be measured in the field using a pyrometer according to ASTM E 1918, *Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field*, or in the laboratory using a Solar Spectrum Reflectometer according to ASTM C 1549, *Standard Test Method for Determining Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer*. The LEED specification program allows the measurement of the solar reflectance using either method. However, there is no document showing the correlation between the results determined by these methods at this moment.

Figure 1 shows a pyrometer for measuring the solar reflectance of the pavement surface in this study. This particular device costs about $2,000. This method requires a minimum pavement area of 10 ft by 10 ft for measuring the surface albedo.

FIGURE 1 ASTM E 1918 method for measuring solar reflectance of low-sloped surfaces.

Figure 2 shows a Solar Spectrum Reflectometer (on right) manufactured by Devices and Services Company in Dallas, Texas. This device costs about $31,000. Thermal emissivity of a pavement material can be determined using a portable emissometer, shown in Figure 2 (on left), according to ASTM C 1371, *Standard Test Method for Determination of Emittance of Materials near Room Temperature Using Portable Emissometers*. The price of this device is approximately $15,000. These methods can measure the solar reflectance and thermal emissivity of a surface using six-inch cores.

FIGURE 2 Portable Emissometer and Solar Spectrum Reflectometer.

4. EFFECT OF MATERIAL PROPERTIES ON SOLAR REFLECTANCE INDEX

The SRI of a pavement surface is significantly influenced by the surface material and varies over a wide range. The surface material can be hot mix asphalt (HMA), portland cement concrete (PCC), or other types of surface treatments.

For new conventional asphalt pavements, the SRI is generally low because there is little reflectance of the black binder film and little exposure of aggregate after construction. If light-colored aggregate is used in the asphalt mix, the SRI can increase over a period of five to ten years. In general, SRI will increase over time due to weathering of binder and more exposure of aggregate.

Unlike what happens with HMA, the SRI of PCC pavements generally starts out higher but decreases over time. Figure 3 shows a comparison of the SRI values for four HMA and PCC parking lot pavements in Auburn, Alabama. The SRI values were determined using the ASTM E 1980 calculator developed by the LBNL (*7*) based on the solar reflectance determined in the field according to ASTM E 1918 on February 25, 2008. For this comparison, it was assumed that both HMA and PCC would have an emissivity of 0.95. These surface mixtures contain gravels; however, the research team was unable to verify if the gravels were from the same source. While the new PCC pavement has a higher SRI than the new HMA pavement, the SRI values for the old PCC and HMA pavements are closer after about seven years in service. Even though limited data points were collected for this comparison, it confirms a general observation found in the literature (*3*).

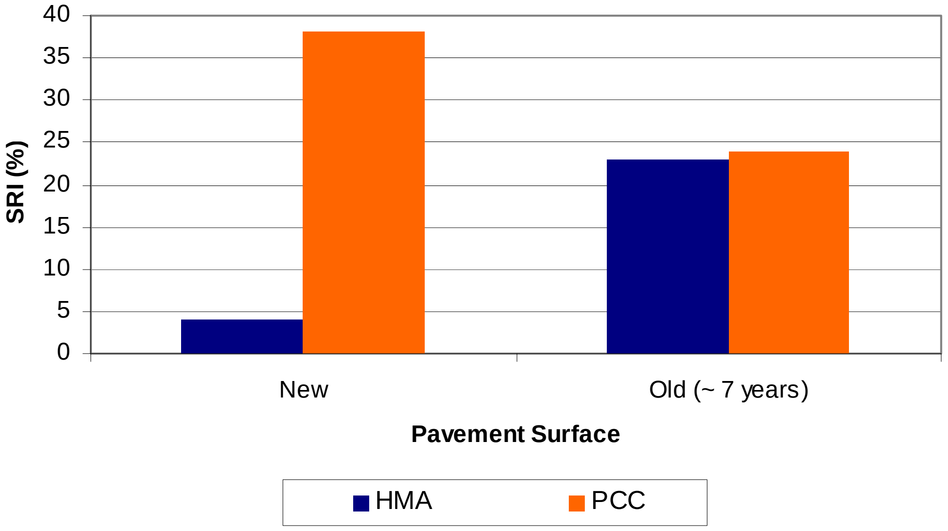

FIGURE 3 Comparison of SRI for PCC and HMA pavements over time.

5. CANDIDATE TECHNOLOGIES FOR IMPROVING SOLAR REFLECTANCE INDEX OF ASPHALT PAVEMENTS

There are several methods for improving the reflectance of asphalt pavements to achieve SRI values of 29 or greater. A brief description of each method is presented in the following sections.

5.1 Surface Gritting Using Light-Colored Aggregate

Surface gritting can enhance the color of asphalt as well as produce safety-related benefits in the form of increased surface friction. The process involves spreading aggregate over newly placed HMA and pressing it in with a roller. When light-colored aggregate is used as the grit material, the process can significantly increase reflectivity. The grit also tends to fill small surface voids in the mat, which decreases surface permeability (*8*).

5.2 Chip-Seals with Light-Colored Aggregate

Chip seals are surface treatments that consist of single or multiple applications of asphalt and aggregate on existing pavement surfaces. A single surface treatment involves spraying either asphalt cement or emulsified asphalt, which is immediately followed by an aggregate cover that is approximately the thickness of one stone. The new surface is rolled as soon as possible in order to seat the aggregate properly in the asphalt material. Although often applied to weathered pavements in order to seal the mat and provide improved durability and a new riding surface for a relatively low cost, chip seals with light-colored aggregates can be used to completely alter the reflective properties of existing pavements (*9*).

5.3 Sand Seals with Light-Colored Aggregate

Also known as a scrub seal, sand seals are often used for preventive maintenance in order to fill low severity cracking and delay pavement deterioration. The process normally involves the application of a polymer modified asphalt emulsion that is broomed into the pavement surface and covered with a fine sand. Excess material is removed by a second brooming and the new surface is rolled with a pneumatic roller. Similar to chip seals, the use of light-colored sand can be used to enhance the reflectivity of the pavement surface (*10*).

5.4 Sand/Shot-Blasting and Abrading Binder Surface

The Blastrac® system (*11*) is an example of this technology. It employs a mechanical process to remove surface coatings using steel shot at high velocity and at a specific angle. The binder coating on the surface is abraded by the steel shot. The loose material together with the shot is vacuumed into a machine to clear the pavement debris. This technology can be used to remove the asphalt coatings from a new pavement surface and expose the natural color of light-colored aggregate used in the asphalt mixture to improve the pavement surface reflectivity.

5.5 Colorless and Reflective Synthetic Binders Used with Light-Colored Aggregate

A specially formulated clear or colored binder can be used with light-colored aggregates to improve the reflectivity of asphalt pavements. This technology has been used in surface courses for sports and leisure areas. Examples of this technology are DuraTint™ from Lafarge (*12*), CS-Asphalt™ from Toda America, Inc. (*13*), and Natratex™ and Colourtex™ from Bituchem Asphalt (*14*).

5.6 Surface Painting Using Light-Colored Paint

The color of an asphalt pavement surface can be altered using a special light-colored paint made for pavements. An example of this technology is the StreetBond™ coating system formulated by Integrated Paving Concepts (IPC), Inc. for the StreetPrint Pavement Texturing™ system. The coating material is a combination of cement fortified acrylic resins, epoxy based polymers and a blend of aggregates to provide a durable color and texture to the asphalt surface. Currently, the coating system has seven colors with SRI values of 29 or greater (*15*).

5.7 Micro-Surfacing Using Light-Colored Materials

Micro-surfacing can be applied to new or existing pavements using a specialized machine, which includes a mixer and a spreader. As the machine moves forward, the material is mixed in the mixer and fed into a full-width surfacing box which will spread the material across the width of a traffic lane in a single pass. If a light-colored material is used, it can lighten the color of asphalt pavements. A good candidate micro-surfacing material for this study was the E-Krete® from PolyCon Manufacturing, Inc. This material consists of a mix of cement, sand, and other fillers and a proprietary liquid blend of emulsified polymer resin. An application system has been designed specifically to apply a thin layer of this material between 1/8 to 1/4 in. thick (*16*).

5.8 Grouting of Open-Graded Course with Cementitious Materials

This technology is available in the U.S. under registered names Salviacim® and Densiphalt® (*17, 18*). Salviacim/Densiphalt is a semi-rigid surfacing process consisting of an open-graded asphalt concrete with 20 to 25 percent voids filled with a high strength cementitious grout. The jointless wearing surface is about 1 1/2 in. thick and strong to provide protection against fuel spillage and resistance to abrasion and rutting. The reflectivity of the grouted surface is expected to be similar to that of concrete materials which has a SRI of 29 to 35 for newly constructed surfaces.

6. CONSTRUCTION OF TEST SECTIONS

This study was planned to evaluate all of the eight technologies identified in the previous sections for the construction of highly reflective asphalt pavements. Technologies 1 through 7 were evaluated using new test sections built off the track in an adjacent storage area of the NCAT Pavement Test Track. For the last technology, the research team worked with Euco Densi LLC to identify a test section for Densiphalt and obtain the SRI results.

A strip of asphalt pavement, as shown in Figure 4, was built in January of 2008. The first part of the strip was constructed using a coarse-graded asphalt mixture, and the second part was built using a fine-graded mix. Both mixtures were produced using a PG 67-22 binder and a combination of coarse and fine limestone aggregates that have the solar reflectance values of 45 and 42 in unbound conditions measured according to ASTM E 1918, respectively.

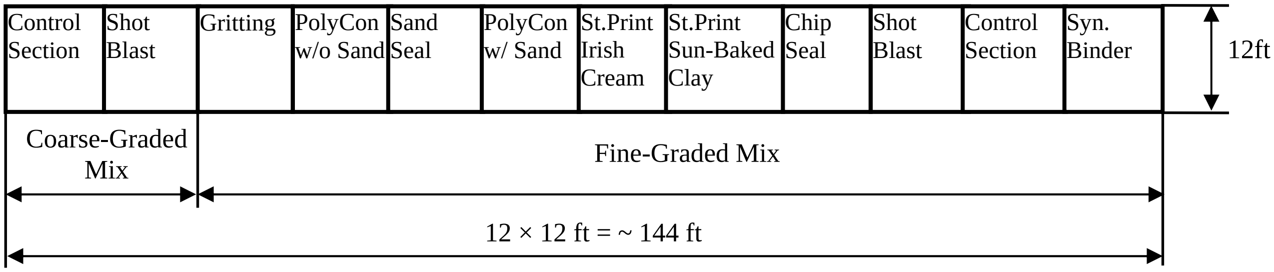

FIGURE 4 Thirteen test sections for new experimental plan.

The test section for surface gritting was constructed by spreading and rolling uncoated light-colored aggregate into the HMA mat after the intermediate rolling. The uncoated aggregates are the same as those used in the HMA mix.

After the pavement had been constructed for several weeks, the installation of other test sections was started. The plan for installation of the test sections is shown in Figure 4. Three companies—Blastrac, Integrated Paving Concepts, Inc., and PolyCon Manufacturing, Inc.—provided personnel, equipment, and material to install test sections for this study. Blastrac treated two test sections: one in each of the coarse- and fine-graded mix parts to evaluate the effect of shot blasting on the mixture gradation.

Integrated Paving Concepts, Inc. (IPC) also installed two test sections using the StreetBond coating materials in Irish Cream and Sun-Baked Clay colors. Both are in the fine-graded mix portion of the test strip. PolyCon Manufacturing, Inc. treated two test sections. One section was micro-surfaced using the E-Krete material only. For the other section, the E-Krete material was applied to the asphalt surface, and then light-color sand was sprayed on top right after the E-Krete was installed to improve the skid resistance and reflectivity.

Toda America, Inc. provided a synthetic binder, CS-Phalt, in a natural color for constructing a test section in this study. CS-Phalt is a pre-mixed material in pellet form and consists of a non-asphaltic binder and pigment. The synthetic binder mix was produced and placed by the Phenix Asphalt Company. The mixture was produced in a pug-mill plant in order to feed CS-Phalt pellets into the mixer manually. First, the mixer and truck were cleaned using a hot batch of clean aggregate. After that, heated aggregate was added to the pug-mill followed by the CS-Phalt pellets. In order not to alter the color of a mix, all equipment must be cleaned before the construction.

The last two test sections—sand and chip seals—were installed by East Alabama Paving Company, Inc. The chip and sand materials are the same ones used in the HMA mixtures for the construction of the test strip.

As planned, two test sections, each with coarse- and fine-graded aggregate blends, were left with no surface treatment to evaluate the change of the surface color over time. Figure 5 shows all test sections built for this study. The near section in Figure 5 was constructed using the synthetic binder, the farthest is the control section for the coarse-graded aggregate blend, and all other sections (shown schematically in Figure 4) lie in between. Pictures taken during the construction of reflectivity test sections are included in Appendix A.

7. MEASUREMENT OF SOLAR REFLECTANCE INDEX

The solar reflectance or albedo of aggregate materials was measured at the asphalt plant prior to the construction. Areas of 10 ft by 10 ft for coarse and fine aggregate materials were leveled by a front end loader. Then, the measurements were taken using a pyrometer, as shown in Figure 1, according to ASTM E 1918 at the center of each area several times. These materials were also sampled and sent to the PRI Construction Materials Technologies laboratory for testing of solar reflectance and emissivity according to ASTM C 1549 and ASTM C 1371, respectively. However, the surfaces of these materials were too irregular and rough to obtain stable and accurate measurements.

FIGURE 5 Twelve test sections constructed at plant site of NCAT Pavement Test Track.

Once the construction of test sections was completed, the solar reflectance of each technology was measured according to ASTM E 1918 and ASTM C 1549, and the thermal emissivity was determined in compliance with ASTM C 1371. First, the measurement of solar reflectance was taken according to ASTM E 1918 at the center of each test section on six Mondays between February 25, 2008 and April 21, 2008 at different time between 10:00 am and 2:00 pm. Since the position and angle of the sun were different during each measurement, it allowed the measurements of six areas within a test section that reflected the solar radiation. The surface temperatures during the solar reflectance measurements ranged from 105 to 135 °F (40.6 to 57.2 ^{o}C). The measured solar reflectance values were repeatable. Then, two cores were extracted from each test section on April 21, 2008 and sent to the PRI Construction Materials Technologies laboratory for determining the solar reflectance according to ASTM C 1549 and thermal emissivity according to ASTM C 1371. The PRI Technologies lab was able to perform both tests on almost all cores, except the thermal emissivity measurement on chip seals surface because its rough surface results in an unstable emittance measurement.

Euco Densit LLC obtained the SRI of a pavement surface using the Densiphalt material. The Densiphalt section used for the SRI measurement was built at the Massachusetts National Air Guard facility in Brockton, Massachusetts. The test was conducted according to ASTM E 1918 by DeLuca-Hoffman Associates, Inc. (*19*).

Table 1 shows the test results obtained in this study, including:

- The average solar reflectance determined in the field according to ASTM E 1918 and in the laboratory in compliance with ASTM C 1549.
- The average thermal emissivity measured in the laboratory in accordance with ASTM C 1371. Since the aggregates used for the chip seals and sand seals were from the same quarry, it was reasonable to assume that both should have similar thermal emittance values.
- The average SRI determined according to ASTM E 1980 using the calculator developed by the Heat Island Group of the Lawrence Berkeley National Laboratory (*7*). The field

and laboratory SRI values were calculated based on the thermal emissivity as well as the solar reflectance measured in the field and laboratory, respectively. The SRI values were determined for medium wind that has a convective coefficient of 12 $Wm^{-2}K^{-1}$.

As shown in Table 1, the two test methods—ASTM E 1918 and ASTM C 1549—produced different solar reflectance values, resulting in different SRI for the same materials. The difference was as high as 11 percent in this study. The rougher the surface, the larger the difference in SRI results determined according to the two test methods. The difference was thought to be due to the following two reasons:

- The ASTM C 1549 method is very sensitive to the roughness of the measured surface; and
- The samples used for the two test methods are different—a 10 ft by 10 ft surface area in the field for ASTM E 1918 and a small surface area of a 6 in. core in the laboratory.

TABLE 1 Solar Reflectance Index (SRI) of Materials Used in This Study

Materials	Avg. Reflectance		Avg.	Avg. SRI (percent)		
	Field	Lab	Emittance	Field	Lab	Difference
Unbound Coarse Aggregate	0.45	N/A*	N/A			
Unbound Fine Aggregate	0.42	N/A	N/A			
Coarse-Graded HMA						
Control Section	0.08	0.06	0.93	5	3	2
Shot Blasting	0.18	0.24	0.96	19	27	-8
Fine-Graded HMA						
Surface Gritting	0.20	0.14	0.97	22	15	7
E-Krete without Sand Spray	0.36	0.36	0.96	42	42	0
Sand Seals	0.40	0.36	0.87	44	39	5
E-Krete with Sand Spray	0.36	0.33	0.94	41	37	4
StreetBond, Irish Cream	0.45	0.46	0.96	54	55	-1
StreetBond, Sun-Baked Clay	0.39	0.42	0.96	46	50	-4
Chip Seals	0.37	0.29	0.87**	40	29	11
Shot Blasting	0.21	0.19	0.91	21	18	3
Control Section	0.08	0.08	0.97	7	7	0
Synthetic Binder	0.30	0.33	0.98	35	39	-4
Densiphalt by EucoDensi (*19*)				24~32		

8. ESTIMATED CONSTRUCTION COST FOR EACH TECHNOLOGY

Table 2 shows estimated construction cost, including material, labor and equipment costs, for each surface treatment technology. The costs were estimated for a virtual parking lot of 20,000 square feet built in Auburn, Alabama at the time of this writing. For a future construction project, the cost for each technology can be obtained by contacting the respective company listed in Appendix B.

TABLE 2 Estimated Costs of Materials Used in This Study

Technology	SRI in this Study	Estimated Cost (USD per S.F.)
Shot Blasting by Blastrac	18 – 27	0.20 – 0.30
Surface Gritting	15 – 22	N/A
E-Krete Micro-Surfacing by PolyCon	37 – 42	0.35 – 0.65
Chip Seals and Sand Seals	29 – 44	0.30 – 0.40
StreetBond Coating by IPC	46 – 55	1.40 – 1.70
Synthetic Binder by Toda America, Inc	35 – 39	N/A
Densiphalt by EucoDensi	24 – 32	N/A

* N/A = Not available

9. DURABILITY TEST

A skid steer loader, as shown in Figure 6, was used to evaluate the durability of the surface treatment materials. The loader was turned in place with the throttle at 100 percent for 30 seconds. It was anticipated that a technology that could survive this steering test would meet the durability requirement for the parking lot application.

FIGURE 6 Skid steer loader for evaluating surface treatment durability.

Figure 7 shows all the test sections after the durability test. Except for three sections that used surface gritting, chip seals and sand seals, all other sections appeared durable after this testing. These sections will be left in place to monitor their durability over time.

FIGURE 7 Skid steer loader for evaluating surface treatment durability.

10. CONCLUSIONS AND RECOMMENDATIONS

This study evaluated several technologies for improving the reflectivity of asphalt pavement surfaces used in parking lot applications. Based on the findings from this effort, the following observations and conclusions are offered:

- Six technologies exhibited SRI values of 29 or greater determined according to ASTM E 1980. The technologies include micro-surfacing by PolyCon E-Krete, StreetBond coating by IPC, synthetic binder by Toda America, Densiphalt by EucoDensi, and chip and sand seals using light-colored aggregates.
- Another technology, surface gritting using light-colored aggregate, most likely would have exhibited SRI values of at least 29 if the aggregate had adhered properly to the asphalt mat.
- The estimated price ranges listed in Table 2 are for reference purposes only. For a specific project, the construction cost for alternative technologies should be verified by contacting the respective companies.
- Currently, the LEED specification program allows the measurement of the solar reflectance using either ASTM E 1918 or ASTM C 1549 method. The SRI calculated based on the results of these test methods can be very different (up to 11 percent in this study) if the measured surface is irregular and/or rough.

The following recommendations are made based on the findings in this study:

- The six technologies exhibited SRI values of 29 or greater can be used for constructing high reflectance surface pavements.

  - The E-Krete micro-surfacing and StreetBond coating can be used for general-purpose parking lot pavements. A very thin layer of these materials is applied on the pavement surface and do not improve the pavement structure capacity.
  - For the synthetic binder strategy, an overlay or thicker pavement can be constructed to improve the parking lot pavement reflectivity. The paving equipment must be cleaned prior to the construction of this mix.
  - Use of the sand and chip seals should be carefully considered because these technologies may not be durable for a parking lot condition.
  - The Densiphalt can be used to protect against fuel spillage and resistance to abrasion and rutting.
- A cost comparison should be conducted for each specific project because the construction cost may vary significantly due to each project scope and size as well as with technological advances associated with each product.
- The research team believes that gritting is a viable technology for improving pavement reflectivity; however, the construction process needs to be further investigated to make sure the uncoated or lightly-coated aggregate will stick to the mat sufficiently.

REFERENCES

1. U.S. Environmental Protection Agency. *Cooling Summertime Temperatures: Strategies to Reduce Urban Heat Islands*. EPA, Washington D.C., 2003.
2. *Brochure on the Use of Cool Pavements to Reduce the Urban Heat Island Effect*. Website: http://www.ci.gilbert.az.us/planning/urbanheatisland.cfm. The Town of Gilbert, Arizona, 2006, Accessed September 29, 2007.
3. Cambridge Systematics. *Cool Pavement Report*. Draft Report for EPA Cool Pavement Study – Task 5, CS, Maryland, 2005
4. U.S. Green Building Council. *The Leadership in Energy and Environmental Design (LEED) for New Construction*. Version 2.2, USGBC, Washington D.C., 2005.
5. Aggregate Industries. *The Aggregate Industries Guide to LEED Certification*. AI, Maryland, Undated.
6. National Asphalt Pavement Association. *Porous Asphalt Pavements*. Information Series 131, NAPA.
7. Levinson, R. *SRI Calculator*. Heat Island Group, Lawrence Berkeley National Laboratory, www.aepspan.com/files/LBNL-SRI-Calculator.xls. Accessed July 15, 2008.
8. This is Not Your Grandfather's Asphalt. *Centerline,* Asphalt Pavement Association of Oregon, Vol. 13, Issue 2, 2004.
9. Roberts, F., P. Kandhal, E.R. Brown, D.Y. Lee, T. Kennedy. *Hot Mix Asphalt Materials, Mixture Design, and Construction*. NAPA, Maryland, 1996.
10. Nebraska Department of Roads. *Pavement Maintenance Manual*. NDOR, Nebraska, 2002.
11. Blastrac. *Blastrac Natural Asphalt Surfacing*. Undated.
12. Lafarge North America. *DuraTint: Product Data Sheet*. Website: http://www.lafargecorp.com/wps/wcm/resources/file/eb13ee4707be25f/DuraTint.pdf. Accessed Sept 29, 2007.
13. Toda America. *CS-Asphalt Series*. Website: http://www.todaamerica.com/products/color/asphalt/csphalt/csp.html. Accessed September 29, 2007.
14. Bituchem Asphalt. Bituchem Asphalt Products. http://www.bituchem.com/products2.htm. Accessed September 29, 2007.
15. Integrated Paving Concept. *StreetPrint and LEED*. Website: http://www.integratedpaving.com/leed/. Accessed April 23, 2008.
16. Newman, J., and J. Shoenberger. *E-Krete Polymer Composite Micro-Overlay for Airfields: Laboraotry results and Field Demonstrations*. US Army Corps of Engineers, Engineer Research and Development Center, Mississippi, 2003.
17. Anderton, G. *User's Guide: Resin Modified Pavement*, U.S. Army Engineer Waterways Experiment Station, Mississippi, 1996.
18. EucoDensit. *Densiphalt® Handbook.* EucoDensit, 2004.
19. Woodman, R. *Solar Reflectance Testing of Densiphalt® at Massachusetts National Air Guard*. DeLuca-Hoffman Associates, Inc., South Portland, Maine, 2007.

Appendix A

Pictures Taken During Construction of Test Sections

FIGURE 8 Construction of HMA test strip.

FIGURE 9 Spreading uncoated aggregate for surface gritting.

FIGURE 10 Construction of surface gritting section using uncoated aggregate.

FIGURE 11 Mixing PolyCon materials.

FIGURE 12 Construction of PolyCon section (without coarse sand).

FIGURE 13 Construction of PolyCon section (with coarse sand on top).

FIGURE 14 Construction of StreetPrint section (Irish Cream Color).

FIGURE 15 Construction of StreetPrint section (Sun-Baked Clay Color).

FIGURE 16 Shot blasting by Blastrac.

FIGURE 17 Before and after shot blasting.

FIGURE 18 Adding synthetic binder into the mix.

FIGURE 19 Placing synthetic binder section.

FIGURE 20 Rolling synthetic binder section.

FIGURE 21 Installing chip and sand seals sections.

FIGURE 22 All test sections constructed for this study.

Appendix B

Contact Information

Blastrac
Greg Bowers
Director of Sales - North America
(770) 533-1888
Greg.bowers@blastrac.com

Integrated Paving Concepts Inc.
Bruce Biles
Manager, Construction & Engineering Services
(604) 574-7510, ext 251
bruce.biles@streetprint.com

PolyCon Manufacturing, Inc.
Jack H. Willson, Sr.
President
350 Industrial Drive
Madison, MS 39110
(601) 898-1024
jhwpolycon@bellsouth.net

Toda America, Inc.
Andreas Jazdanian
Manager-Marketing & New Business Development
1920 N. Thoreau Dr.
Suite 110
Schaumburg, IL 60173
(847) 397-7060
andy@todaamerica.com