Lawrence Berkeley National Laboratory

A Primer on Cool Schoolyards

Schoolyard design can mitigate discomfort and poor air quality that stem from high temperatures and sun exposure by incorporating shade structures, vegetation, pervious surfaces, and reflective pavements. The ***Cool Schoolyard Roundtable Discussion*** will focus on one aspect of this suite of sustainable schoolyard design strategies—solar reflective pavement materials.

This primer compiles resources that will aid and inform the July 10 roundtable discussion. The primer begins by discussing the health and safety risk posed by rising temperatures. It next introduces the basic science of cool surfaces, before describing the potential benefits of applying reflective surfaces to schoolyards. It then highlights reflective pavement products that are currently available, real-life implementation examples, and policies that promote the use of reflective pavements. The primer concludes with questions for consideration and discussion.

The danger of rising temperatures

Extreme heat is currently the leading cause of weather-related deaths in the United States.[1] With climate change models projecting higher temperatures in California over the next several decades, ***extreme heat events*** are likely to grow more frequent, severe, and protracted.[2] That means that more days will reach into the orange and red areas of the heat index chart shown in **Figure 1**.

Figure 1. Heat index chart

Extreme Danger | Danger | Extreme Caution | Caution | Most common in AZ

°F	RELATIVE HUMIDITY (%)																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
140	125																				
135	120	128																			
130	117	122	131																		
125	111	116	123	131	141																
120	107	111	116	123	130	139	148														
115	103	107	111	115	120	127	135	143	151												
110	99	102	105	108	112	117	123	130	137	143	150										
105	95	97	100	102	105	109	113	118	123	129	135	142	149								
100	91	93	95	97	99	101	104	107	110	115	120	125	132	138	144						
95	87	88	90	91	93	94	96	98	101	104	107	110	114	119	124	130	136				
90	83	84	85	86	87	88	90	91	93	95	96	98	100	102	106	109	113	117	122		
85	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	95	97	99	102	105	108
80	73	74	75	76	77	77	78	79	79	80	81	81	82	83	85	86	86	87	88	89	91
75	69	69	70	71	72	72	73	73	74	74	75	75	76	76	77	77	78	78	79	79	80
70	64	64	65	65	66	66	67	67	68	68	69	69	70	70	70	71	71	71	71	71	72

Source: Arizona Department of Health Services

Children are susceptible to ***heat-related illness***, even when they are otherwise healthy.[3] Moreover, the vigorous nature of many outdoor activities for children in schoolyards further lowers the threshold temperature for safe activity. Higher temperatures are also more conducive to smog formation, which compromises air quality and increases children's risk of ***respiratory illnesses*** such as asthma.[4]

Extreme temperatures thus pose a disproportionate risk to the health and safety of California's schoolchildren when they are outdoors. As a consequence, dangerous temperatures force children to spend more time indoors than is advisable for physical fitness.

The science of cool surfaces

Paved surfaces can get very hot in the sun. Compare the surface temperature of the dark asphalt parking lot in Rio Verde, Arizona with the white lines and grassy sections bordering it, shown below in **Figure 2**.

Figure 2. Visible (left) and infrared (right) images of Arizona parking lot

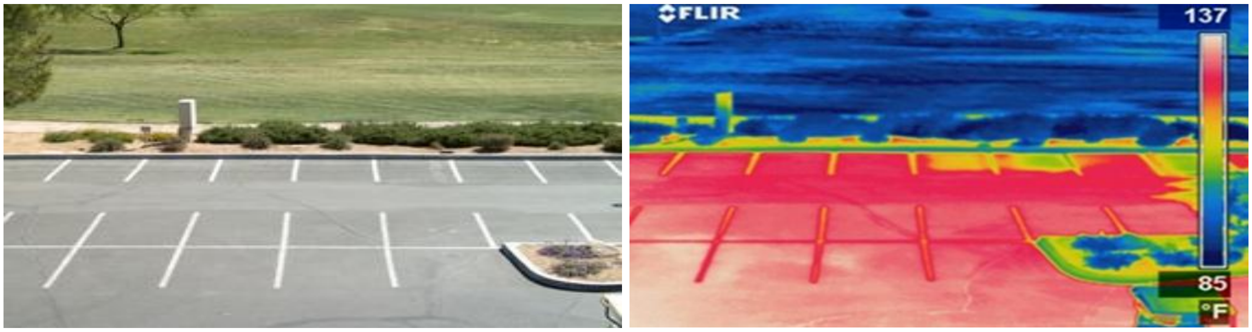
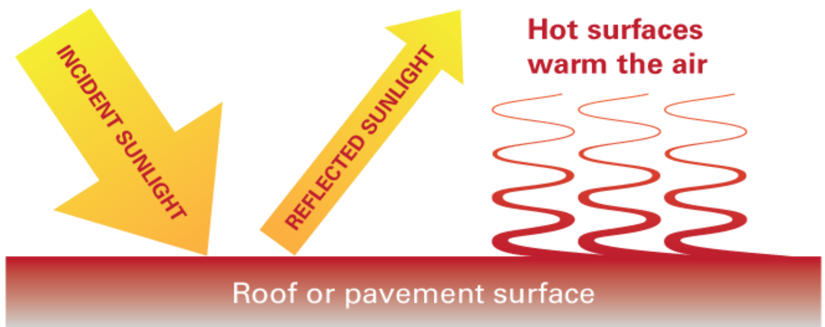


Image credit: Larry Scofield (APCA)

Notice that the dark asphalt pavement is much hotter than the vegetation, and is even noticeably hotter than the white stripes in the parking lot.

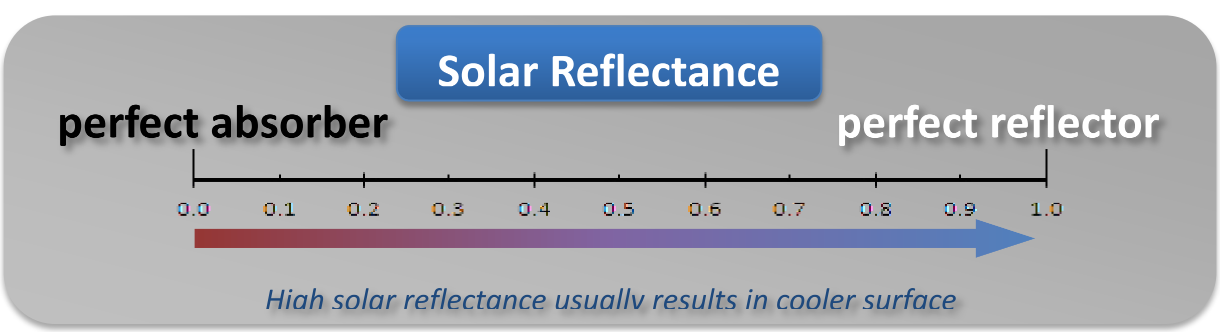
This phenomenon occurs because outdoor surfaces absorb a portion of incoming sunlight and reflect the rest (see **Figure 3**). The extent to which they absorb this radiation determines how much the surfaces warm up and heat surrounding air:

Figure 3. Solar absorption and reflection by surfaces



Light-colored surfaces stay cooler in the sun because they have higher ***solar reflectance*** (ratio of reflected sunlight to incident sunlight, abbreviated SR) than conventional dark surfaces. See **Figure 4** below for an illustration of the measurement scale.

Figure 4. Solar reflectance scale



The benefits of cool schoolyards

During the day…

The use of solar reflective surfaces can confer significant public health benefits. Cool schoolyards would reflect relatively more sunlight and thus remain cooler than traditional blacktop surfaces. This can cool the schoolyard air and ***enhance outdoor comfort***. A recent study in Greece found that applying reflective pavement materials in a large park outside Athens reduced the surface temperature by 12°C (22°F) which in turn reduced the ambient air temperature by 2°C (3°F).[5] On a normal day, this means that cool surfaces will be more comfortable, but on an especially hot summer day, cool surfaces could mean the difference between discomfort and danger. Reducing the frequency of dangerous heat conditions will ***reduce heat-related stress*** that can lead to dehydration, heat stroke, and death.

The lower air temperatures maintained by cool schoolyard surfaces can also ***improve air quality*** by slowing the photochemical reactions that lead to smog formation, reducing the likelihood that kids will develop asthma. By cooling the air, cool schoolyards can also decrease schools' electricity demand for air conditioning, which reduces greenhouse gas emissions from power plants and spreads the air quality improvements that result from having a cool schoolyard.

By keeping schoolyard air cooler and cleaner, even on the warmest days, cool surfaces will allow kids to get the outdoor activity they need while diminishing their exposure to unsafe conditions.

And at night…

Dark surfaces absorb more sunlight during the day and continue to radiate heat into the local environment at night.[6] Cool surfaces, on the other hand, absorb less sunlight during the day and radiate less heat once the sun sets, which allows communities to ***cool down overnight*** and reduce the severity of heat waves.

By reflecting more light, cool surfaces also improve visibility and require less lighting to provide illumination at night. This improves public safety and further reduces energy usage and greenhouse gas emissions from power plants.

Cool pavement materials

Sealcoats are applied to existing "blacktop" schoolyard surfaces every 5-7 years as a routine maintenance measure to protect the structural integrity of the pavement. The sealcoat acts as a waterproofing agent and prevents oxidation of the asphalt. We have identified three classes of "cool" pavement alternatives to traditional black sealcoats (SR 0.05; cost \$0.05-0.10/ft^2):

- ***Coatings –*** Designed to be applied on top of existing asphalt concrete, these polymeric and/or cementitious coatings are available in a wide range of colors. SR 0.30-0.50; cost \$0.70-2.00/ft^2

- ***Cement concrete*** – Sometimes called "whitetopping," this technique is used to rehabilitate rutted/damaged asphalt by placing a 50-100mm thick layer of cement concrete over a milled asphalt surface. SR 0.35-0.50; cost \$1.00-1.50/ft^2

- ***Asphaltic*** – An emulsion of light-colored aggregate and an asphalt binder mixed with color additives (sometimes TiO_2), these sealcoats are more reflective than black sealcoats. SR 0.15-0.20; cost \$0.15-0.50/ft^2

Invited industry representatives:

- ***Emerald Cities Cool Pavement***
- ***Graniterock***
- ***Plexipave***
- ***StreetBond***
- ***Western Colloid***

See attached vendor materials for more information on each vendor's product offerings.

Real-world examples

Earlier this summer, Berkeley Lab installed four Emerald Cities solar reflective coatings over a new asphalt parking lot. On a mild summer afternoon—22.5°C (72.5°F) ambient air temperature at 2:45 pm PDT on June 26, no wind or clouds—the following surface temperatures shown in **Figure 5** were observed on new asphalt concrete, a neighboring patch of old cement concrete, and the coatings:

Figure 5. Infrared temperature measurements in Berkeley Lab parking lot

Asphalt concrete (SR 0.06) – 58.8°C (138°F)

Cement concrete (SR unknown) – 47.4°C (117°F)

Aubergine (SR 0.37) – 43.6°C (110°F)

Celadon (SR 0.32) – 46.2°C (115°F)

Latte (SR 0.46) – 41.4°C (107°F)

Teal (SR 0.39) – 43.8°C (111°F)

The reflective coatings were 13-17°C (23-31°F) cooler than the black asphalt surface.

This concept has already been successfully deployed in some California schoolyards, such as those in the West Contra Costa Unified School District (WCCUSD), which adopted design criteria from the Collaborative for High Performance Schools (CHPS) in 2006. CHPS rewards the extensive use of high-reflectance paved surfaces, such as the StreetBond coating that was installed in a WCCUSD schoolyard in 2011, shown in **Figure 6**.

Figure 6. Reflective coating at Martin Luther King, Jr. Elementary School

Architect: Quattrocchi Kwok

Landscape architect: Vallier Design Associates

Another elementary school in WCCUSD is planning an extensive renovation that will include similar reflective pavement materials (denoted by tan sections of schematic design landscape plan shown in **Figure 7**).

Figure 7. Schoolyard renovation plan for Coronado Elementary School

Architect: WLC Architects, Inc.

Review of current policies that promote cool schools

- ***Collaborative for High Performance Schools (CHPS) –*** The CA-CHPS Criteria attempts to define a high performance school in California. CA-CHPS addresses site and material selection, energy and water efficiency, indoor environmental quality and provides sustainable policies and operations to be adopted by school districts. School districts are encouraged to adopt the criteria for their new buildings and major modernizations. Awards one point when at least 50% of non-roof, paved surfaces are either shaded or use light-colored/high-albedo materials.[7]

- ***High Performance Incentive (HPI) Grants –*** Sponsored by the CA Department of General Services, HPI grants draw from a $100 million incentive fund established in the Governor's Strategic Growth Plan to promote high performance attributes in new construction and modernization projects for K-12 schools. High performance attributes include designs and materials that promote energy and water efficiency, maximize the use of natural lighting, improve indoor air quality, and utilize recycled materials, among other best practices. Criteria for determining grant size and eligibility are based on CHPS or LEED criteria.[8]

- ***California Green Building Standards Code (CALGreen) –*** CALGreen is a code with mandatory requirements for new residential and nonresidential buildings (including public schools) throughout California. CALGreen was established to reduce construction waste, make buildings more efficient in the use of materials and energy, and reduce environmental impact during and after construction. Requires that at least 50% of a site's hardscape be shaded, use light-colored materials (initial SR ≥ 0.30), or use open-grid, pervious, or permeable pavement systems.[9]

Questions for consideration and discussion

1. How can we describe the various uses and functions of schoolyards? What are performance criteria/specifications for their design and maintenance?

2. To what extent is heat considered a health concern to be addressed through schoolyard design and maintenance?

3. How can solar reflective surfaces address these concerns?

4. Have you considered using cool surfaces in schoolyards or incorporating them into design guidelines? Why or why not?

5. If you were successful, to what do you attribute your success? If you were unsuccessful, what obstacles did you confront and what lessons did you learn?

6. In your opinion, what are the barriers to adoption of cool schoolyard surfaces?

7. Where do you see opportunities to leverage existing efforts or interest to accelerate adoption of cool schoolyard surfaces?

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