A novel technique for the production of cool colored concrete tile and asphalt shingle roofing products

Ronen Levinson*, Hashem Akbari and Paul Berdahl
Heat Island Group
Lawrence Berkeley National Laboratory

Kurt Wood, Wayne Skilton and Jerry Petersheim
Arkema, Inc., Philadelphia, PA USA

*Presented at the Second International Conference on Countermeasures to Urban Heat Islands

21 September 2009 • Berkeley, CA

* RML27@cornell.edu
tel. +1-510-486-7494
Sunlight — more than meets the eye

Solar Irradiance Distribution (AM1GH)

- 6.6% ultraviolet (300-400 nm)
- 44.7% visible (400-700 nm)
- 48.7% near-infrared (700-2500 nm)

Solar reflectance $R_{\text{sol}} = 6.6\% \times \text{ultraviolet reflectance } R_{\text{uv}} + 44.7\% \times \text{visible reflectance } R_{\text{vis}} + 48.7\% \times \text{near-infrared reflectance } R_{\text{nir}}$

AM1GH = (clear sky) air mass 1 global horizontal
White, cool color, warm color

- White roof
- Cool red roof
- Gray roof

Graph showing reflectance and irradiance over wavelength (nm):
- Standard white ($R_{sol}=0.82$)
- Cool red ($R_{sol}=0.39$)
- Dark gray ($R_{sol}=0.23$)
Conventional methods for coloring concrete tiles

- Gray-cement concrete
  - low NIR reflectance
- Coloring techniques
  - integrated color
  - cementitious slurry coating
- Limitations
  - gray cement + cool pigment → dark hot color
  - white cement + cool pigment → light cool color

\[ R_{sol} = SR = S = R = \text{solar reflectance} \]
Alternative approach to coloring concrete tiles

- Two-layer polymer coating
  - white basecoat
  - cool color topcoat
  - layering → dark cool color
- Technique already used for tile retrofit coatings
- New process intended for factory line
  - Kynar Aquatec® aqueous polyvinylidene fluoride (PVDF)/acrylic technology
  - pass under white spray
  - pass under cool color spray
  - thin (~30 µm DFT) pigmented latex coatings dry in seconds near room temperature

- NIR-reflective basecoat (e.g., titanium dioxide white in acrylic)
- Cool topcoat (e.g., iron oxide red in acrylic)
- Opaque substrate (e.g., gray concrete or gray granule)

Two-coat system (for NIR-absorbing substrate)

Polymer retrofit coatings

Solar reflectance gain = +0.37 +0.26 +0.23 +0.15 +0.29 +0.29

Standard concrete tile (same color)

Cool concrete tile R ≥ 0.40
Prototype concrete tiles

\[ S = \text{solar reflectance} \]
\[ L^* = \text{CIELAB lightness} \]
New method yields darker cool colored tiles
Conventional method for coloring asphalt shingles

- Fiberglass asphalt shingle = asphalt-saturated fiberglass web fully surfaced with granules
- Granule = crushed gray rock with colored ceramic coating
  - pigmented ceramic coating baked onto granules
  - colored granules pressed into hot asphalt
- Bare granules have low NIR reflectance
- Adding white ceramic basecoat can halve rate of granule production

regular “barkwood” (SR ~ 0.10) without basecoat

cool “barkwood” (SR ~ 0.25) using ceramic white basecoat
Alternative approach to coloring asphalt shingles

- Two-layer polymer coating (same as for tiles)
- We color granules after they have been pressed into shingles
  - coats only exposed side of granules
  - avoids slowing production

- bare (SR = 0.06)
- white (SR = 0.62)
- cool brown over white (SR = 0.30)
Prototype asphalt shingles

S = solar reflectance
L* = CIELAB lightness

Solar reflectance ≥ 0.25
New method yields darker cool colored shingles

- A: white polymer + cool color polymer (shingle coating)
- B: white ceramic + cool color ceramic (granule coating)
- C: proprietary cool color ceramic (granule coating)
- D: cool color ceramic (granule coating)

Solar reflectance vs. Lightness (CIELAB L*)

SR = 0.40
SR = 0.25

asphalt shingle
Roughness reduced shingle reflectance

- Some light reflected from rough surface will return
  - for coated shingle, light return probability ~ \( \frac{1}{3} \)
  - light return reduced shingle reflectance by up to 0.10

- Rough surface area ~ 50% greater than footprint area
  - shingle coatings were ~ \( \frac{1}{3} \) thinner than tile coatings
  - adding 50% more coating could increase shingle solar reflectance by up to 0.12
Summary

• **24 prototype cool color concrete tiles**
  - solar reflectance $S$ ranged from 0.26 to 0.57
  - over half had $S \geq 0.40$

• **24 prototype cool color asphalt shingles**
  - $S$ ranged from 0.18 – 0.34
  - over half had $S \geq 0.25$
  - could increase $S$ by up to 0.12 by using 50% more coating

• Prototypes darker for given $S$, or more reflective for given lightness $L^*$

• **Next steps:** explore
  - thicker shingle coatings
  - other cool pigments
  - multicolor coatings
  - patterned coatings
  - factory-line trials

We thank the California Energy Commission for support of this project.