Inclusion of Solar Reflectance and Thermal Emittance Prescriptive Requirements for Steep-Sloped Roofs in Nonresidential Title 24

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Cooling roofs by increasing solar reflectance

- A conventional dark roof absorbs most sunlight
- Increasing solar reflectance
  - reduces solar heat gain
  - lowers roof temperature
- High thermal emittance
  - facilitates radiative cooling
  - helps keep roof temperature low
- Lowering roof temperature can reduce
  - building cooling electricity use
  - peak power demand
  - ambient air temperature
Environmental impacts of cooling roofs

• Benefits
  – increased human comfort
  – slowed smog formation
  – mitigation of urban heat islands in summer
  – decreased waste from disposal of roofs

• Penalties
  – slightly higher wintertime heating energy use
  – degraded wintertime urban air quality
“Cool” products for steep-sloped roofs

• Limited but growing material availability
  – clay tile
  – concrete tile coating
  – metal
  – fiberglass asphalt shingles

• Products are rated by the Cool Roof Rating Council (CRRC)
  – labels solar reflectance, thermal emittance
  – website: www.coolroofs.org
Increasing solar reflectance of concrete tiles: American Rooftile Coatings

- Can increase solar reflectance $\rho$ by up to 0.50
- Gain greatest for dark colors

$\Delta\rho$ values:
- black: $\Delta\rho = 0.37$
- blue: $\Delta\rho = 0.26$
- gray: $\Delta\rho = 0.23$
- terracotta: $\Delta\rho = 0.15$
- green: $\Delta\rho = 0.29$
- chocolate: $\Delta\rho = 0.29$

Illustration of material colors with corresponding $\rho$ values:
- cooler: black, blue, gray
- warmer: terracotta, green, chocolate
Increasing solar reflectance of metal roofing: BASF Ultra-Cool® metal roof coatings

Concord Cream 872T4 87.3 (80.4)
Slate Gray 870D3 39 (19.9)
Evergreen 870G4 29.4 (12.5)

Rawhide 872T8 57 (47)
Bright Red 872R5 38.6 (38.6)
Hartford Green 872G3 28.3 (10.8)

Sierra Tan 870T7 53.6 (37.6)
Brick Red 872R6 36.6 (24.7)
Teal 872Q4 28.1 (24.8)

Pearl Gray 872D4 48.7 (31.5)
Medium Bronze 872T10 34.6 (12)
Regal Blue 872B4 27.6 (19.6)

Marine Green 870G2 41 (31.9)
Slate Blue 872B6 34.4 (21.3)
Charcoal Gray 872D2 27.4 (14.2)

Patina Green 872G5 41 (29.2)
Slate Bronze 870T5 30.6 (8.6)
Dark Bronze 872T0 26.6 (8)

numbers denote solar reflectances: cooler (warmer)
## Increasing solar reflectance of clay tiles: MCA Clay Tile cool colored tiles

<table>
<thead>
<tr>
<th>Model</th>
<th>Color</th>
<th>Initial solar reflectance</th>
<th>Solar reflectance after 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weathered Green Blend</td>
<td><img src="image1.png" alt="Image" /></td>
<td>0.43</td>
<td>0.49</td>
</tr>
<tr>
<td>Natural Red</td>
<td><img src="image2.png" alt="Image" /></td>
<td>0.43</td>
<td>0.38</td>
</tr>
<tr>
<td>Brick Red</td>
<td><img src="image3.png" alt="Image" /></td>
<td>0.42</td>
<td>0.40</td>
</tr>
<tr>
<td>White Buff</td>
<td><img src="image4.png" alt="Image" /></td>
<td>0.68</td>
<td>0.56</td>
</tr>
<tr>
<td>Tobacco</td>
<td><img src="image5.png" alt="Image" /></td>
<td>0.43</td>
<td>0.41</td>
</tr>
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</table>
MonierLifetile concrete tiles
(Source: http://www.fsec.ucf.edu/bldg/pubs/cr670/index.htm#Figure%204)

<table>
<thead>
<tr>
<th></th>
<th>300</th>
<th>302A</th>
<th>302B</th>
<th>303A</th>
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<tbody>
<tr>
<td>ρ</td>
<td>0.73</td>
<td>0.34</td>
<td>0.67</td>
<td>0.56</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>303B</th>
<th>308A</th>
<th>308B</th>
<th>330A</th>
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</thead>
<tbody>
<tr>
<td>ρ</td>
<td>0.62</td>
<td>0.39</td>
<td>0.23</td>
<td>0.43</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>330B</th>
<th>348A</th>
<th>348B</th>
<th>MRD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ρ</td>
<td>0.28</td>
<td>0.34</td>
<td>0.22</td>
<td>0.24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>MRW</th>
<th>TAUPE</th>
<th>Flat White</th>
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</thead>
<tbody>
<tr>
<td>ρ</td>
<td>0.23</td>
<td>?</td>
<td>0.77</td>
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</table>
Increasing solar reflectance of fiberglass asphalt shingles: 
Elk Prestique® Cool Color Series
3M “cool” granules for fiberglass asphalt shingles

Courtesy 3M

<table>
<thead>
<tr>
<th>Color</th>
<th>Reflectance (ρ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tan</td>
<td>0.32</td>
</tr>
<tr>
<td>Brown</td>
<td>0.25</td>
</tr>
<tr>
<td>Blue Grey</td>
<td>0.27</td>
</tr>
<tr>
<td>Grey</td>
<td>0.27</td>
</tr>
</tbody>
</table>

ρ = solar reflectance
Increasing solar reflectance of fiberglass asphalt shingles: prototypes

- Cooler: $\rho = 0.28$
- $\rho = 0.36$
- $\rho = 0.37$

- Warmer: $\rho = 0.23$
- $\rho = 0.27$
- $\rho = 0.28$

$\rho = \text{solar reflectance}$
“Cool” roof requirements in T24: a timeline

<table>
<thead>
<tr>
<th>Building</th>
<th>Roof</th>
<th>Low-Slope</th>
<th>Steep-Slope</th>
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</thead>
<tbody>
<tr>
<td>Residential</td>
<td></td>
<td>2008</td>
<td>2008</td>
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<tr>
<td>Non-Residential</td>
<td>2005</td>
<td></td>
<td>2008</td>
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</tbody>
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Scope of current study

• Introduce requirements for **steep-sloped roofs** on nonresidential buildings
  – Study proposes minimum aged values of solar reflectance, thermal emittance
  – Based on new building energy analyses

• Update 2005 requirements for **low-sloped roofs** on nonresidential buildings
  – Current code specifies only **initial** values of solar reflectance, thermal emittance
  – Study proposes minimum **aged** values of these properties
  – Based on building energy analysis from previous T24 study
Methodology

- Review measure availability and cost
  - technologies, market share
  - manufacturers, distribution
  - availability, cost premium
  - useful life

- Perform building cost/benefit analysis
  - evaluate measured energy savings
  - simulate cooling and heating energy uses
  - net savings ($) = cooling savings ($) - heating penalty ($)

- Project state-wide savings
Cost-effectiveness of increasing solar reflectance

- Simulated increasing three-year-aged solar reflectance $\rho_{\text{aged}}$ of steep-sloped roofing products
  - fiberglass asphalt shingle (increased $\rho_{\text{aged}}$ to 0.25 from 0.10)
  - concrete tile (increased $\rho_{\text{aged}}$ to 0.40 from 0.10)
  - metal (increased $\rho_{\text{aged}}$ to 0.40 from 0.10)

- Cost premium for higher-reflectance roofing
  - about $0.20 per square foot of roof area

- All simulated increases were cost effective
  - 30-year net present value of TDV energy savings $\geq$ $0.20/ft^2$ in all California climate zones
30-year net present value of savings ($/1000 ft²): shingle roofs
30-year net present value of savings ($/1000 ft²): concrete tile roofs
30-year net present value of savings ($/1000 ft²): metal roofs

<table>
<thead>
<tr>
<th>California Climate Zone</th>
<th>Equip</th>
<th>Energy</th>
<th>Total Savings [Equipment + 30-Year NPV Energy] ($/1000 ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41</td>
<td>495</td>
<td>511</td>
</tr>
<tr>
<td>2</td>
<td>57</td>
<td>1,053</td>
<td>1,095</td>
</tr>
<tr>
<td>3</td>
<td>41</td>
<td>847</td>
<td>821</td>
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<tr>
<td>4</td>
<td>61</td>
<td>1,128</td>
<td>1,189</td>
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<tr>
<td>5</td>
<td>47</td>
<td>919</td>
<td>966</td>
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<tr>
<td>6</td>
<td>57</td>
<td>1,870</td>
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<tr>
<td>7</td>
<td>48</td>
<td>2,141</td>
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<td>8</td>
<td>83</td>
<td>2,181</td>
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<tr>
<td>9</td>
<td>88</td>
<td>1,561</td>
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<td>10</td>
<td>71</td>
<td>1,330</td>
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<td>11</td>
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<td>1,243</td>
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<td>12</td>
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<td>13</td>
<td>72</td>
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<tr>
<td>16</td>
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<td></td>
</tr>
</tbody>
</table>

- **Equip**: Equipment cost
- **Energy**: Energy savings
- **$0.10/ft²**: Cost of energy
Projected annual statewide savings: 
new construction

- Increase in NR roof area.................................78 Mft^2
- Increase in AC steep-sloped NR roof area......14 Mft^2
- Electricity TDV savings.................................15 GWh
- Natural gas TDV deficit................................4.2 GBTU
- Net source energy TDV savings.................... 46 GBTU
- Peak power demand savings..........................1.4 MW
- Equipment savings.................................... $0.4M
- TDV NPV savings.......................................$10M
Projected annual statewide savings: new construction + reroofing

- Applicable AC steep-sloped NR roof area......70 Mft$^2$
- Electricity TDV savings..............................69 GWh
- Natural gas TDV deficit..............................20 GBTU
- Net source energy TDV savings................. 210 GBTU
- Peak power demand savings...................... 6.3 MW
- Equipment savings.................................. $1.9M
- TDV NPV savings.................................... $48M
Proposed requirements for three-year-aged values of solar reflectance ($\rho_{\text{aged}}$), thermal emittance ($\varepsilon_{\text{aged}}$)

- Fiberglass asphalt shingle with $\varepsilon_{\text{aged}} \geq 0.75$:
  
  $$\rho_{\text{aged}} \geq 0.25$$

- All other products with $\varepsilon_{\text{aged}} \geq 0.75$:
  
  $$\rho_{\text{aged}} \geq 0.40$$

- All products with $\varepsilon_{\text{aged}} < 0.75$:
  
  $$\rho_{\text{aged}} \geq 0.40 + 0.31 \times (0.75 - \varepsilon_{\text{aged}})$$
Determining three-year-aged values of solar reflectance, thermal emittance

- Use CRRC aged values $\rho_{\text{aged}}$, $\varepsilon_{\text{aged}}$ if labeled
- If CRRC labels only initial values $\rho_{\text{initial}}$, $\varepsilon_{\text{initial}}$, we estimate $\rho_{\text{aged}}$ and $\varepsilon_{\text{aged}}$:
  - $\rho_{\text{aged}} = 0.20 + 0.70 \times (\rho_{\text{initial}} - 0.20)$
  - $\varepsilon_{\text{aged}} = \varepsilon_{\text{initial}}$
- If the product does not have a CRRC label, default values are
  - $\rho_{\text{aged}} = 0.10$
  - $\varepsilon_{\text{aged}} = 0.75$
Sections of T24 standards to be modified

- Section 101 - Definitions And Rules Of Construction
- Section 118(f) - Mandatory Requirements for Insulation and Cool Roofs
- Section 143 - Prescriptive Requirement for Building Envelopes
  - Section 143(a) - Envelope Component Approach
  - Section 143(b) - Overall Envelope Approach
- Section 149 –Addition, Alteration, and Repairs to Existing Buildings
- Alternative Calculation Manual (ACM)
Proposed requirements for 3-year-aged values of Solar Reflectance Index (SRI)

- **Prescriptive requirements can be simpler**
- Fiberglass asphalt shingle: SRI $\geq 23$
- All other products: SRI $\geq 43$