New Energy Efficient Roofing Materials With Phase Change Material (PCM) Treatment

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Introduction

**Problem:**
The roof is a weak point in a building’s thermal performance.

Hot days: the living space underneath the roof gets overheated, leading to the decrease in thermal comfort.

Cold nights: significant heat loss through the roof, increased heating loads on the building.

**Solution:** Application of phase change material (PCM), a highly productive thermal storage medium.
Two Types of Heat Storage

Latent Heat Storage
Change in physical state
Heat absorption during the melting of 1 kg ice into water at 0°C:

335 kJ/kg

Sensible Heat Storage
Change in temperature
Heat absorption during the heating of 1 kg water (C = 4.19 kJ/kg K) from 1°C to 84°C:

335 kJ/kg
Building Materials with PCM Treatment

- Non-combustible salt hydrate PCMs (A and B) with latent heat storage capacities of about 340 kJ/kg (146 Btu/lb) (PCM A) and 280 kJ/kg (120 Btu/lb) (PCM B) are used.
- PCMs are integrated into a silicone rubber coating compound which is then applied to a textile carrier material by knife over roll coating.
Arrangement in a Roof System

- Roof tiles
- Coated fabric with PCM A (underlayment)
- Thermal insulation
- Coated fabric with PCM B (vapor retarder)
- Dry wall / Substructure
## Technical Data of the PCM based Building Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Underlayment with PCM A</th>
<th>Vapor retarder with PCM B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latent heat absorption</td>
<td>55 °C (131 °F)</td>
<td>25 °C (77 °F)</td>
</tr>
<tr>
<td>Latent heat release</td>
<td>50 °C (122 °F)</td>
<td>20 °C (68 °F)</td>
</tr>
<tr>
<td>Latent heat storage capacity</td>
<td>450 kJ/m² (355 Btu/yd²)</td>
<td>300 kJ/m² (237 Btu/yd²)</td>
</tr>
<tr>
<td>Weight</td>
<td>1.3 kg/m² (2.4 lb/yd²)</td>
<td>1.1 kg/m² (2 lb/yd²)</td>
</tr>
<tr>
<td>Thickness</td>
<td>2 mm (0.08 in.)</td>
<td>1.5 mm (0.06 in.)</td>
</tr>
</tbody>
</table>
Thermal Effects

- Latent heat absorption of the PCM A on hot days reduces heat flux into the building (passive cooling system).
- Latent heat release of the PCM B in cold nights reduces the heat flux out of the building (decreased heating demands).
- PCM therefore controls the heat flux through the roof, adapting the roof’s thermal insulation to prevailing needs.
- Adding PCM creates “smart” building materials.
The PCM’s heat flux control feature leads to

- Enhanced comfort,
- Decreased heating and cooling loads on the building,
- Improved energy efficiency.

Specifically, the PCM application in the roof eliminates peak energy demands.
Temperature measurements and computer simulation carried out on a residential building located in Germany.

PCM application in the entire roof with a size of 130 m² (1,400 ft²) leads to a latent heat storage capacity of about 97,500 kJ (92,412Btu).
Temperature Measurements

- Ambient temperature
- Room temperature (with PCM)
- Room temperature (without PCM)
Energy and Cost Savings

Energy savings:
• Decreased heating demand: up to 25 %,
• Decreased cooling demand: up to 40 %.

Cost savings for residential building in Germany:
• Annual heating demand: 13,500 kWh
  (heating costs of about € 1000),
• Annual savings in heating energy: 3,300 kWh
  (cost savings of about € 250),
• Annual reduction of CO₂-emissions: 0.9 tons (1800 lb),
• Investment payoff in about 5 years.
Conclusions

Newly-developed PCM-based building materials offer substantial improvements in the thermal management of buildings which, in turn,

• leads to enhanced thermal comfort,

• reduces the building’s heating and air-conditioning demands,

• improves the energy efficiency of the structures.