PCM’s in application for acclimatization of buildings
Nick Barnard, Faber Maunsell
VSK2008, Workshop on heat storage
Overview

– Case study building

– Cooling solution 1: Night cooling + thermal mass

– Cooling solution 2: Night cooling + thermal mass + phase change material

– Cooling solution 3: Local refrigeration + night cooling + thermal mass + phase change material

– Conclusions

– Further information and acknowledgements
Case study building
Case study building
Stevenage Borough Council

- Summer overheating issues

- Passive measures preferred as part of the Council’s ‘Best Value’ approach to address overheating
Case study building
Thermal analysis
- Simulation modelling used to quantify benefits
- Benchmarked against monitoring results
- Solar blinds + thermal mass

Comparison of logged & simulated data

Logged
Apache Simulation
Case study building
Issues with direct exposure of soffit
- Aesthetics
- Acoustics
- Integration of high level services
- Potential impact on heating demand
Cooling solution 1: Night cooling + thermal mass
Cooling Solution 1
Solution based on retaining false ceiling

– Fans circulate air between the void and space to create and control thermal link

– CoolDeck elements used to improve performance in selected zones
Cooling Solution 1
Operating strategy

- **Night**
  - Cool air introduced into space by window fans
  - Ceiling fans operate to store cooling in slab

- **Day**
  - Ventilation by windows under manual occupant control
  - Ceiling fans operate when temperatures rise to release stored cooling
Cooling Solution 1
Concept

- Blow air under sheeting elements to improve surface heat transfer by creating turbulent air flow (10-20 W/m²K)
Cooling Solution 1
Enhanced heat transfer

Slab
CoolDeck
Highly turbulent air flow
High rates of surface heat transfer
Cooling Solution 1

Installation

- Ceiling void approximately 220 mm deep
- Predicted energy ~10% AC
- Cost ~25% AC
Cooling Solution 1
Monitoring

- Monitored before (1998) and after (1999)
- Temperature reductions in the region of 5 K (as predictions)
- 1-2 K due to solar blinds
- Offices ‘fresh’ rather than stuffy in morning
- Expected COP ~20 (not monitored)
Cooling solution 2: Night cooling + thermal mass + phase change material
Cooling Solution 2
PCM enhanced heat transfer

- Slab
- CoolDeck + PCM
- Highly turbulent air flow
- High rates of surface heat transfer
Cooling Solution 2
PCM installation – CoolDeck elements
Cooling Solution 2
PCM installation – fans and ductwork
Cooling Solution 2
PCM installation - PCM
Cooling Solution 2
PCM CoolDeck element

The Cooldeck cassette is a holder of the PCM. The ClimSel CoolDeck Pouches is an aluminium laminate pouch filled with phase change material (PCM)*. The main ingredients are sodium sulphate and additives. Installed in a room or cabinet this is a unique component for stabilising the temperature at 24° C (75 deg F).

**Physical data for the Cooldeck cassette**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>2375 mm</td>
</tr>
<tr>
<td>Width</td>
<td>556 mm</td>
</tr>
<tr>
<td>Two ClimSel modules is fitting in one cassette.</td>
<td></td>
</tr>
</tbody>
</table>

**Physical Data for one module of ClimSel CoolDeck C 24**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase Change Temperature</td>
<td>24 °C</td>
</tr>
<tr>
<td>Maximum temperature</td>
<td>50 °C</td>
</tr>
<tr>
<td>Storage capacity 19-29 deg C</td>
<td>173 Wh</td>
</tr>
<tr>
<td>Latent Heat of Fusion</td>
<td>163 Wh</td>
</tr>
<tr>
<td>Specific Heat appr. in PCM</td>
<td>1 Wh/°C</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>1.45 kg/l</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>0.5-0.7 W/m°C</td>
</tr>
<tr>
<td>Weight</td>
<td>5.8 kg</td>
</tr>
<tr>
<td>Thickness</td>
<td>15 mm</td>
</tr>
<tr>
<td>Length</td>
<td>1090 mm</td>
</tr>
<tr>
<td>Width</td>
<td>490 mm</td>
</tr>
</tbody>
</table>
Cooling Solution 2
Integrating PCM

- Storage capacity 5 to 10 times concrete
- Used to augment concrete slab providing ~40% of storage
- Phase change temperature selected at ~ 24°C to match cooling source (outside air in this case)
Cooling solution 3: Local refrigeration + night cooling + thermal mass + phase change material
Cooling Solution 3
Integration with mechanical refrigeration

- Increasingly difficult to avoid the use of air conditioning with new CIBSE weather data, in particular London Design Summer Year
- Often a client requirement to meet maximum temperature limit

<table>
<thead>
<tr>
<th>Annual number of hours that external dry bulb temperature is exceeded</th>
<th>&gt; 15°C</th>
<th>&gt; 20°C</th>
<th>&gt; 25°C</th>
<th>&gt; 28°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heathrow Example Weather Year</td>
<td>2000</td>
<td>420</td>
<td>27</td>
<td>2</td>
</tr>
<tr>
<td>London Test Reference Year</td>
<td>2125</td>
<td>631</td>
<td>127</td>
<td>24</td>
</tr>
<tr>
<td>London Design Summer Year</td>
<td>2554</td>
<td>1045</td>
<td>283</td>
<td>72</td>
</tr>
</tbody>
</table>
Cooling Solution 3

Local DX top-up

- Overheating predicted for night cooling using new CIBSE weather data
- Local DX units provided in ceiling voids for top-up cooling
Cooling Solution 3
Layout

- Night cooling by CoolDeck system normally
- Local DX units provide top-up cooling night and day during peak periods
- Cost ~50% AC
Cooling Solution 3
Local DX unit control

- Control temperature is a key parameter affecting overheating and energy consumption
- Predicted energy ~25% AC at 27°C, ~50% AC at 23°C
# Cooling Solution 3

## Monitoring results

<table>
<thead>
<tr>
<th>1st August 2007</th>
<th>3rd Floor Daneshill House Cooldeck Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00 AM</td>
<td>12.00</td>
</tr>
<tr>
<td>Desk Level Temp.</td>
<td>25.26</td>
</tr>
<tr>
<td>T3 Air in Plate</td>
<td>26.46</td>
</tr>
<tr>
<td>T7 Air out of Plate</td>
<td>23.49</td>
</tr>
<tr>
<td>Total</td>
<td><strong>2.97</strong></td>
</tr>
</tbody>
</table>

### Graphs:

- **01-T3 inlet to plate.0** Temperature = 26.14 °C
- **07-T7 Exit.0** Temperature = 23.08 °C
- **AC2 outlet.0** Temperature = 18.03 °C
- **Outside T2/H2.0** Temperature = 15.95 °C
### Client Satisfaction

<table>
<thead>
<tr>
<th>Location</th>
<th>Excellent/Good</th>
<th>Neutral</th>
<th>Bad/Very Bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall (279)</td>
<td>54</td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td>3rd floor old block (29)</td>
<td>76</td>
<td>21</td>
<td>3</td>
</tr>
<tr>
<td>2nd floor new block (15)</td>
<td>73</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>3rd floor new block (15)</td>
<td>61</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>6th floor (29)</td>
<td>61</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>4th floor new block (12)</td>
<td>54</td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td>1st floor atrium (19)</td>
<td>53</td>
<td>32</td>
<td>15</td>
</tr>
<tr>
<td>2nd floor old block (21)</td>
<td>52</td>
<td>33</td>
<td>15</td>
</tr>
<tr>
<td>5th floor (15)</td>
<td>46</td>
<td>31</td>
<td>23</td>
</tr>
<tr>
<td>1st floor new block (21)</td>
<td>43</td>
<td>38</td>
<td>19</td>
</tr>
<tr>
<td>Ground floor atrium (37)</td>
<td>38</td>
<td>19</td>
<td>43</td>
</tr>
<tr>
<td>4th floor old block (13)</td>
<td>23</td>
<td>8</td>
<td>69</td>
</tr>
</tbody>
</table>

Source: AMA Workware Toolkit:2007/sept, AMA (472.)
Query: Q15: Overall, how do you rate your office environment?
Conclusions
Conclusions

- Night cooling can provide a low cost low energy solution to cooling
- Hotter summers may mean mechanical refrigeration is required to achieve comfort in some applications
- Hybrid solutions potentially offer a balanced approach to meeting cost, comfort and energy requirements
- PCMs can provide cost effective thermal storage in buildings
Further information and acknowledgements
Further information

**Retrofitting for Environmental Viability Improvement of Valued Architectural Landmarks**

- Energy Demonstration Project
- **Refurbishment of Non-Domestic to improve Energy Performance & Internal Comfort Conditions**
  - EU Funded ‘THERMIE’ grant (5.6m Euros)
  - Demonstration sites in five EU Countries
  - 5 Year Project (2003 to 2008)
  - Covers Design, Construction, Monitoring
Further information

**PHASE CHANGE MATERIALS IN BUILDINGS**

Virtual thermal mass

**What is thermal mass?**

It is the part of the building which stores heat over the daily cycle. It is important because it delays the heat gains, and reduces the risk of overheating in lightweight materials, but it is essential and/or the space in which the gains are made available to offset the heat load later in the day.

**How does it help us?**

Winter sunshine may bring 1/2 kW into the room through facing glazing. This may be much greater than the current heat load for the room and in a room with no capacity to store heat lead to overheating, and prevention of the heat by opening the window or running the A/C plant. A room with accessible thermal mass, would heat up much more slowly because more heat is absorbed by the mass. When the sun was no longer present, the temperature of the massed, this heat would be released into the room, delaying the need for auxiliary heating (fig 3). Thus, thermal mass is normally regarded as an essential constituent of solar architecture.

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 Thermal mass is only effective in storing heat if the heat can flow into it. The deeper into the material, the less heat flows into it (in a given time) and so the less impact it has (fig 6). The result is that for diurnal (24 hour) temperature cycles, for thermally massive materials such as masonry or concrete, only the first 50mm has much effect. For longer cycles – e.g. a sequence of hot days (or heat wave), deeper thermal mass will slow down the gradual heating up of the building. Only very deep mass, e.g. that which might be found in buildings such as cathedrals and castles, will have a significant effect on a seasonal level – i.e. mean monthly temperatures inside will lag behind the mean monthly temperatures outside. These effects are described as thermal inertia.
Acknowledgements

- Stevenage Borough Council
- Climator