INITIAL DEVELOPMENT OF A COMBINED PCM AND TABS SOLUTION FOR HEAT STORAGE AND COOLING

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CONCRETE DECK DESIGN
WHAT IS PCM?
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• What is PCM- concrete element

• Assumption to modeling of combined PCM concrete deck element (COMSOL)

• Results

• Conclusion
### Assumption to Combined PCM-Concrete Material

<table>
<thead>
<tr>
<th>PCM [%]</th>
<th>density [kg/m³]</th>
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<tbody>
<tr>
<td>0</td>
<td>2300</td>
</tr>
<tr>
<td>1</td>
<td>2287</td>
</tr>
<tr>
<td>4</td>
<td>2247</td>
</tr>
<tr>
<td>6</td>
<td>2221</td>
</tr>
<tr>
<td>10</td>
<td>2168</td>
</tr>
<tr>
<td>15</td>
<td>2102</td>
</tr>
<tr>
<td>20</td>
<td>2036</td>
</tr>
<tr>
<td>40</td>
<td>1772</td>
</tr>
<tr>
<td>60</td>
<td>1508</td>
</tr>
<tr>
<td>80</td>
<td>1244</td>
</tr>
</tbody>
</table>

*Calculated as weight average

<table>
<thead>
<tr>
<th>Temperature [°C]</th>
<th>Specific heat capacity [J/kgK]</th>
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</thead>
<tbody>
<tr>
<td>15</td>
<td>5000</td>
</tr>
<tr>
<td>16</td>
<td>10000</td>
</tr>
<tr>
<td>17</td>
<td>15000</td>
</tr>
<tr>
<td>18</td>
<td>20000</td>
</tr>
<tr>
<td>19</td>
<td>25000</td>
</tr>
<tr>
<td>20</td>
<td>30000</td>
</tr>
</tbody>
</table>

*Ccalculated based on enthalpy curves obtained from DSC for pure PCM

<table>
<thead>
<tr>
<th>PCM [%]</th>
<th>λ [W/mK]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,78</td>
</tr>
<tr>
<td>2</td>
<td>1,77</td>
</tr>
<tr>
<td>3</td>
<td>1,75</td>
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<tr>
<td>4</td>
<td>1,73</td>
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<tr>
<td>5</td>
<td>1,72</td>
</tr>
<tr>
<td>6</td>
<td>1,7</td>
</tr>
<tr>
<td>10</td>
<td>1,63</td>
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<tr>
<td>15</td>
<td>1,55</td>
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<tr>
<td>20</td>
<td>1,47</td>
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<td>40</td>
<td>1,14</td>
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<tr>
<td>60</td>
<td>0,8</td>
</tr>
<tr>
<td>80</td>
<td>0,47</td>
</tr>
</tbody>
</table>

*Calculated according to area average equation for inhomogeneous constructions
ASSUMPTION - BOUNDARY CONDITION

- **Convection + Radiation**
  - Combined convective and radiative heat transfer coefficient:
    - \( h \ [\text{W/m}^2\text{K}] \ (2, 4, \ldots, 30) \)

- **adiabatic**

- **Indoor air temperature**
  - Graph showing temperature variations over time.
ASSUMPTION-LOCATION OF PCM

Reference:

Geometry 1:
- 1cm PCM
- 2cm PCM
- 3cm PCM
- 4cm PCM

Geometry 2:
- 1cm concrete 2cm PCM
- 2cm concrete 2cm PCM
**Passive vs. Thermally Activated Deck**

- **Passive**
  - All variables: \( \rho, C_p, \) conductivity, combined heat transfer coefficient, geometry

- **Active**
  - Water temperature: 16\(^\circ\)C, 18\(^\circ\)C, 20\(^\circ\)C
  - Pipe location
  - Control strategy: 24 h active, 12 h active, 8 h active
  - All variables: \( \rho, C_p, \) conductivity, combined heat transfer coefficient, geometry
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Passive – Results (Geometry1)

1 cm PCM

2 cm PCM

3 cm PCM

4 cm PCM

- Only concrete
- 1%
- 4%
- 6%
- 10%
- 15%
- 20%
- 40%

Heat storage capacity [W/m²] vs. h (convective + radiative) [W/m²K]
IMPROVEMENT OF DYNAMIC HEAT STORAGE

1 cm PCM vs Only concrete

Increase of dynamic heat storage capacity [%]

h(convective+radiative) [W/m²K]
IMPROVEMENT OF DYNAMIC HEAT STORAGE

2 cm PCM vs Only concrete

Increase of dynamic heat storage capacity [%]

h(convective+radiative) [W/m²K]

- 1%
- 4%
- 6%
- 10%
- 15%
- 20%
- 40%
IMPROVEMENT OF DYNAMIC HEAT STORAGE

3 cm PCM vs Only concrete

Increase of dynamic heat storage capacity [%]

h(convective+radiative) [W/m²K]

1% 4% 6% 10% 15% 20% 40%
IMPROVEMENT OF DYNAMIC HEAT STORAGE

4 cm PCM vs Only concrete

Increase of dynamic heat storage capacity [%]

h(convective+radiative) [W/m²K]

- 1%
- 4%
- 6%
- 10%
- 15%
- 20%
- 40%
PASSIVE – RESULTS (GEOMETRY 2)

2cm PCM layer relocated to the inside of the deck vs Only concrete

Increase of dynamic heat storage [%]

$h (\text{convective } + \text{radiative})[\text{W/m}^2\text{K}]$

- 1% PCM_2cm layer-on the bottom
- 1% PCM_2cm layer- 1cm from the bottom
- 1% PCM_2cm layer- 2cm from the bottom
ACTIVE — MODELING ASSUMPTION

- Water flow is turned on (24h, 12h, 8h).
- Geometry 1: 1 cm with PCM on the bottom of the deck.
- Location of center of the pipe from the bottom is:

  20 mm

  51 mm
24 HOUR ACTIVATION

Heat storage capacity/cooling power [Wh/m²]

h_(convective+radiative) [W/m²K]

Passive_only concrete
Passive_40%_1cm PCM
Passive_40%_2cm PCM
Passive_40%_3cm PCM
Passive_40%_4cm PCM
L=20mm_1%_16 [°C]
L=20mm_1%_18 [°C]
L=20mm_1%_20 [°C]
L=20mm_40%_16 [°C]
L=20mm_40%_18 [°C]
L=20mm_40%_20 [°C]
L=20mm_only concrete_16 [°C]
L=20mm_only concrete_18 [°C]
L=20mm_only concrete_20 [°C]
L=50mm_1%_16 [°C]
L=50mm_1%_18 [°C]
L=50mm_1%_20 [°C]
L=50mm_40%_16 [°C]
L=50mm_40%_18 [°C]
L=50mm_40%_20 [°C]
L=50mm_only concrete_16 [°C]

0  5  10  15  20  25  30
h_(convective+radiative) [W/m²K]
0  200  400  600  800  1000  1200  1400  1600  1800  2000  2200  2400
Heat storage capacity/cooling power [Wh/m²]
12 HOURS ACTIVATION

12 hours activation

Heat storage capacity/cooling power [Wh/m²]

$h_{(\text{convective + radiative})}$ [W/m²K]

- Passive_only concrete
- Passive_40%_1cm PCM
- Passive_40%_2cm PCM
- Passive_40%_3cm PCM
- Passive_40%_4cm PCM
- L=20mm_1%_16 [°C]
- L=20mm_1%_18 [°C]
- L=20mm_1%_20 [°C]
- L=20mm_40%_16 [°C]
- L=20mm_40%_18 [°C]
- L=20mm_40%_20 [°C]
- L=20mm_only concrete_16 [°C]
- L=20mm_only concrete_18 [°C]
- L=20mm_only concrete_20 [°C]
- L=50mm_1%_16 [°C]
- L=50mm_1%_18 [°C]
- L=50mm_1%_20 [°C]
- L=50mm_40%_16 [°C]
- L=50mm_40%_18 [°C]
- L=50mm_40%_20 [°C]
- L=50mm_only concrete_16 [°C]
- L=50mm_only concrete_18 [°C]
- L=50mm_only concrete_20 [°C]
8 HOURS ACTIVATION

8 hours activation

h_(convective + radiative) [W/m²K]

Heat storage capacity/ cooling power [Wh/m²]

Passive_only concrete
Passive_40%_1cm PCM
Passive_40%_2cm PCM
Passive_40%_3cm PCM
Passive_40%_4cm PCM
L=20mm_40%_16 [°C]
L=20mm_40%_18 [°C]
L=20mm_40%_20 [°C]
L=20mm_only concrete_16 [°C]
L=20mm_only concrete_18 [°C]
L=20mm_only concrete_20 [°C]
L=50mm_40%_16 [°C]
L=50mm_40%_18 [°C]
L=50mm_40%_20 [°C]
L=50mm_only concrete_16 [°C]
L=50mm_only concrete_18 [°C]
L=50mm_only concrete_20 [°C]
CONCLUSIONS

- If PCM shall be implemented in concrete deck element then the best location seems to be closest to its surface.

- To improve dynamic heat storage capacity of already heavy element it is necessary to make sure that heat transfer coefficient on the surface is possibly highest (high convection or high radiation or both convection and radiation must be high).

- Implementation of PCM in the concrete deck might be not enough to guaranty good indoor climat.

- In order to achieve sufficient cooling effect it is necessary to activate heavy construction by for example providing hydronic technology.

- PCM can damp effect from thermaly activated system TABS.

- If thermaly activated system together with PCM can have sufficient cooling effect then further optimization shall be focused on control of TABS.
Thank you for attention