HiPerMat 2016

COMPOSITE FAÇADE ELEMENTS WITH FUNCTIONAL SURFACES

P. Fontana, L. Miccoli, R. Kocadag, N. Silva, D. Qvaeschning, O. Kreft, C. Cederqvist
Outline

- [H]house project
- Element design
- Material properties
- Functional surfaces
- Conclusions and outlook
**[H]house project**  
Concept

Half panel for renovation

- Inner layer: Original standard concrete
- Insulation layer: CLC or AAC
- Outer layer: TRC or UHPC (functionalized)

Sandwich panels UHPC/AAC

- Inner layer: UHPC
- Insulation layer: AAC
- Surface functionalized UHPC outer layer

Sandwich panels TRC or UHPC/CLC

- Inner finish: functional earthen board
- Inner layer: TRC or UHPC
- Insulation layer: CLC
- Surface functionalized TRC or UHPC outer layer

March 9-11, 2016  HiPerMat 2016
Goals

- UHPC composite precast elements with insulation made of Autoclaved Aerated Concrete (AAC) or Cellular Lightweight Concrete (CLC) for refurbishment and new construction
- Additional increase of sustainability of the light-weight construction by use of binders with reduced clinker content
- Self-cleaning element surfaces
  - Photocatalysis
  - Super hydrophobicity
Element design

Insulation
$U \leq 0.15 \text{ W/(m}^2\cdot\text{K)}$
Element design

March 9-11, 2016  HiPerMat 2016
Element design
Dyckerhoff Nanodur® Compound:
Particles < 250 μm
Portland cement, blast furnace slag, quartz powder, synthetic silica

<table>
<thead>
<tr>
<th>Material</th>
<th>Reference</th>
<th>1% TiO₂</th>
<th>3% TiO₂</th>
<th>5% TiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanodur® Compound</td>
<td>1050</td>
<td>1028</td>
<td>984</td>
<td>940</td>
</tr>
<tr>
<td>Sand 0/2 mm</td>
<td>1150</td>
<td>1150</td>
<td>1150</td>
<td>1150</td>
</tr>
<tr>
<td>Titaniumdioxide (TiO₂)</td>
<td>--</td>
<td>22</td>
<td>66</td>
<td>110</td>
</tr>
<tr>
<td>PCE superplasticiser</td>
<td>17.9</td>
<td>30.0</td>
<td>53.3</td>
<td>80.0</td>
</tr>
<tr>
<td>Water</td>
<td>178.5</td>
<td>178.5</td>
<td>178.5</td>
<td>178.5</td>
</tr>
</tbody>
</table>

→ Compressive strength > 100 MPa (> 50 MPa after 1 day)
**Materials**

**Insulation – AAC/CLC**

**Xella Multipor®:** $\lambda = 42-47 \text{ mW/(m} \cdot \text{K)}, \ 85-115 \text{ kg/m}^3$

**Aercrete/CBI CLC:** $\lambda < 45 \text{ mW/(m} \cdot \text{K)}$ at 150 kg/m$^3$ → Quartzene® aerogel

---

![Graphs of AAC and CLC](image)
Functional surfaces
Photocatalytic self-cleaning

Decomposition of organic material

Removal of decomposed matter by draining rainwater or wind

Side effect:
Reduction of airborne pollutants
**Functional surfaces**
Photocatalytic self-cleaning

Pollution with methylene blue  
Artificial weathering

- 24h UV(A) at 23 °C, 50% RH  
- > Splash water (15 sec / 2 bar)
Functional surfaces
Photocatalytic self-cleaning

Initial state
After 24 h UV(A)
After 48 h UV(A)
Functional surfaces
Photocatalytic self-cleaning

L*-a*-b* colour space

Graph showing the effect of different concentrations of TiO2 on color change over time with UV radiation.
Functional surfaces
Photocatalytic self-cleaning

<table>
<thead>
<tr>
<th></th>
<th>Decrease of pollution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>81</td>
</tr>
<tr>
<td>Type 2</td>
<td>36</td>
</tr>
<tr>
<td>Reference</td>
<td>1% TiO₂</td>
</tr>
<tr>
<td></td>
<td>3% TiO₂</td>
</tr>
<tr>
<td></td>
<td>5% TiO₂</td>
</tr>
</tbody>
</table>

March 9-11, 2016    HiPerMat 2016
Functional surfaces
Super hydrophobicity

Lotus effect
Functional surfaces
Super hydrophobicity

Micro structuring with technical fabrics

CBI
Functional surfaces
Super hydrophobicity

Fabric

UHPC
Functional surfaces
Super hydrophobicity

Structured
Structured & impregnated

March 9-11, 2016  HiPerMat 2016
Functional surfaces
Super hydrophobicity
Test series with several silane/siloxane based agents

- Series 1:
  UHPC cast on fabric, impregnation 24 h after demoulding

- Series 2:
  UHPC cast in formwork (PVC) without fabric, impregnation 24 h after demoulding

- Series 3:
  Application of agent on fabric before UHPC cast
Functional surfaces
Super hydrophobicity

Contact angle

Roll-off angle
**Functional surfaces**
Super hydrophobicity

Contact angle

Roll-off angle

- Contact angle
- Roll-off angle

**Type of water-repellent agent**

- Impregnated (fabric)
- Impregnated (PVC)
- Agent on fabric

March 9-11, 2016   HiPerMat 2016
Functional surfaces
Super hydrophobicity

Agents applied with paintbrush on fabric before concrete cast

Type A  Type B  Type G
Functional surfaces
Super hydrophobicity
Conclusions and outlook

- Fabrics suitable for manufacture of micro-structured UHPC, but tend to swelling and deforming.
- Application of water-repellent agent on fabric substrate before concrete cast most efficient.
- Excellent water repellence obtained with silane-based agents.
- Concept of box-shaped UHPC is a simple and robust solution for the composite façade elements.

→ Consistently good performance of water repellence after preliminary artificial weathering tests.
→ UHPC with water-repellent and with photocatalytic surfaces currently exposed to urban environment.
→ Numerical modelling to identify heat bridges and to find optimum compromise between structural and hygrothermal performance.
Acknowledgements

H-HOUSE is a research project funded by the European Commission under the 7th Framework Programme (Grant Agreement No. 608893)

The authors thank also Mr. Erdi Kaplan and Mr. Serdar Bilgin for their important support in experimental testing and data analysis.