Ultra High Performance Fibre Reinforced Concrete (UHPFRC) for rehabilitation of bridges (WP 5) - Recent advances in Slovenia

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1. Motivation

- Limited resources for management of road structures (time and money, including user’s costs)!

- Limit duration of sites
- Increase durability and efficiency
  - for rehabilitations
  - for new constructions

- Promote Strategy A

- Make best use of most advanced materials
- Combine materials in efficient composite structures!
2. UHPFRC materials

- Ultra High Performance Fibre Reinforced Concretes
- Ultra compact cementitious matrix – Outstanding Durability
- Multilevel fibrous reinforcement – Tensile strain hardening
- Outstanding mechanical and protective properties

“Selfcompacting”

CEMTECmultiscale® developed by Rossi et al. (2002)

“Ductile as steel”
UHPFRC composition

- Matrix

- Silica fume - SF/C = 0.05 to 0.26 (mass)
- Superplasticizer – SP/C = 1 % (mass, dry extract)
- Water/Binder = 0.125 to 0.140
- Cement: 1051 to 1434 kg/m³
UHPFRC composition

• Fibrous reinforcement

- Steel wool + 10 mm/0.2 mm straight fibres
- Total dosage 468 - 706 kg/m³ (6 to 9 % Vol.)

CEMTECmultiscale® developed by Rossi et al. (2002)
Fractured surface of UHPFRC with pulled-out steel fibres
3. What is proposed?

Liquid water + Cl\textsuperscript{−} = XD2, XD3
Most aggressive for structures!

- Apply protective watertight UHPFRC overlay
- Improve durability and load carrying capacity
4. Existing knowledge/experiences

→ Successful « Structural rehabilitations » are a **major challenge for engineers**

Major issues:

→ Processing
→ Monolithic behaviour
→ Protective function
→ Mechanical performance
→ Durability
• Numerous laboratory tests on UHPFRC materials and composite members, since 1999 at MCS/EPFL – EU Project SAMARIS.

5. Recent advances in Slovenia

Challenges

➤ Develop UHPFRC mixes from local components (overcome cement-superplasticiser compatibility issues)
➤ Make the mixes tolerant to slopes of 5 %
➤ Improve surfacing technique (« barefoot walk »)
➤ Apply new materials on a bridge!
ARCHES WP 5 team

Dr. E. Denarié, MCS-EPFL (CH) – WP Leader

- MCS-EPFL (CH): Prof. E. Brühwiler, Dr. H. Sadouki, Mrs A. Switek, Mr H. Kamyab, Mrs T. Noshiravani, Mr C. Oesterlee, Dr J. Wuest
- ZAG (Slovenia): Dr A. Šajna, Mrs J. Šuput, Mr V. Bras
- Salonit (Slovenia): Mrs L. Reščič
- IBDIM (Poland): Prof. M. Lagoda, Mr. A. Sakowski
- LCPC/FEHRL (France): Dr. P. Rossi
New UHPFRC matrices

A: pure CEM I 52.5 cement (Salonit)

B: CEM I 52.5 cement (Salonit) blended with mineral addition

Similar recipes with Water/(Cement+Addition) ratio = 0.155

- Case A: impossible to achieve sufficient workability when fibres are added
- Case B: excellent workability, comparable to reference UHPFRC mixes with reference cement – perfectly adapted for addition of fibres at high dosages

Denarié - 2007
Improved slope tolerance

A: UHPFRC without thyxotropizer

B: UHPFRC with thyxotropizer

MCS tests

Slovene based similar recipes with W/C = 0.170
New unconfined slope test from EPFL/MCS

- Case A: no slope tolerance to 3 %
- Case B: tolerance to slope of 3 %

ZAG confirmed results and extended to 5 % slope
Field trial tests – Salonit (SL) - 2008

300 litres batches
Total 900 litres
Loss = 50 litres

Slopes of 5% can be cast without difficulties
Application time:
10 m² = 10 minutes

CEMTEC multiscale
Validation - Protective functions

<table>
<thead>
<tr>
<th>UHPFRC</th>
<th>Reference</th>
<th>Air permeability [10^{-16} m^2]</th>
<th>Capillary water absorption coefficient [g/m^2.h^{0.5}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bad concrete</td>
<td>2</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>Good concrete</td>
<td>0.03</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>CM23 (ref.)</td>
<td>0.003</td>
<td>45 (EPFL meas.)</td>
<td></td>
</tr>
<tr>
<td>CM24</td>
<td>0.008</td>
<td>53 (EPFL meas.)</td>
<td></td>
</tr>
<tr>
<td>CM27</td>
<td>n.a</td>
<td>23 (ZAG meas.)</td>
<td></td>
</tr>
<tr>
<td>CM29</td>
<td>n.a</td>
<td>23 (ZAG meas.)</td>
<td></td>
</tr>
</tbody>
</table>

- Recipes CM24, CM27 and CM29 with Slovenian components exhibit excellent protective properties comparable to reference mix CM23 (project SAMARIS).
Validation - Mechanical performance

Recipes CM24, CM32_11 and CM32_13 with Slovenian components exhibit excellent mechanical performance comparable to the reference mixes CM23 and CM22_TKK.

- Flexural response under 4 PT bending
- Plates 50 x 20 x 3 cm
- Span 42 cm
- Average curves on 5 to 10 specimens

[Graph showing force vs. average mid-span deflection]

MA = Mineral addition
Full scale application – SLOVENIA

Owner: Municipality of Bovec

Log Čezsoški bridge – Soča river, July 2009
- rehabilitation of the sidewalk, and deck with UHPFRC, replacement of dilation
12.7 km detour

**Challenge**
- Limit site duration
- Increase durability and efficiency of rehabilitation
• 12 m³ UHPFRC applied in 2.5 to 3 cm layers.
• Execution in 2 days with a transversal joint at mid-deck surface
Surfacing with ZEMDRAIN®

2.5 cm UHPFRC

Application of a continuous watertight UHPFRC on the deck and footpaths
Laboratory validation

Combination with ZEMDRAIN®

➔ Surfacing technique of UHPFRC (ZAG-2009)
Preparation works

Low roughness requirements
Preparation works
Execution

Batches of 320 litres
2 or 3 batches per truck
Mixing time = 12 minutes
Execution
The bridge after rehabilitation
## Owner, user, contractor

<table>
<thead>
<tr>
<th></th>
<th>Tradition rehabilitation</th>
<th>vs.</th>
<th>UHPFRC rehabilitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site duration</td>
<td>3 months</td>
<td>&gt;</td>
<td>1 month</td>
</tr>
<tr>
<td>Costs</td>
<td>for 12 MM</td>
<td>≫</td>
<td>for 12 m³ UHPFRC</td>
</tr>
<tr>
<td>Durability and efficiency of rehabilitation</td>
<td>App. 30 years</td>
<td>≪</td>
<td>more than double</td>
</tr>
<tr>
<td>CO₂ balance</td>
<td></td>
<td></td>
<td>Next presentation</td>
</tr>
</tbody>
</table>
Dare try and be creative !!!

- Focus on the conceptual approach – why and where are UHPFRC really needed in your structures
- Use local components for UHPFRC mixes
- Cast in-situ and prefabrication applications
- Use simple tools and existing facilities
- Foster training of contractors
- Take advantage of combination UHPFRC-rebars for reinforcement of your structures
6. Conclusions

- «Targeted local hardening» or reinforcement of structures, in most critical zones, by using UHPFRC and rebars.
- Simplification of the construction.
- Increase of the efficiency of existing and new structures (protection and reinforcement).
- Concept successfully validated (technically and economically) in full scale applications in Switzerland and more recently in Slovenia.
- Several new planned in different countries.
7. Links and documents

EU 5\textsuperscript{th} FP SAMARIS/WP 14, deliverables D22 and D25 - \url{http://samaris.zag.si}

EU 6\textsuperscript{th} FP ARCHES/WP 5, deliverables D06 and D14 - \url{http://arches.fehrl.org}

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Salonit Anhovo: Mrs. L. Reščič
TKK Srpenica: Mrs. L. Černilogar

Local partners of the application

Municipality of Bovec (Slovenia): Mr. D. Krivec (Mayor)
Primorje: Mr. B. Ipavec (Designer)
CPG: Mr. M. Popović, Mr. Z. Jerkič, Mr. J. Brecelj (Contractor)
Thank your for attention!