Ultra High Performance Fibre Reinforced Concrete (UHPFRC) for rehabilitation of bridges (WP 5)

- Recent advances in Slovenia

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ZAG LJUBLJANA 60 15 1949 • 1994 • 2009

OUTLINE

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2. UHPFRC materials
3. What is proposed ?
4. Existing knowledge/experiences
5. Recent advances in Slovenia
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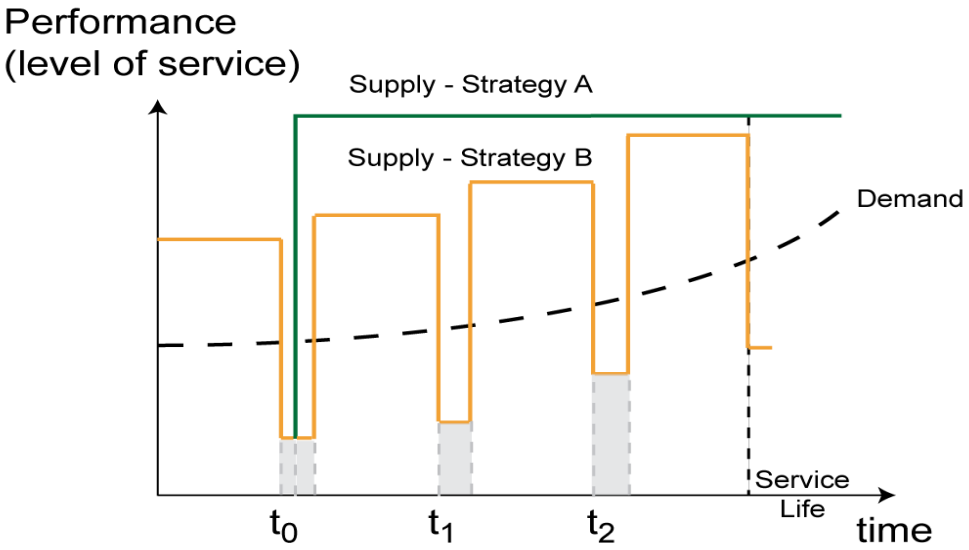
1. Motivation

➔ 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

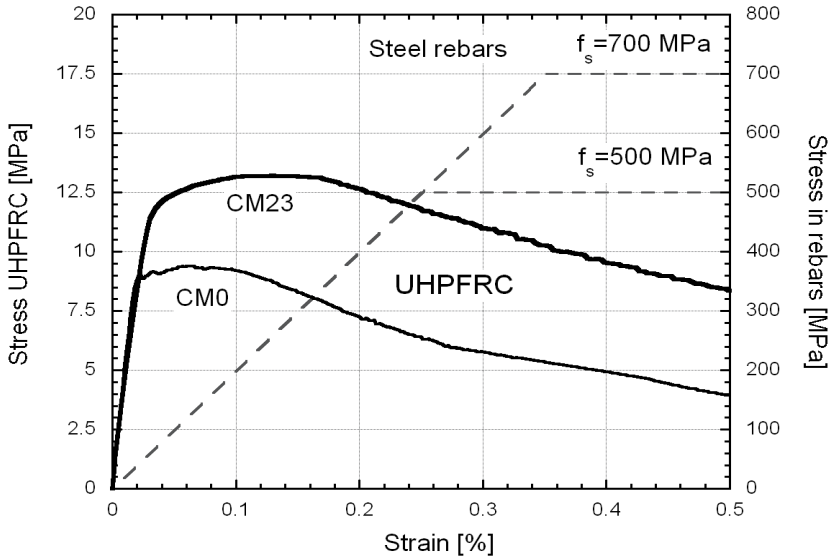
➔ Make best use of most advanced materials

➔ 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"



"Ductile as steel"

CEMTEC$_{multiscale}$® developed by Rossi et al. (2002)

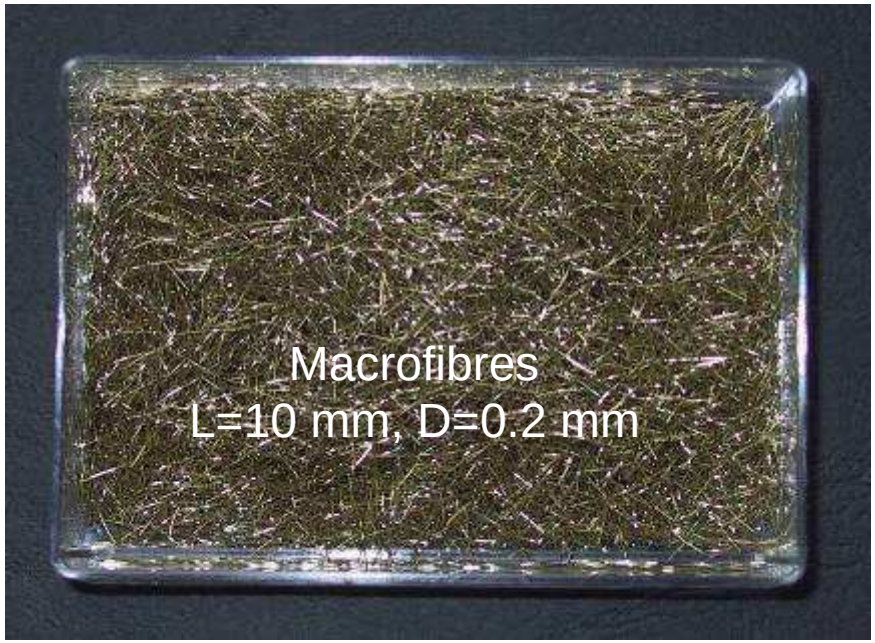
UHPFRC composition

- 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/m^3

UHPFRC composition

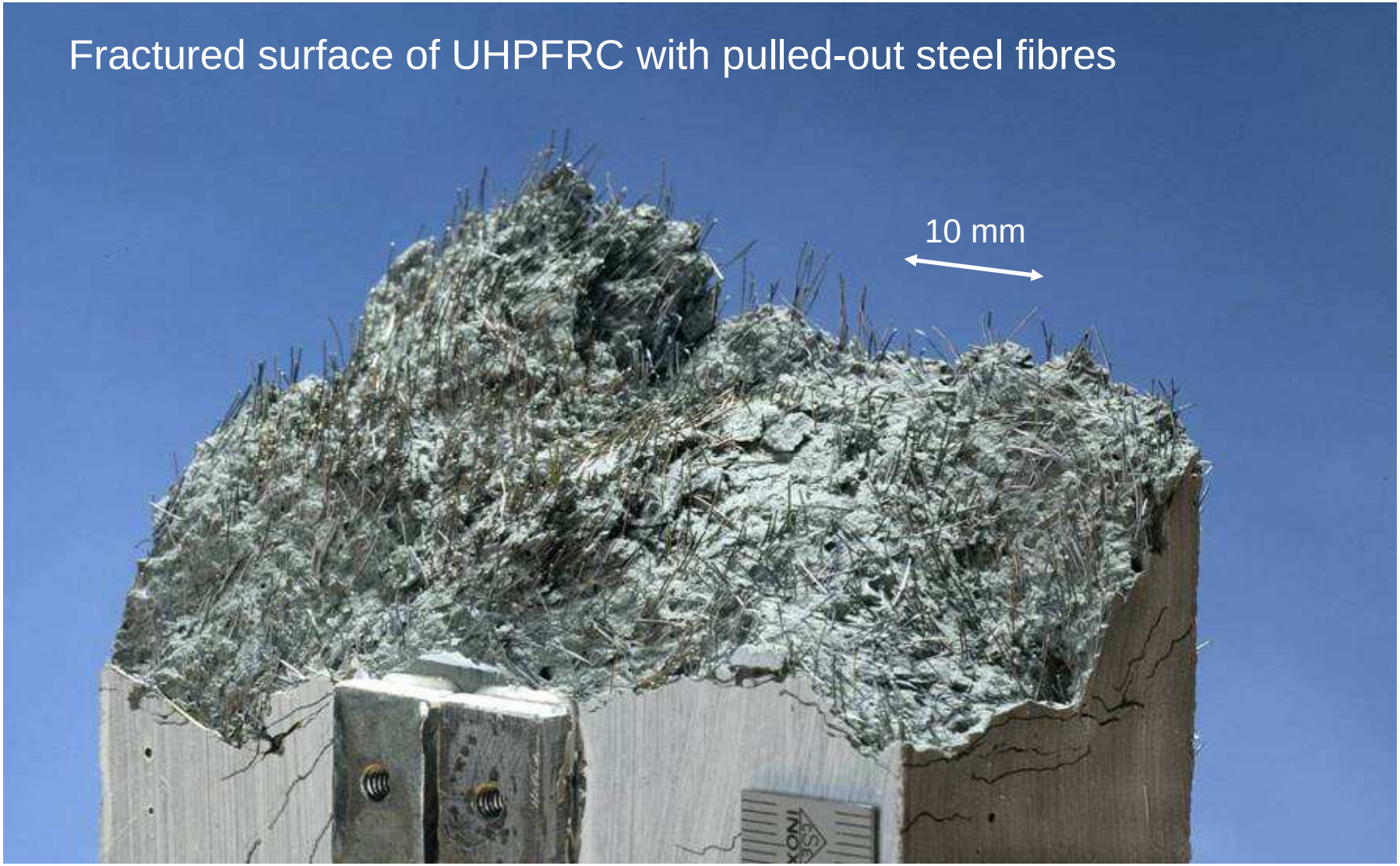
- Fibrous reinforcement



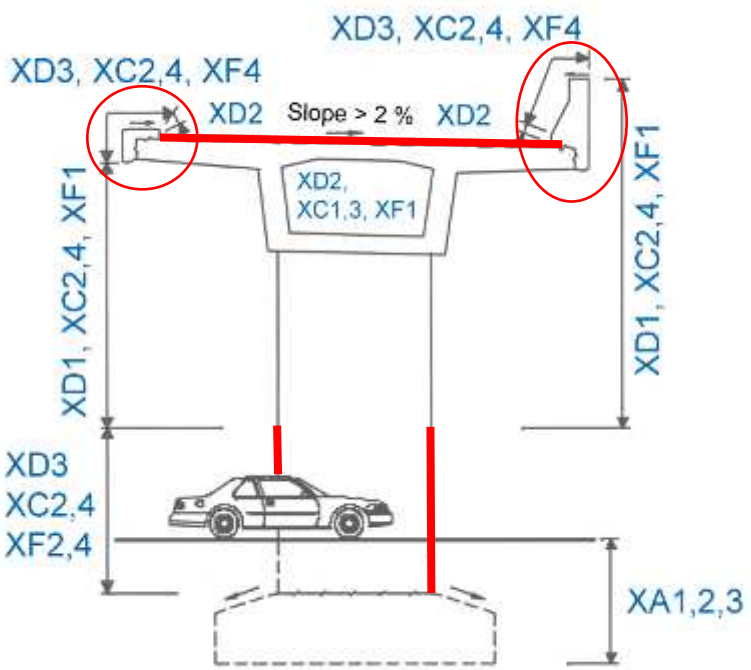
- Steel wool + 10 mm/0.2 mm straight fibres
- Total dosage 468 - 706 kg/m^3 (6 to 9 % Vol.)

CEMTEC$_{multiscale}$® developed by Rossi et al. (2002)

Fractured surface of UHPFRC with pulled-out steel fibres

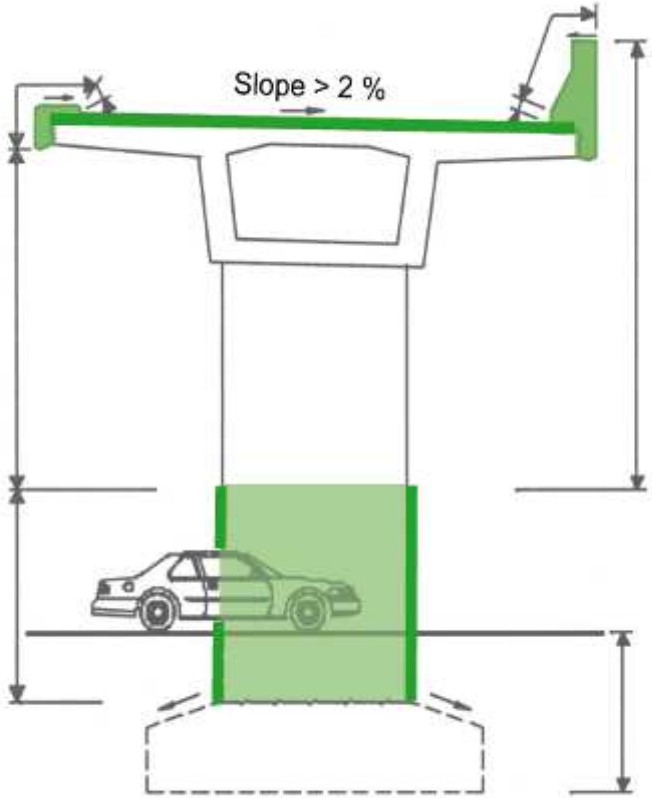


3. What is proposed ?



Brühwiler
1999

UHPFRC



➔Liquid water + Cl^- = XD2, XD3

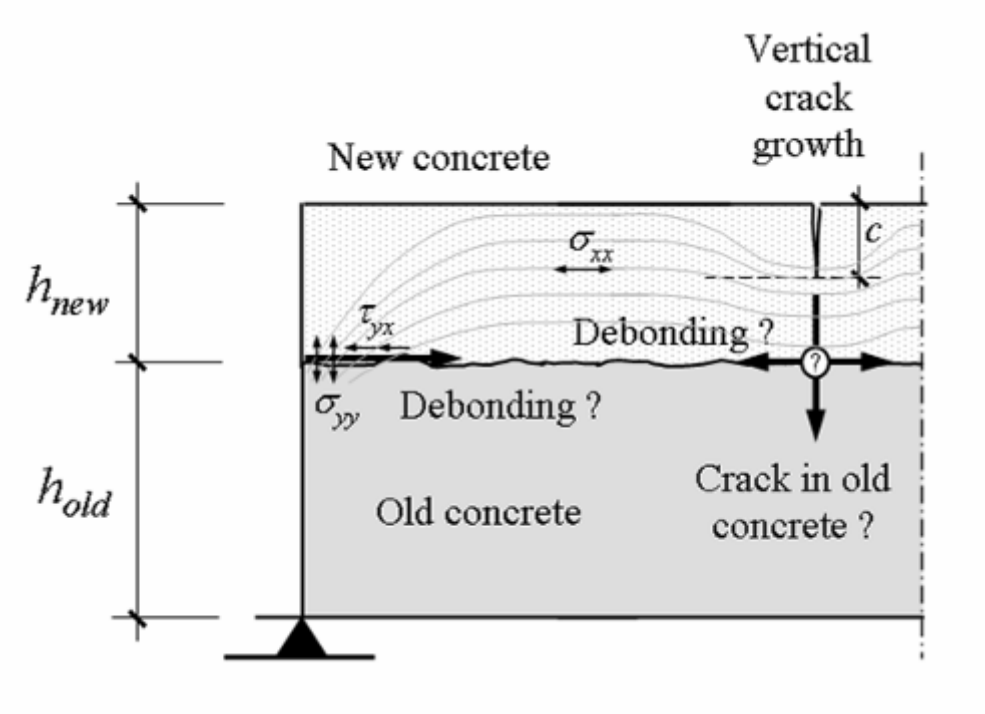
➔Most aggressive for structures !

➔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

Validation /application

- Numerous laboratory tests on UHPFRC materials and composite members, since 1999 at MCS/EPFL – EU Project SAMARIS.

- 6 successful full-scale applications realised in Switzerland (2004, 2006, 2007, 2008) on road bridges and industrial buildings

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

Denarié - 2007

A: pure CEM I 52.5 cement (Salonit)

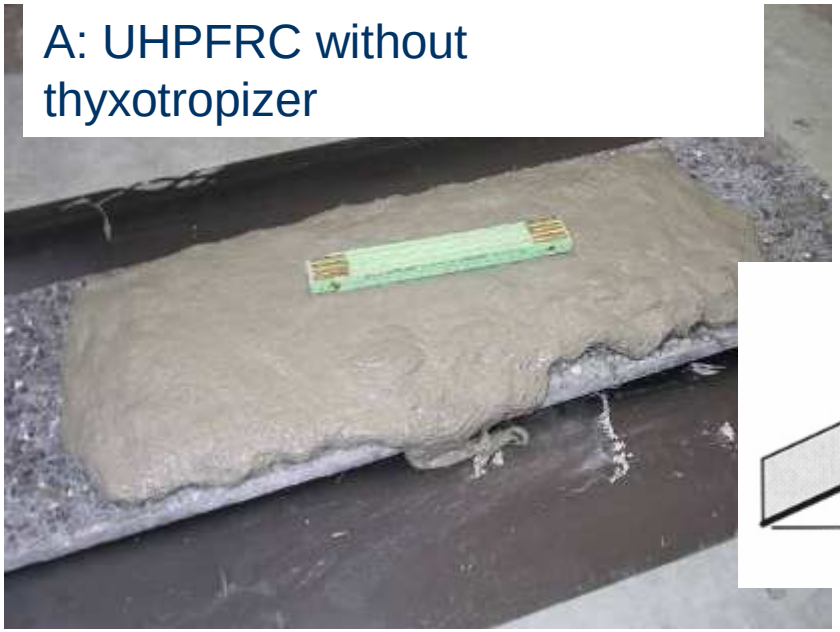
B: CEM I 52.5 cement (Salonit) blended with mineral addition

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

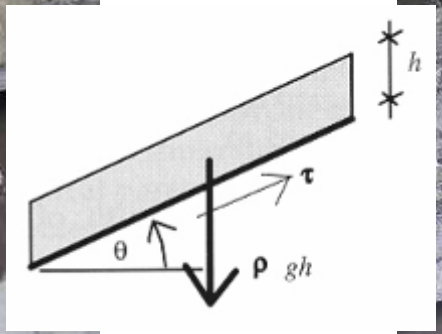
➔ Case A: impossible to achieve sufficient workability when fibres are added

➔ Case B: excellent workability, comparable to reference UHPFRC mixes with reference cement – perfectly adapted for addition of fibres at high dosages

Improved slope tolerance



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

LCPC Laboratoire Central des Ponts et Chaussées

EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

SALONIT ANHOVO gradbeni materiali, d.d.

ZAG Zavod za gradbeništvo Slovenije

Validation - Protective functions

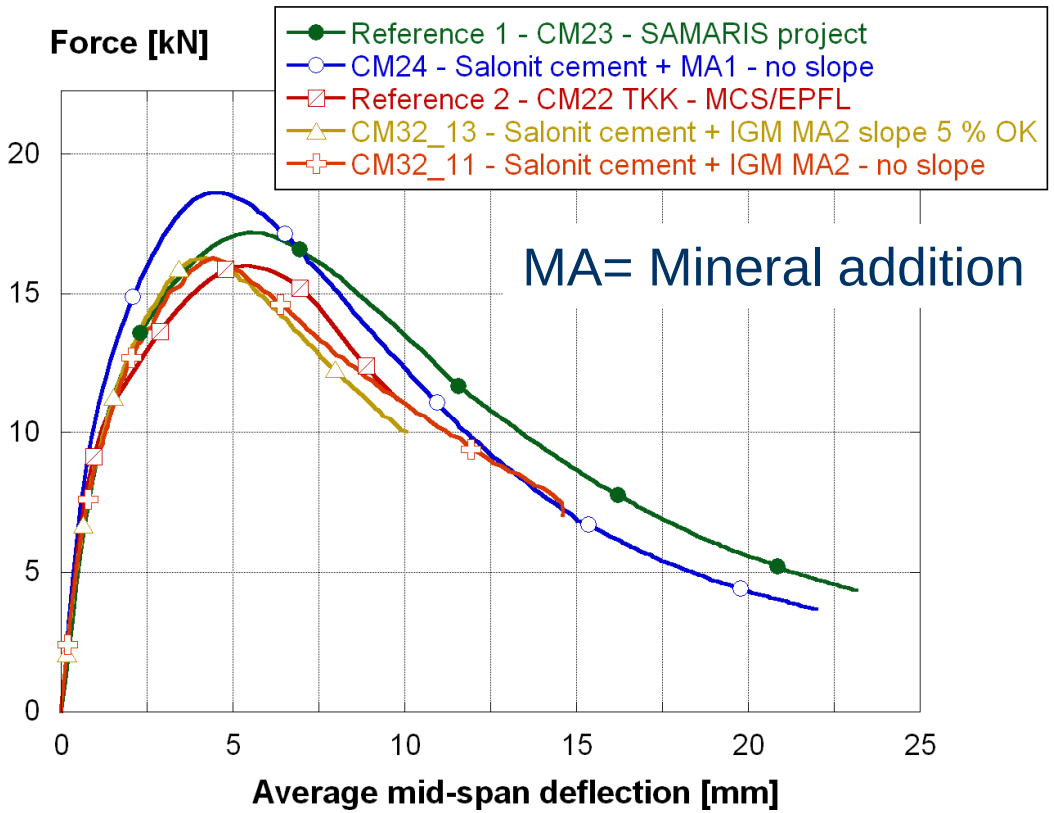
UHPFRC

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

Air permeability testing

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

Validation - Mechanical performance



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

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

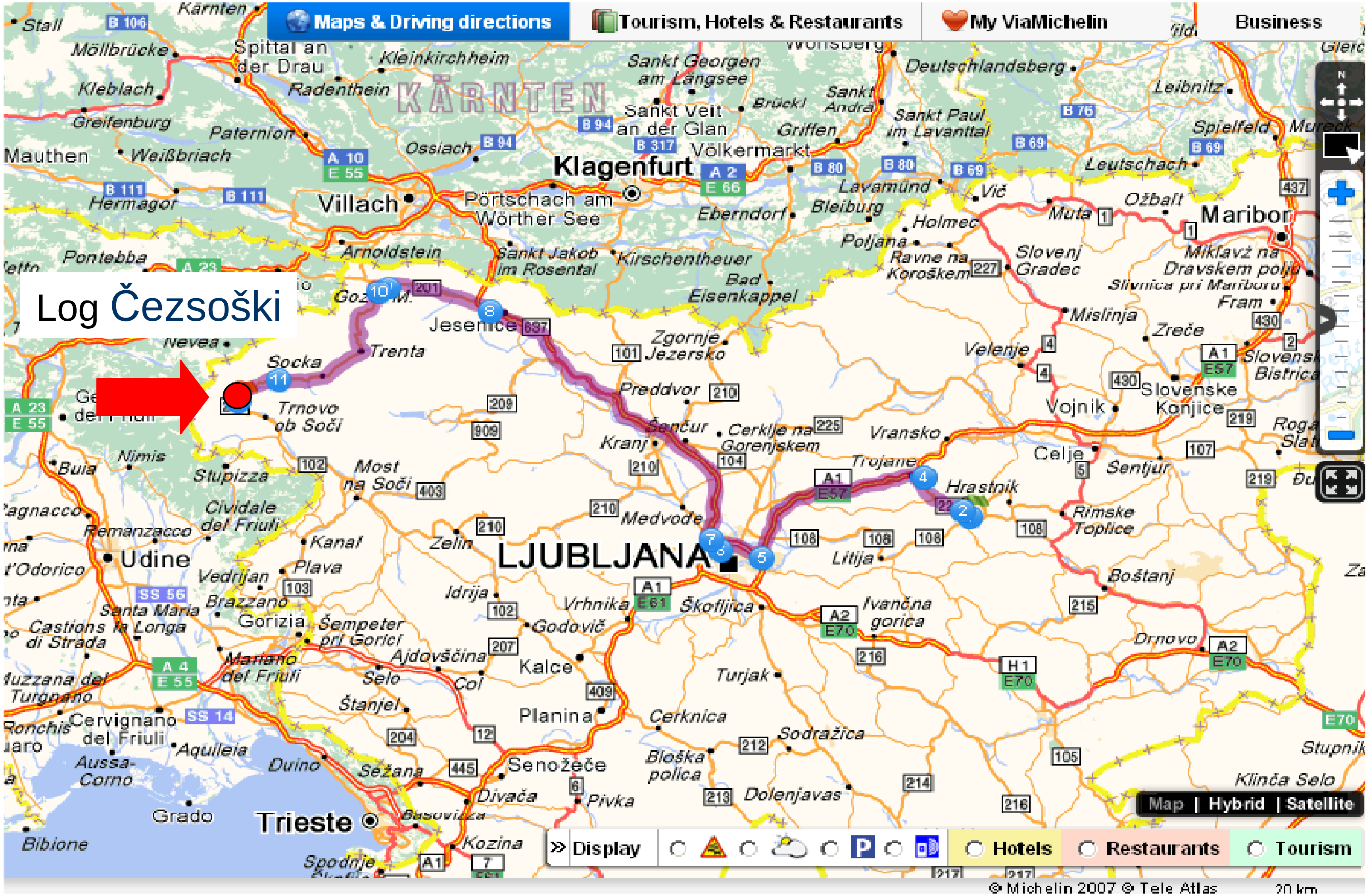
Full scale application – SLOVENIA

Owner: Municipality of Bovec

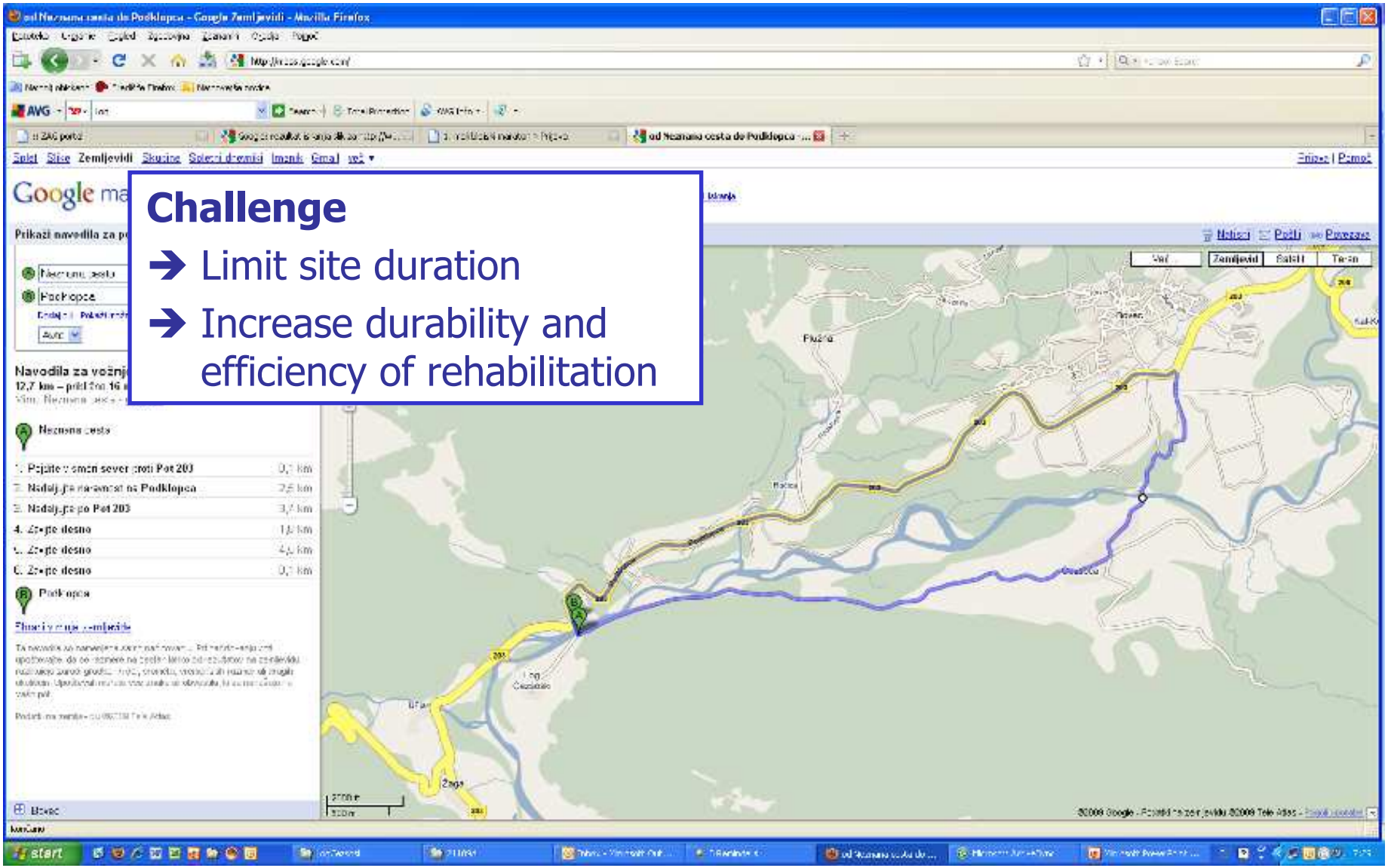
Log Čezsoški bridge – Soča river, July 2009

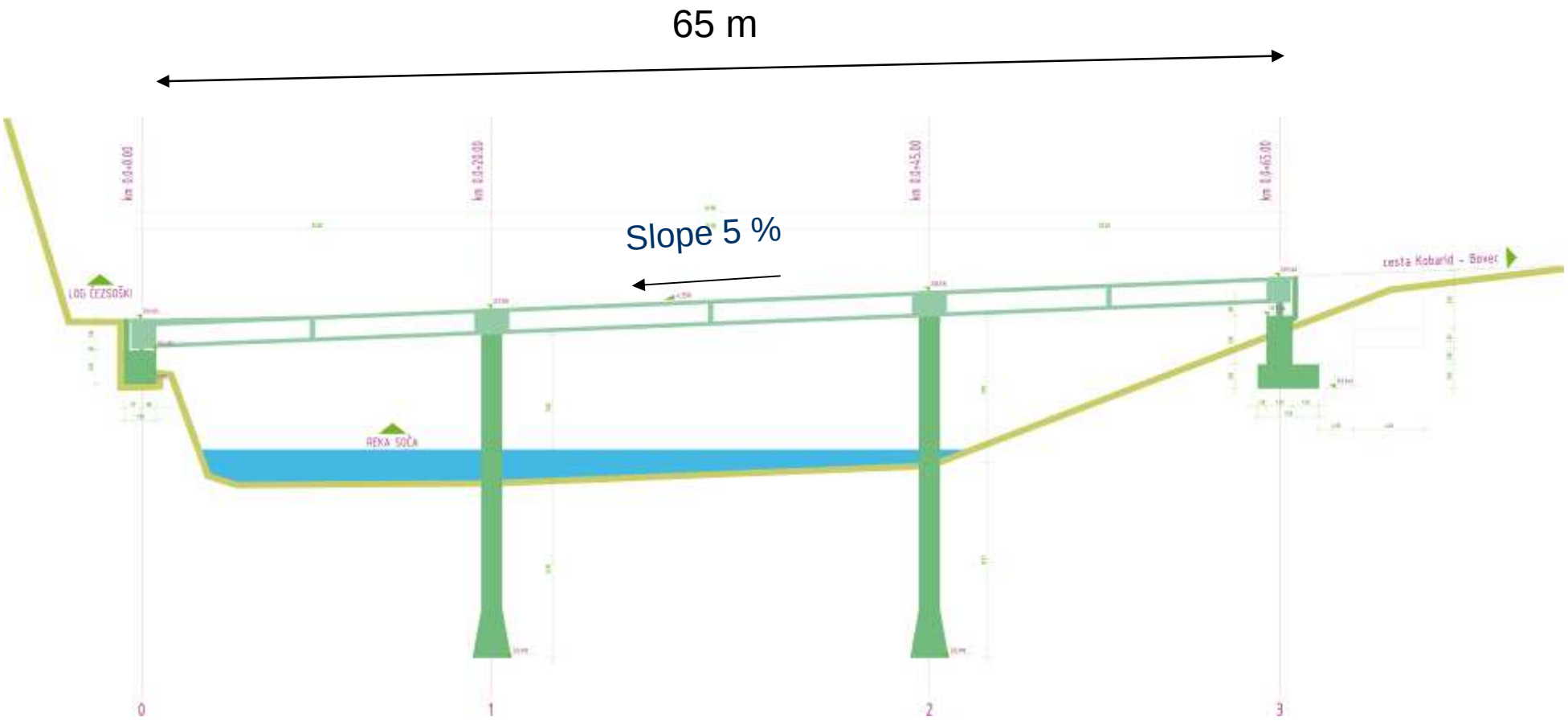
- rehabilitation of the sidewalk, and deck with UHPFRC, replacement of dilation

Log Čezsoški



12,7 km detour



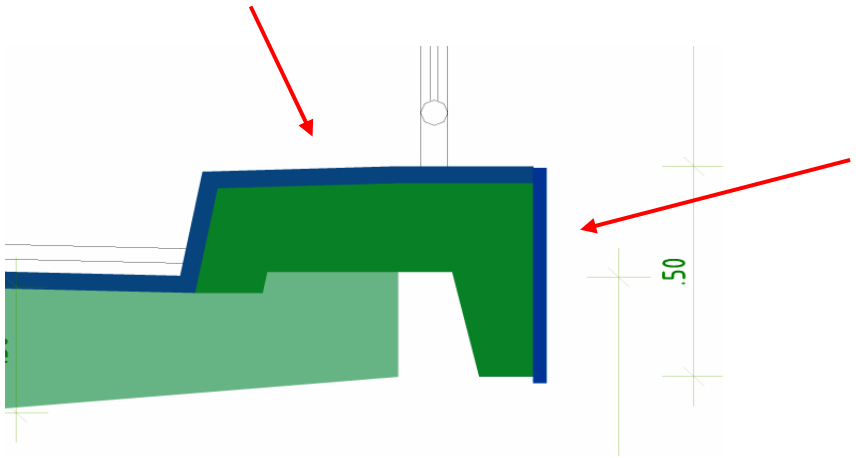


- 12 m^3 UHPFRC applied in 2.5 to 3 cm layers.
- Execution in 2 days with a transversal joint at mid-deck surface

➔ 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

	Tradition rehabilitation	vs.	UHPFRC rehabilitation
Site duration	3 months	>	1 month
Costs	for 12 MM	>>	for 12 m^3 UHPFRC
Durability and efficiency of rehabilitation	App. 30 years	<<	more than double
CO_2 balance	Next presentation		

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 [illegible] and rebars.
- Simplification of the construction
- Increase of the efficiency [illegible] new structures (protection and reinfo[illegible]
- Concept succes[illegible] technically and economica[illegible] applications in Switzerland and m[illegible] Slovenia
- Seve[illegible] planned in different countries.

Why not you ?

7. Links and documents

➔ EU 5th FP SAMARIS/WP 14, deliverables D22 and D25 - *http://samaris.zag.si*

➔EU 6th FP ARCHES/WP 5, deliverables D06 and D14 - *http://arches.fehrl.org*

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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 !