COST Action TU1207

Next Generation Design Guidelines for Composites in Construction

GENERAL MEETING

Textile Reinforced Mortars

Industry Seminar

Management Committee Meeting

ESR meeting

4-6 April 2016

Practical Information Guide

Technical Programme

4-6 April 2016

Łódź, Poland
Local Organising Committee
Renata Kotynia (Chair)
PhD Eng., Associate Professor
Vice-Dean for Innovations and Cooperation with Industry
renata.kotynia@p.lodz.pl
lodz.tu1207@gmail.com

Kinga Adamczewska
Beata Matuszyńska
Monika Kaszubska
Damian Szczech
Karolina Zwierzchowska
Tomasz Waśniewski
Piotr Szymczak

Student scientific circles: 'PKS', 'Momencik', 'ŻURAW', 'KMK PZITB'
Student Faculty Council

Honorary Patronage

Partners
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**About COST**

Founded in 1971, COST – European Cooperation in Science and Technology – is the first and widest European framework for the transnational coordination of nationally funded research activities. It is based on an inter-governmental agreement between 35 European countries.

COST enables break-through scientific developments leading to new concepts and products and thereby contributes to strengthen Europe’s research and innovation capacities. It is a unique means for European researchers to jointly develop their own ideas and new initiatives across all scientific disciplines through trans-European networking of nationally funded research activities.

COST key features are:
- building capacity by connecting high-quality scientific communities throughout Europe and worldwide;
- providing networking opportunities for early career investigators
- increasing the impact of research on policy makers, regulatory bodies and national decision makers as well as the private sector.

Through its inclusiveness, COST supports integration of research communities, leverages national research investments and addresses issues of global relevance.

As a precursor of advanced multidisciplinary research, COST plays a very important role in building a European Research Area (ERA). It anticipates and complements the activities of the EU Framework Programmes, constituting a “bridge” towards the scientific communities of emerging countries. It also increases the mobility of researchers across Europe and fosters the establishment of scientific excellence in the nine key domains:
- Biomedicine and Molecular Biosciences
- Food and Agriculture
- Forests, their Products and Services
- Materials, Physics and Nanosciences
- Chemistry and Molecular Sciences and Technologies
- Earth System Science and Environmental Management
- Information and Communication Technologies
- Transport and Urban Development
- Individuals, Societies, Cultures and Health

In addition, Trans-Domain Proposals allow for broad, multidisciplinary proposals to strike across the nine scientific domains.

COST is funded through the EU RTD Framework Programmes.

**About Transport and Urban Development (TUD)**

TUD fosters research coordination in the fields of transport and the built environment, which play a strategic role in the modern society and economy.

The Domain is by definition cross-sectoral and multidisciplinary, encompassing a wide range of scientific expertise within the transport and land use planning, design, and management activities with a special emphasis on the strong interrelationships among the relevant policy fields as well on all aspects related to sustainable development.

The domain activities should be innovative and complementary to other European programmes in the relevant fields. The aim is to cover both basic and applied research activities including technical and technological developments and their changeovers that are relevant to policy and decision making processes.

A significant concern is devoted to activities exploring new research needs and developments.
About COST Action TU 1207

Construction is rapidly becoming the leading outlet for FRP composites. Although the use of composite materials in construction started in the 1980s, civil engineers only recently started gaining confidence in this technology for use in primary structural applications. Despite the considerable technological developments in this field, there are still key scientific and logistical issues that need to be addressed for the widespread acceptance in construction. For example, existing design recommendations are largely based on work carried out more than fifteen years ago on first generation reinforcing products and their conservativeness is hindering the development of innovative and more efficient products and design solutions.

This Action aims to:

• coordinate European research in the field
• develop and maintain a critical mass of researchers
• offer a link between academia and industry
• develop a new generation of design guidelines based on European Standards

This will facilitate the adoption of European products not only in Europe but also internationally and help Europe stay one step ahead of International competitors.

General information
Start of Action: 12/04/2013
End of Action: 11/04/2017

Chair of the Action: Dr Maurizio GUADAGNINI (UK)
Vice Chair of the Action: Prof Stijn MATTHYS (BE)

Scientific Officer: Dr Mickael PERO
Administrative Officer: Ms Carmencita MALIMBAN

Domain website: http://www.cost.eu/tud
Action website: http://www.tu1207.eu
### Action TU1207 Working Groups

<table>
<thead>
<tr>
<th>WG1 Material Development and Characterisation</th>
<th>WG2 New Reinforced Concrete (RC) Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chair: Renata KOTYNIA (PL)</td>
<td>Chair: Lluis TORRES (ES)</td>
</tr>
<tr>
<td>Co-Chair: Adorjan BOROSNYOI (HU)</td>
<td>Co-Chair: Kypros PILAKOUTAS (UK)</td>
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</tbody>
</table>

- Assessing the different tests so as to select candidates for standardisation
- Bond behaviour of FRPs to concrete, steel, timber and masonry
- Behaviour of FRPs at elevated temperatures
- Accelerated tests and development of models to assess durability of FRPs in typical environments, including embedment in cement mortars and concrete
- Behaviour of confined concrete using different types of fibres and bonding systems
- Behaviour of strengthened reinforced concrete, masonry, steel and timber elements, in flexure, shear and punching shear
- Models and techniques for the prestressing of strengthening systems to enhance the utilisation of composites at service conditions
- Novel seismic strengthening and rehabilitation solutions and development of design models to avoid shear, anchorage, splice and buckling failures
- Serviceability requirements
- New products and prefabricated solutions
- Long-term behaviour
- Behaviour of FRP RC elements exposed to fire or elevated temperatures
- Whole-life cost assessment of new FRP reinforced concrete structures
- Whole-life cost assessment of rehabilitated structures
- Recycling and reuse of composite materials
- Innovative structural solutions using existing and future materials

<table>
<thead>
<tr>
<th>WG3 Strengthening Applications</th>
<th>WG4 Whole-life-costing and life cycle assessments</th>
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<tbody>
<tr>
<td>Chair: Thanasis TRIANTAFILOU (EL)</td>
<td>Chair: Matthias PAHN (DE)</td>
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<tr>
<td>Co-Chair: Francesca CERONI (IT)</td>
<td>Co-Chair: Jose SENA CRUZ (PT)</td>
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<th>WG5 Knowledge Transfer</th>
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<tr>
<td>Chair: Joaquim BARROS (PT)</td>
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<td>Co-Chair: Christoph CZADERSKI (CH)</td>
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</table>

WG5 will coordinate and promote inter-sectorial collaboration and outreach activities, including the maintenance and management of the Action website, organisation of industry seminars, training schools, Short-Term Scientific Mission (STSMs), maintenance of online databases, preparation and dissemination of reports and publications.
### Programme at a glance

#### Monday 4 April

**Venue:** Sala Widowiskowa and Sala Konferencyjna - Lodz University of Technology (TUL)

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>09:00 – 09:30</td>
<td>Arrival and Registration</td>
</tr>
<tr>
<td>09:30 – 10:00</td>
<td><strong>Opening</strong>&lt;br&gt;Session chairs: Maurizio Guadagnini, Renata Kotinia&lt;br&gt;Welcome: Renata Kotinia, Authorities of Lodz, Rector of TUL, Dean of Faculty&lt;br&gt;Introduction of activities: Maurizio Guadagnini</td>
</tr>
<tr>
<td>10:00 – 11:10</td>
<td><strong>FRCM Composites in Constructions</strong> (joint session TU1207/RILEM TC250-CSM)&lt;br&gt;Session chairs: Gianmarco De Felice, Maurizio Guadagnini</td>
</tr>
<tr>
<td>11:10 – 11:30</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>11:30 – 13:00</td>
<td><strong>FRCM Composites in Constructions</strong> (joint session TU1207/RILEM TC250-CSM)&lt;br&gt;Session chairs: Gianmarco De Felice, Maurizio Guadagnini</td>
</tr>
<tr>
<td>13:00 – 14:30</td>
<td>Lunch</td>
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<tr>
<td>14:30 – 16:30</td>
<td><strong>Externally Bonded Reinforcement / Innovative Solutions</strong>&lt;br&gt;Session chairs: Theodoros Rousakis and Sousana Tastani&lt;br&gt;Round Robin Test on tensile and bond behaviour of FRCM reinforcements&lt;br&gt;Session chair: Carlo Poggi</td>
</tr>
<tr>
<td>16:30 – 17:00</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>17:00 – 18:00</td>
<td><strong>COST Action TU1207 MC Meeting</strong>&lt;br&gt;Chair: Maurizio Guadagnini&lt;br&gt;Round Robin Test on tensile and bond behaviour of FRCM reinforcements&lt;br&gt;Session chair: Gianmarco de Felice</td>
</tr>
<tr>
<td>18:00</td>
<td>Closure of Day 1</td>
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</table>

19:30 | Visit tour and COST TU1207 Dinner at the Central Museum of Textiles, The White Factory<br><br>**Location:** Piotrrewska Street 282, Łódź (see further details on page 16)

#### Tuesday 5 April 2016

**Venue:** Sala Widowiskowa and Sala Konferencyjna - Lodz University of Technology (TUL)

<table>
<thead>
<tr>
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<td>09:10 – 11:00</td>
<td><strong>Textile Reinforced Mortars/ Innovative Solutions</strong>&lt;br&gt;Session chairs: Francesca Roscini and Stefano De Santis</td>
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<tr>
<td>11:00 – 11:30</td>
<td>Coffee Break / Arrival and Registration for Industry Seminar</td>
</tr>
<tr>
<td>11:30 – 13:00</td>
<td><strong>Industry Seminar (Session I)</strong>&lt;br&gt;Session chairs: Renata Kotynia and Stijn Matthys</td>
</tr>
</tbody>
</table>
**Tuesday 5 April 2016**

**Venue:** Sala Widowiskowa and Sala Konferencyjna - Lodz University of Technology (TUL)

<table>
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<tr>
<th>Time</th>
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<tr>
<td>13:00 – 14:30</td>
<td>Lunch and poster presentation/competition</td>
</tr>
<tr>
<td>14:30 – 16:00</td>
<td><strong>Industry Seminar (Session II)</strong>&lt;br&gt;Session chairs: Martin Hüppi and Maurizio Guadagnini</td>
</tr>
<tr>
<td>16:00 – 16:30</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>16:30 – 18:00</td>
<td><strong>Seismic Strengthening / Strengthening of Steel Structures</strong>&lt;br&gt;Session chairs: David Escolano and Reyes Garcia&lt;br&gt;<strong>Internal FRP Reinforcement and Hybrid Solutions</strong>&lt;br&gt;Session chairs: Ana Veljkovic and Matteo Di Benedetti</td>
</tr>
<tr>
<td>18:00 – 18:30</td>
<td>Closure of Day 2</td>
</tr>
<tr>
<td>20:30</td>
<td>Visit tour and COST TU1207 Dinner at the Museum of the City of Lodz, Poznanski Palace</td>
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</table>

**Address:** Ogrodowa Street 15, Łódź (transport will be arranged - see further details on page 16)

**Wednesday 6 April 2016**

**Venue:** Auditorium B10 and B12 - Lodz University of Technology (TUL), Faculty of Civil Engineering, Architecture and Environmental Engineering

<table>
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<td>Opening</td>
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<tr>
<td>09:10 – 11:00</td>
<td><strong>ESR Meeting</strong>&lt;br&gt;<strong>TU1207 Core Group Meeting</strong></td>
</tr>
<tr>
<td>11:00 – 11:20</td>
<td>Coffee Break</td>
</tr>
<tr>
<td>11:20 – 13:00</td>
<td><strong>ESR Meeting</strong></td>
</tr>
<tr>
<td>13:00 – 15:00</td>
<td>Lunch and laboratory visit</td>
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</table>
## Detailed Programme of Activities

### Monday 4 April

**Joint Workshop COST Action - RILEM TC 250-CSM**

**Reinforcement of Structures with Fabric Reinforced Cementitious Composites**

**Venue:** Sala Widowiskowa - Lodz University of Technology (TUL)

<table>
<thead>
<tr>
<th>Time</th>
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</table>
| 10:00 – 11:10 | **FRCM Composites in Constructions** (joint session TU1207/RILEM TC250-CSM)  
Session chairs: Gianmarco De Felice, Maurizio Guadagnini |
| 10:00 – 10:10 | Workshop Introduction & the Round Robin Tests on FRCM  
Gianmarco De Felice, Università Degli Studi Roma Tre, Italy |
| 10:10 – 10:30 | Textile Reinforced Mortar vs. Fibre Reinforced Polymers  
Thanasis Triantafillou, University of Patras, Greece |
| 10:30 – 10:50 | Use of FRCM/TRM in Italy: Qualification and Acceptance criteria  
Luigi Ascione, Università degli Studi di Salerno, Italy |
| 10:50 – 11:10 | Mechanical characterization of the tensile properties of FRCM composites  
Carlo Poggi, Politecnico di Milano, Italy |
| 11:10 – 11:30 | Coffee Break |
| 11:30 – 13:00 | **FRCM Composites in Constructions** (joint session TU1207/RILEM TC250-CSM)  
Session chairs: Gianmarco De Felice, Maurizio Guadagnini |
| 11:30 – 11:50 | FRCM-quasi brittle material bond behavior: numerical modeling; rate effect, and open issues  
Christian Carloni, University of Bologna, Italy |
| 11:50 – 12:10 | Strengthening of masonry with Textile Reinforced Mortars  
Corina Papanicolaou, University of Patras, Greece |
| 12:10 – 12:30 | Strengthening of masonry vaults with FRCM: experimental studies and applications  
Maria Rosa Valluzzi, The University of Padova, Italy |
| 12:30 – 12:50 | Remarks on potential and design criteria for FRCM seismic strengthening of masonry  
Andrea Prota, University of Naples Federico II, Italy |
| 12:50 – 13:00 | Closure |

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## Technical Sessions

**Venue:** Sala Widowiskowa - Lodz University of Technology (TUL)

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<thead>
<tr>
<th>Time</th>
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</table>
| 14:30 – 16:30 | **Externally Bonded Reinforcement / Innovative Solutions**  
Session chairs: Theodoros Rousakis and Sousana Tastani |
| 14:30 – 14:45 | The Behavior of CFRPs externally bonded to concrete under cyclic loading  
Thorsten Leusmann |
| 14:45 – 15:00 | Durability of RC slabs strengthened in flexure with prestressed CFRP strips  
José Sena-Cruz, Luís Correia, Gonçalo Escusa, Julien Michels, Paulo França, Eduardo Pereira |
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<td><strong>Externally Bonded Reinforcement / Innovative Solutions</strong>&lt;br&gt;<strong>Session chairs: Theodoros Rousakis and Sousana Tastani</strong></td>
</tr>
<tr>
<td>15:00 – 15:15</td>
<td><strong>Fatigue Behavior and Design of Reinforced Concrete Beams Strengthened in Flexure with FRP</strong>&lt;br&gt;<strong>Barbara Charalambidi, Theodoros Rousakis, Athanasios Karabinis</strong></td>
</tr>
<tr>
<td>15:15 – 15:30</td>
<td><strong>Numerical simulations and parametric studies of RC beams strengthened with prestressed CFRP laminates</strong>&lt;br&gt;<strong>Renata Kotynia, Szymon Seręga, Krzysztof Lasek</strong></td>
</tr>
<tr>
<td>15:30 – 15:45</td>
<td><strong>Innovative method for strengthening concrete beams using pre-stressed FRP laminates and some field applications</strong>&lt;br&gt;<strong>Robert Kliger, Reza Haghani and Mohammad Al-Emrani</strong></td>
</tr>
<tr>
<td>15:45 – 16:00</td>
<td><strong>CFRP rock anchors</strong>&lt;br&gt;<strong>Haifeng Fan, Thomas Keller, Anastasios P. Vassilopoulos</strong></td>
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<tr>
<td>16:00 – 16:15</td>
<td><strong>Hoop/Radial Fracture Energies and Cohesive Meso-scale Modelling of GFRP Pipes Failure Through Iterative Numerical/Experimental Procedure</strong>&lt;br&gt;<strong>Hugo Faria</strong></td>
</tr>
<tr>
<td>16:15 – 16:30</td>
<td><strong>The effect of hybrid mass reinforcement (carbon nanotubes and polypropylene fibers) on strain resilient cementitious composites -to- steel bar bond mechanism</strong>&lt;br&gt;<strong>S.P. Tastani, M.S. Konsta-Gdoutos, S.J. Pantazopoulou</strong></td>
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<td>14:30 – 16:30</td>
<td><strong>Round Robin Test on tensile and bond behaviour of FRCM reinforcements</strong>&lt;br&gt;<strong>Session chair: Carlo Poggi</strong></td>
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<td></td>
<td><strong>FRCM with basalt textiles</strong>&lt;br&gt;<strong>Gian Piero Lignola, University of Naples, Italy</strong></td>
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<td><strong>FRCM with steel textiles</strong>&lt;br&gt;<strong>Stefano De Santis, Roma Tre University, Italy</strong></td>
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<td><strong>FRCM with glass textiles</strong>&lt;br&gt;<strong>Marianovella Leone, University of Salento, Italy</strong></td>
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<td><strong>FRCM with PBO and aramid textiles</strong>&lt;br&gt;<strong>Carmelo Caggegi, University of Lyon, France</strong></td>
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<td><strong>Round Robin Test on tensile and bond behaviour of FRCM reinforcements</strong>&lt;br&gt;<strong>Session chair: Gianmarco de Felice</strong></td>
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<td></td>
<td><strong>FRCM with carbon textiles</strong>&lt;br&gt;<strong>Tommaso D'Antino, Politecnico of Milan, Italy</strong></td>
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<td></td>
<td><strong>FRCM: discussion on the experimental results of the Round Robin Test</strong></td>
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</table>
## Tuesday 5 April 2016

### Technical Sessions

**Venue:** Sala Widowiskowa - Lodz University of Technology (TUL)

<table>
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<tr>
<th>Time</th>
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<td><strong>Textile Reinforced Mortars / Innovative Solutions</strong></td>
<td>Session chairs: Francesca Roscini and Stefano De Santis</td>
</tr>
<tr>
<td>09:10 – 09:25</td>
<td>Flexural behavior of R/C Beams Strengthened with Steel-Reinforced Inorganic Polymers under Fatigue Loadings</td>
<td>Konstantinos Katakalos and Christos Papakonstantinou</td>
</tr>
<tr>
<td>09:25 – 09:40</td>
<td>Novel TRM Systems for Shear strengthening of full-scale T-beams</td>
<td>Zoi Tetta, Lampros Koutas, Dionysios Bournas</td>
</tr>
<tr>
<td>09:40 – 09:55</td>
<td>Flexural Strengthening of Two-Way RC Slabs with Externally Bonded TRM layers</td>
<td>Lampros Koutas and Dionysios Bournas</td>
</tr>
<tr>
<td>09:55 – 10:10</td>
<td>SINTEF: How to contribute to the development of textiles for mortar reinforcements?</td>
<td>Alexandre Garcia, Nathalie Labonnote, Susie Jahren</td>
</tr>
<tr>
<td>10:10 – 10:25</td>
<td>Effect of epoxy resins cross-linking parameters on mechanical properties of adhesive joints</td>
<td>Renata Kotynia, Anna Strąkowska, Marcin Masłowski, Kinga Adamczewska</td>
</tr>
<tr>
<td>10:25 – 10:40</td>
<td>A Resonance based Fatigue Testing Facility for very high cycle fatigue</td>
<td>Steffen Marx</td>
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<tr>
<td>10:40 – 11:00</td>
<td>Discussion and Closure</td>
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### Industry Seminar

**Venue:** Sala Widowiskowa - Lodz University of Technology (TUL)

<table>
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>11:00 – 11:30</td>
<td>Coffee Break / Arrival and Registration for Industry Seminar</td>
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<tr>
<td>11:30 – 13:00</td>
<td><strong>Industry Seminar (Session I)</strong></td>
<td>Session chairs: Renata Kotynia and Stijn Matthys</td>
</tr>
<tr>
<td>11:30 – 11:40</td>
<td>Opening</td>
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<tr>
<td>11:40 – 12:00</td>
<td>Case studies about strengthening by using prestressed FRP and seismic reinforcement</td>
<td>Martin Hüppi (S&amp;P Clever Reinforcement Company AG), Marek Makarewicz (S&amp;P Polska Sp. z o.o.)</td>
</tr>
<tr>
<td>12:00 – 12:20</td>
<td>Carbon fibre cord as supplemental element of CFRP &lt;Sika CarboDur&gt; strengthening system</td>
<td>Thierry Berset (Sika Services AG - Building Systems &amp; Industry), Tomasz Gutowski (SIKA POLAND), Janusz Potrzebowski (SIKA POLAND)</td>
</tr>
<tr>
<td>12:20 – 12:40</td>
<td>FRP composites in bridge engineering in Poland: the subjective overview</td>
<td>Tomasz Siwowski (Promost Consulting, Rzeszow)</td>
</tr>
<tr>
<td>12:40 – 13:00</td>
<td>Industrial production and FRP material development of various innovative composite technologies</td>
<td>Żanna Sikorska-Pejsz, Przemysław Sikorski (MINBUD)</td>
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<tr>
<td>13:00 – 14:30</td>
<td>Lunch and poster presentation/competition</td>
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<tr>
<td>14:30 – 16:00</td>
<td><strong>Industry Seminar (Session II)</strong>&lt;br&gt;&lt;i&gt;Session chairs: Martin Hüppi and Maurizio Guadagnini&lt;/i&gt;</td>
<td></td>
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<tr>
<td>14:30 – 14:50</td>
<td>Innovative FRCM and SRG systems for the strengthening and rehabilitation of existing structures: research, development and application&lt;br&gt;&lt;i&gt;Giorgio Giacomin (G &amp; P Intech S.r.l.)&lt;/i&gt;</td>
<td></td>
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<tr>
<td>14:50 – 15:10</td>
<td>Ultra High Strength Steel and Basalt fibers with Natural Mortars matrices for strengthening reinforced concrete and masonry structures: from laboratory to field applications&lt;br&gt;&lt;i&gt;Paolo Casadei (KERAKOLL Spa)&lt;/i&gt;</td>
<td></td>
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<tr>
<td>15:10 – 15:30</td>
<td>First application of gradient anchorage for pretensioned CFRP laminates on the concrete bridge in Poland.&lt;br&gt;&lt;i&gt;Renata Kotynia (TUL), Julien Michels (Empa) , Michal Staskiewicz (TUL), Christoph Czaderski (Empa), Masoud Motavalli (Empa), Martin Hüppi (S&amp;P Clever Reinforcement Company AG), Marek Makarewicz (S&amp;P Polska Sp. z o.o.), Tomasz Bartosik (Euro-projekt)&lt;/i&gt;</td>
<td></td>
</tr>
<tr>
<td>15:30 – 15:50</td>
<td>Composites in Construction: A Vision for the Future&lt;br&gt;&lt;i&gt;Stijn Matthys (Ghent University)&lt;/i&gt;</td>
<td></td>
</tr>
<tr>
<td>15:50 – 16:00</td>
<td>Conclusion</td>
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</tbody>
</table>

### Technical Sessions

**Venue:** Sala Widowiskowa - Lodz University of Technology (TUL)

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>16:30 – 18:00</td>
<td>Seismic Strengthening / Strengthening of Steel Structures&lt;br&gt;&lt;i&gt;Session chairs: David Escolano and Reyes Garcia&lt;/i&gt;</td>
</tr>
<tr>
<td>16:30 – 16:45</td>
<td>Numerical and experimental investigation on seismically damaged RC wall panels retrofitted with Textile Reinforced Mortar&lt;br&gt;&lt;i&gt;V. Stoian, C. Todut, D. Dan&lt;/i&gt;</td>
</tr>
<tr>
<td>16:45 – 17:00</td>
<td>Seismic retrofitting of reinforced concrete structures using composites. Scientific and Technical Documents&lt;br&gt;&lt;i&gt;Emmanuel Ferrier, Marc Quiertant, Laurent Michel&lt;/i&gt;</td>
</tr>
<tr>
<td>17:00 – 17:15</td>
<td>Application of FRP materials for a renovation of steel railway bridges&lt;br&gt;&lt;i&gt;Pavel Ryjáček, Kamila Cábová, Ludvík Kolpaský, Jan Vůjtěch, Ondřej Hráský, Vít Lojda&lt;/i&gt;</td>
</tr>
<tr>
<td>17:15 – 17:30</td>
<td>Presentation of the FASST-Bridge project (Fast and effective - solution for steel bridges life-time extension) in the framework of INFRAVATION ERA-NET program&lt;br&gt;&lt;i&gt;S. Chataigner, M. Quiertant, K. Benzarti&lt;/i&gt;</td>
</tr>
<tr>
<td>17:30 – 17:45</td>
<td>Short- and long-term behaviour of bridge deck slabs strengthened in transverse direction with EB CFRP strips&lt;br&gt;&lt;i&gt;Juan Manuel Gallego, Christoph Czaderski and Julien Michels&lt;/i&gt;</td>
</tr>
<tr>
<td>17:45 – 18:00</td>
<td>Discussion and Closure</td>
</tr>
</tbody>
</table>

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10
**Venue:** Sala Konferencyjna - Lodz University of Technology (TUL)

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:30 – 18:00</td>
<td><strong>Internal FRP Reinforcement and Hybrid Solutions</strong></td>
<td><strong>Session chairs: Ana Veljkovic and Matteo Di Benedetti</strong></td>
</tr>
<tr>
<td>16:30 – 16:45</td>
<td>Long term performance of GFRP bars under the combined effects of sustained load and severe environments</td>
<td><strong>Hamed Fergani, Matteo Di Benedetti, Maurizio Guadagnini</strong></td>
</tr>
<tr>
<td>16:45 – 17:00</td>
<td>Crack width in GFRP RC beams: an experimental study</td>
<td><strong>Cristina Barris, Lluís Torres</strong></td>
</tr>
<tr>
<td>17:00 – 17:15</td>
<td>Finite element analysis of concrete beams strengthened with rods in basalt fiber</td>
<td><strong>Todor Zhelyazov, Eythor Rafn Thorhallsson, Jónas Thór Snæbjörnsson</strong></td>
</tr>
<tr>
<td>17:15 – 17:30</td>
<td>Experimental investigation of the thin sandwich wall system reinforced with GFRP rebars</td>
<td><strong>Marcin M. Haffke, Matthias Pahn</strong></td>
</tr>
<tr>
<td>17:30 – 17:45</td>
<td>Response To Thermo-Mechanical Loading of GFRP Reinforced Concrete Sandwich Panels</td>
<td><strong>Andreas Schmitt, Marcin Haffke, Valter Carvelli, Matthias Pahn</strong></td>
</tr>
<tr>
<td>17:45 – 18:00</td>
<td>Vegetable fibres reinforced polymer: testing in progress</td>
<td><strong>Francesca Giglio, Giulia Savoja</strong></td>
</tr>
</tbody>
</table>
About Łódź

Łódź is Poland’s third biggest city, and the capital of the Łódzkie Voivodship. Unlike most other large Polish cities, which boast impressive long histories, Łódź was created almost from scratch during the 19th century textile industry boom to house textile mills, their owners and their workers, and rapidly grew to become an important industrial and commerce centre. In recent years, Łódź has been battling rising unemployment and youth migration resulting from the failing textile industry and is repositioning itself as a hub for design and creative industries.

Owing to its history, Łódź boasts an impressive collection of residential, commercial and industrial 19th-century architecture including some of Europe's largest factory buildings, now mostly repurposed as shopping centres or lofts. Recent local investment and a long-standing cultural scene ensures there is always something more to do than just sightseeing or shopping, with the city hosting some of the best museums and art galleries in the country. The close proximity of Warsaw and Łódź’s location at the crossroads of the Polish motorway system make it an ideal destination for a day trip or longer city break.

For more information:
http://www.bais.p.lodz.pl/TU1207Meeting/
https://en.wikivoyage.org/wiki/%C5%81%C3%B3d%C5%BA
http://en.turystyczna.lodz.pl/page/
http://www.inyourpocket.com/lodz
http://www.arrivalguides.com/en/Travelguides/Europe/Poland/Lodz

About Lodz University Of Technology (TUL) – Politechnika Łódzka


How to get to Łódź

By air:
• From Łódz Airport

The airport is located on the south-west part of Lodz, only 6 km from meeting venue.

Connections between airport and meeting venue:
Bus no. 55: Journey from Lotnisko Terminal Pasażerski to Piotrkowska street; frequency 20-30min (timetables, tickets info); approximate journey time 23min.
Taxi: taxi fare from the airport to city center is 25zł/6€; estimated journey 17min.

• From Warsaw (Warszawa) Chopin Airport

The airport is located in capital city of Poland, 140km from Lodz.

Connections between airport and Lodz:
Train: From the airport to Warszawa Zachodnia train station and change for train to Łódź Kaliska (frequency less than 1h; timetables and search for connections); approximate journey time 2-3h.
Modlinbus: Bus destination: Łódź Kaliska; frequency 3-4h (timetables and info); approximate journey time 2h10min.
Taxi: taxi fare for Taxismart is 390zł/90€ and 780zł/180€ for minivan; estimated journey 1h45min.

• From Warsaw Modlin Airport

The airport is located on the north-west from Warsaw, 145km from Lodz.

Connections between airport and Lodz:
Modlinbus: bus destination: Łódź Kaliska; frequency 3-4h (timetables and info); approximate journey time 3h30min.
Train: train destination: Łódź Kaliska (always with change); frequency less than 1h (timetables and search for connections); approximate journey time from 2h to 4h.
Taxi: taxi fare for Taxismart is 430zł/100€ and 830zł/190€ for minivan; estimated journey 2h.

By train:
The main railway station is Łódź Kaliska (timetables and search for connections). Station is located 3,3km from meeting venue and 4km from city center.

By bus:
Lodz has a lot of international bus connections provided by polskibus. Destination is Łódź Kaliska station.

By car:
Lodz has a good road connection from various directions:
form west - by motorway A2 (E40)
from south - by motorways A4 (E67) than A8
from east - by motorway A2 (E40)

For more detailed information link website.

Map

![Map of Lodz](image-url)
Meeting venue:
The first two days of the meeting (4th and 5th April) will be held at Lodz University of Technology (TUL), Campus B, Lodz, in the “Auditorium and Conference Hall” on the first floor of the C15 building.

Address:
Sala Widowiskowa-Konferencyjna
Building C15 (first floor), Campus B
al. Politechniki 3a, 93-590 Łódź

The third day meeting (6th April) will be held at Lodz University of Technology (TUL), Campus B, Faculty of Civil Engineering, Architecture and Environmental Engineering on the first floor of the B7 building (Auditoriums: B10-B12).

Address:
Faculty of Civil Engineering, Architecture and Environmental Engineering
Building 7 (first floor), Campus B
al. Politechniki 6
90-924 Łódź

How to get to the meeting venue

By bus:
Lines 50, 55, 77 cross the campus zone. Buses are equipped with ticket machines but you need to pay by credit card. Tickets are available also at the airport or Łódź Kaliska train station.

By tram:
Lines 15, 15A cross the campus zone. Trams are equipped with ticket machines in the first carriage, but You need to pay by credit card. Tickets are available also at the airport or Łódź Kaliska train station.

By taxi:
Taxis are cheap and easy to find In Lodz. Taxi fare is 0,40€/km plus initial charge 1,5€. There is no extra charge for a luggage.

From the airport:
Bus no. 55: Journey from Lotnisko Terminal Pasażerski to POLITECHNIKA; frequency 20-30min (timetables, tickets info); approximate journey time 18min.
Taxi: taxi fare from airport to South Campus of TUL is 20zł/5€; estimated journey 13min.

From the Łódź Kaliska train station:
Bus no. 50: Journey from Dworzec Łódź-Kaliska to POLITECHNIKA; frequency 30min (timetables, tickets info); approximate journey time 11min.
Taxi: taxi fare from Łódź Kaliska to North Campus of TUL is 20zł/5€; estimated journey 13min.
On foot: through the Poniatowski Park (about 30 min walk).
## Accommodation

<table>
<thead>
<tr>
<th>Name</th>
<th>Cat.</th>
<th>Address</th>
<th>Contact</th>
<th>Distance from the venue</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Tree Hilton</td>
<td>4*</td>
<td>Łąkowa 29 90-554 Łódź,</td>
<td>+ 48 42 208 80 00</td>
<td>Distance: 1,5km;</td>
<td>Near the Poniatowski Park and hotels: Focus, Qubus, Tobaco</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><a href="http://www.doubletreelodz.pl/">http://www.doubletreelodz.pl/</a></td>
<td>by tram/bus line no 15</td>
<td></td>
</tr>
<tr>
<td>Holiday Inn</td>
<td>4*</td>
<td>Piotrkowska 229/231 90-456 Łódź</td>
<td>+48 42 208 2000</td>
<td>Distance: 1,0km</td>
<td>At the promenade</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><a href="http://hilodz.com/">http://hilodz.com/</a></td>
<td>by tram/bus line no 57</td>
<td></td>
</tr>
<tr>
<td>Hotel Novotel</td>
<td>4*</td>
<td>Piłsudskiego 11A 90-368 Łódź</td>
<td>+48 42 254 39 00</td>
<td>Distance: 2,2km</td>
<td>Near the city center and promenade and Hotel Ibis</td>
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<tr>
<td>Hotel Tobacco 3*</td>
<td>Kopernika 64 90-553 Łódź</td>
<td>+48 42 207 07 07 <a href="http://www.hoteltobaco.pl/">http://www.hoteltobaco.pl/</a></td>
<td>Distance: 2,0km by tram/bus line no 15</td>
<td>Near the Poniatowski Park and Hotels: Focus, Qubus, Double Tree by Hilton</td>
<td></td>
</tr>
<tr>
<td>Hotel Qubus 3*</td>
<td>Mickiewicza 7 90-443 Łódź</td>
<td>+48 42 275 5 100 <a href="http://www.qubushotel.com/pl/hotel/lodz/9/">http://www.qubushotel.com/pl/hotel/lodz/9/</a></td>
<td>Distance: 1,0km by tram/bus line no 15</td>
<td>Near the Poniatowski Park and Hotels: Focus, Double Tree by Hilton, Tobaco</td>
<td></td>
</tr>
<tr>
<td>Hotel Focus 2*</td>
<td>Łąkowa 23/25 90-554 Łódź</td>
<td>+48 42 637 12 00 <a href="http://www.focushotels.pl/lodz/30.html">http://www.focushotels.pl/lodz/30.html</a></td>
<td>Distance: 1,5km by tram/bus line no 15</td>
<td>Near the Poniatowski Park and Hotels: Double Tree by Hilton, Qubus, Tobaco</td>
<td></td>
</tr>
<tr>
<td>Hotel Ibis 2*</td>
<td>Piłsudskiego 11A 90-368 Łódź</td>
<td>+48 42 638 67 00 <a href="H3096@ACCOR.COM">H3096@ACCOR.COM</a><a href="http://www.ibis.com/pl/hotel-3096-ibis-lodz-centrum/index.shtml">http://www.ibis.com/pl/hotel-3096-ibis-lodz-centrum/index.shtml</a></td>
<td>Distance: 2,2km by tram/bus line no 10, then 15</td>
<td>Near the city center and the promenade and Hotel Novotel</td>
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**Meals**

Lunches and coffee breaks will be provided by the local organiser.

**Dinners**

Visiting tours and dinners on the evenings of **Monday 4 April** and **Tuesday 5 April** have been organised by the local organiser but will have to be paid directly by the participants. **Participants will be requested to pay in advance for their dinners at the registration desk to avoid complications and delays at the venue.**

**Monday 4 April:** Dinner at the Textile Museum (White Factory) combined with a tour of the museum *(price:110 PLN - about 25 Euro – please bring local currency)*

**Tuesday 5 April:** Dinner at the Poznanski Palace combined with a visit to the Museum of the City of Lodz *(price:130 PLN - about 30 Euro – please bring local currency)*
Abstracts

Externally Bonded Reinforcement / Innovative Solutions

The Behavior of CFRPs externally bonded to concrete under cyclic loading
Thorsten Leusmann

The bond behavior of externally bonded reinforcement under cyclic loading has a significant influence on the deformations and the sustainability of reinforced concrete members. The damage process of the bond between CFRP and concrete is examined under cyclic loading with up to two million load cycles at varying upper and lower loads. The bond length of the investigated specimens in cyclic double shear tests with near end support is 1100 mm. Three different concrete strength classes and two different types of externally bonded CFRPs were examined.

On the basis of strain and slip measurements existing concepts on the crack formation between CFRP and concrete are partially confirmed and extended with respect to the influence of the lower load level. The developed S-N-curve gives a description of the relationship between the achievable number of load cycles, the lower load level and the load range of the CFRPs. The concept behind the S-N-curve can be transformed to a formulation for the crack growth rate depending on the decoupled length and the upper and lower load. The experimental procedure allows the identification of the necessary model parameters in a few experiments.

Durability of RC slabs strengthened in flexure with prestressed CFRP strips
José Sena-Cruz, Luís Correia, Gonçalo Escusa, Julien Michels, Paulo França, Eduardo Pereira

Externally bonded reinforcement (EBR) technique with FRP materials is the most widely used strategy to retrofit concrete structures. By prestressing these FRP materials attached to the concrete substrate, the advantages of the EBR technique and external prestressing are combined. The present work investigates the durability of reinforced concrete (RC) slabs strengthened in flexure with prestressed CFRP strips according the EBR technique. Two different anchorage systems were studied: (i) the Mechanical Anchorage (MA) and (ii) Gradient Anchorage (GA). The durability of the specimens was evaluated by exposing the strengthened slabs to one out of four environmental conditions (slabs submersed in water, slabs submersed in water with chlorides, slabs submitted to wet-dry and control slabs). These actions were combined with a sustained load of 1/3 of the ultimate load for a period of 8 months. Finally, the slabs were monotonically tested up to failure by using a four-point bending test configuration. This work presents the general description of the experimental program, the analysis of the main results, as well as the retained conclusions.

Fatigue Behavior and Design of Reinforced Concrete Beams Strengthened in Flexure with FRP
Barbara Charalambidi, Theodoros Rousakis and Athanasios Karabinis

The aim of the present research is the experimental and analytical investigation of the response of CFRP strengthened RC beams under fatigue loading. For this purpose, beams were cast with web dimensions of 200 mm x 500 mm and 3050 mm in length. Beams were strengthened in flexure with externally bonded CFRP laminate or with NSM CFRP laminates. Two different amplitudes of cycles were investigated, simulating the service loads of a bridge beam and the maximum steel stress limit for the SLS. The available fatigue prediction models in literature provide the number of cycles to failure with respect to the steel stress range assuming indirectly a sustained load between a minimum and maximum level. The present research also aims to introduce a new analytical model for predicting the fatigue life of FRP strengthened RC beams. The parameters used are the maximum stress of tensile steel (?max) to the yielding strength (fy) ratio, as well as the axial rigidity of longitudinal steel (ks) and FRP (kf) reinforcement. The predictions of the proposed model
Numerical simulations and parametric studies of RC beams strengthened with prestressed CFRP laminates

Renata Kotynia, Szymon Seręga, Krzysztof Lasek

A presentation shows results of experimental tests of reinforced concrete beams strengthened in flexure with pretensioned carbon fiber reinforced polymer (CFRP) laminates. The original achievement of this study is the analysis of the load history influence before strengthening on the strengthening efficiency in the ULS and SLS. A practical aspect of the research focuses on the preloading level on the gain of strengthening and the exhaustion of the tensile strength of the composite. Two levels of slabs preloading were considered: the slab self-weight acting alone and the self-weight plus an additional external load. The influence of the tensile steel reinforcement ratio, adhesion between the prestressed CFRP laminate and concrete and preloading level on the ultimate load carrying capacity following strengthening is discussed. The presentation shows results of numerical simulations of the experiments carried out on the element with adhesion between concrete and CFRP laminate. The RC beams were modelled in 2D DIANA FEM system with reproduction of loading/strengthening history using phase analysis. The uncoupled user-interface model with damage memory was used for modelling behaviour between concrete and CFRP laminate. Results of numerical simulations show very good agreement with the experiments for the full range of loading and the model was used for a parametric study to investigate a behaviour of strengthened RC structures using prestressed CFRP materials.

Innovative method for strengthening concrete beams using pre-stressed FRP laminates and some field applications

Robert Kliger, Reza Haghani and Mohammad Al-Emrani

Applying fibre-reinforced-polymer (FRP) laminates to strengthen and repair structural members has been proven to be an effective and economical method. The high strength and stiffness, light weight and good fatigue and durability properties of FRP composites, together with advantages offered by adhesive bonding, have made them a suitable alternative for traditional strengthening and repair techniques. It has also been recognised that pre-stressing the FRP laminates prior to bonding offers additional advantages such as reduced crack widths, postponing yielding in tensile reinforcement, increasing the load-bearing capacity and saving reinforcement material. Using pre-stressed laminates is, however, associated with very high interfacial stresses in the bond line at the laminate ends, which necessitates the use of mechanical anchors. This paper presents a new and innovative method and a device for applying pre-stressed FRP laminates to flexural structural members without the need for mechanical anchorage of the laminates. The principle of the method is based on controlling the interfacial stresses in the bond line using a non-uniform pre-stressing force profile. The principle of the method, together with lab verifications and field applications, are presented and discussed.

CFRP rock anchors

Haifeng Fan, Thomas Keller, Anastasios P. Vassilopoulos

A new prestressed and permanent rock or ground anchor is presented, in which the conventional steel tensile elements are replaced by non-corroding carbon fiber-reinforced polymer (CFRP) tendons. In the new design, a precast anchor is fabricated by embedding the two-strap end of the CFRP tendon in a high-strength grout medium. CFRP confinement rings are placed around each strap end in order to increase the compressive strength of the grout. Low-strength grout is injected after the precast part is inserted into the borehole in rock. Pull-out experiments were conducted to validate this design, where different rock mediums were simulated by steel tubes with different thicknesses. Three full-scale anchor specimens with two different tube thicknesses (5 and 10 mm) were investigated. The results showed that all anchors could reach a load capacity.
of more than 1300kN with final failure in the CFRP tendons. The confinement provided by the steel tube and CFRP rings was sufficient for preventing the failure in the grout.

**Hoop/Radial Fracture Energies and Cohesive Meso-scale Modelling of GFRP Pipes Failure Through Iterative Numerical/Experimental Procedure**

*Hugo Faria*

Realistic numerical models of the behavior of glass-fiber reinforced plastic (GFRP) pipes under two loading conditions – ring deflection and internal pressure – representative of their typical applications were developed and experimentally validated. A 2D modeling approach was implemented, using cohesive elements to accurately represent at the layer/laminate level the damage mechanisms leading to failure of these composite structures and estimate their ultimate strength under those loading conditions. The innovative and advantageous feature of these models is their ability to identify the load level at which damage is initiated, its location and the way it propagates thus giving a realistic assessment to the composite pipes’ behavior.

Inter-layer delamination and transverse fiber breakage were identified as main damage mechanisms occurring up to the catastrophic failure of the pipes. The numerical-experimental procedure conducted in this study allowed also to determine the proper values of material’s physical properties such as inter- and intra-layer energy release rates governing the failure mechanisms.

**The effect of hybrid mass reinforcement (carbon nanotubes and polypropylene fibers) on strain resilient cementitious composites -to- steel bar bond mechanism**

*S.P. Tastani, M.S. Konsta-Gdoutos, S.J. Pantazopoulou*

Stress transfer between reinforcing bars and concrete comprises longitudinal bond stresses and radial pressure. The radial pressure is equilibrated by hoop tension undertaken by the concrete cover. In the case of ordinary concrete, due to its poor tensile deformation capacity, this equilibrium is instantly released upon radial cracking of the cover along the anchorage with abrupt loss of the bond strength. By substituting concrete with a tensile strain resilient cementitious composite (SRCC) the aim is the bar-matrix assembly to respond in a ductile manner marked by pullout failure even in the absence of external confinement. This study investigates the local bond of steel bars developed in SRCC cover under tensile stress conditions. The SRCC comprises a novel material reinforced with hybrid mass reinforcement: polypropylene microfibers with the synergistic action of carbon nano-tubes. Local bond is developed over a short anchorage length occurring in the constant moment region of a four-point bending short beam. Parameter of investigation was the cover varying from a brittle to a ductile one. The attributes of the experimental local bond response curves (in the form of applied load versus mid deflection) were higher strength and a slowly descending branch up to large levels of specimen deflection (suggesting controlled bar slippage), very similar in form to the response curve of confined anchorages. This high bond toughness response is owing to the extremely high fracture energy of the matrix, which results from the bridging effect (both at nano- and micro scaling) provided by the hybrid mass reinforcement in a fine-grained cementitious matrix against crack growth and stabilization. Using data from these tests a local bond –slip law was calibrated to be used in a numerical solution of a bar embedded in SRCC where both materials are mobilized in direct tension. An interesting finding is that the higher the bond toughness of the local bond - slip law the higher the gain in strain development capacity of the bar is for a certain embedded length, illustrating the significance of fracture energy in the matrix, as a prerequisite for development of high strength steel/FRP reinforcement.
Textile Reinforced Mortars / Innovative Solutions

Flexural behavior of R/C Beams Strengthened with Steel-Reinforced Inorganic Polymers under Fatigue Loadings
Konstantinos Katakalos and Christos Papakonstantinou

Steel-reinforced polymer (SRP) composite materials are very attractive due to their low weight and high strength. The ease of installation which significantly reduces repair time and expense is another major advantage. One of the main disadvantages of SRP materials is that the matrices used for their fabrication are typically organic and thus they are susceptible to fire. In this study, a newly developed retrofit system is being used. It consists of high strength steel fibers impregnated in a fireproof inorganic matrix. The objective of this study is to examine the effects of this hybrid rehabilitation system on the fatigue performance of strengthened reinforced concrete beams. Sixteen 100 mm × 150 mm × 1200 mm reinforced concrete beams with enough transverse reinforcement to avoid shear failure were used in this study. Nine beams were strengthened with steel fiber sheets on their tension faces. The results from the present study indicate that the fatigue life of reinforced concrete beams, subjected to the same cycling load, can be significantly extended using externally bonded sheets. A rather important finding is that although the strengthening system increases the fatigue life of the beams, the failure mechanism remains the same in both strengthened and nonstrengthened beams. Thus, it is possible to predict the fatigue life of a cyclically loaded beam using existing fatigue models. Furthermore, no delamination failures were observed due to fatigue loading.

Novel TRM Systems for Shear strengthening of full-scale T-beams
Tetta Zoi; Koutas Lampros; Bournas Dionysios

This paper presents a study on the effectiveness of TRM jacketing in shear strengthening of full-scale reinforced concrete (RC) T-beams focusing on the behaviour of a novel end-anchorage system comprising textile-based anchors. The parameters examined in this study include: (a) the use of textile–based anchors as end-anchorage system of TRM U-jackets; (b) the number of TRM layers; (c) the textile properties; and (d) the strengthening system, namely TRM jacketing and FRP jacketing for the case without anchors. In total, 11 full-scale RC T-beams were constructed and tested as simply supported in three-point bending. The results showed that: (a) The use of textile–based anchors increases dramatically the effectiveness of TRM U-jackets; (b) increasing the number of layers in non-anchored jackets results in an almost proportional increase of the shear capacity, whereas the failure mode is altered; (c) the use of different textile geometries with the same reinforcement ratio in non-anchored jackets result in practically equal capacity increase; (d) TRM jackets can be as effective as FRP jackets in increasing the shear capacity of full-scale RC T-beams. Finally, a simple design model is proposed to calculate the contribution of anchored TRM jackets to the shear capacity of RC T-beams.

Flexural Strengthening of Two-Way RC Slabs with Externally Bonded TRM layers
Lampros Koutas; Dionysios Bournas

The application of textile-reinforced mortar (TRM) as a means of increasing the flexural capacity of two-way reinforced concrete (RC) slabs is investigated in this study. The parameters examined include the number of TRM layers, the strengthening configuration, the textile fibers material (carbon versus glass) and the role of initial cracking in the slab. For this purpose six large-scale RC slabs were built and tested to failure under monotonic loading distributed at four points. It is mainly concluded that TRM increases substantially the initial stiffness, the cracking load, the post-cracking stiffness and eventually the flexural capacity of two-way RC slabs, whereas the strengthening configuration plays an important role the effectiveness of the technique.
Simple equations based on the test results provide good estimation of the flexural moment resistance and can be used for design purposes.

SINTEF: How to contribute to the development of textiles for mortar reinforcements?
Alexandre Garcia, Nathalie Labonnote, Susie Jahren

For more than 60 years SINTEF has developed solutions and innovations both for society and customers all over the world. As a result, SINTEF has become a world-leading research institute. The collaboration of two main SINTEF’s institutes (Building and Materials Chemistry) in the area of building and construction markets will lead to the development of new reinforcements for building markets.

Effect of epoxy resins cross-linking parameters on mechanical properties of adhesive joints
Renata Kotynia, Anna Strłąkowska, Marcin Masłowski, Kinga Adamczewska

The interface between concrete and epoxy is usually regarded to be stronger when compared to the strength of the concrete substrate. This is generally true when the interface is under dry conditions, however, the durability of such a bimaterial system deteriorate under environmental condition, moisture, alkaline medium, or influence of thermal shock. The maximum achieved heat resistance of epoxy adhesives is limited as the glass transition temperature (Tg) may be higher than the curing temperature by no more than 40 degree C due to appearance of chain defects. An increase of upper temperature limit of operation of adhesive joints based on epoxy resins with Tg higher than 70 degree C, will permit the possibility of their operation in high temperature conditions. The presence of high thermomechanical properties of such epoxy formulations may be explained by the significant exothermic effect of curing process. However, the presence of the greater exothermic effect reduces considerable the gel time and technical service life and make the use of such adhesives unworkable in industrial conditions. Additionally, in the case of high heat emission, the system is cured irregularly, which leads to reduction of adhesive strength. The test results carried out on three variable types of adhesives indicate an influence of the curing temperature, time of curing and time of cooling on the bond strength of the epoxy adhesive.
Numerical and experimental investigation on seismically damaged RC wall panels retrofitted with Textile Reinforced Mortar

V. Stoian, C. Todut, D. Dan

Taking into account the building stock in Romania, built using precast panels, a theoretical and an experimental program was conducted at the Politehnica University Timisoara in order to investigate the seismic performance of the precast reinforced concrete wall panels (PRCWP) and strengthening solutions using FRP materials. The experimental study presented here is based on a number of two precast reinforced concrete wall panels tested under seismic conditions, repaired and post-damage strengthened using textile reinforced mortar. Both wall panels have an initial small window opening, but the second panel has the opening enlarged into a large window opening in order to investigate also the cut-out effect. The behavior and failure details are presented and analyzed for both unstrengthened and post-damage strengthened situations. The experimental results indicate that the performance of the elements, repaired and strengthened, were almost equal to or higher than the reference elements.

Seismic retrofitting of reinforced concrete structures using composites. Scientific and Technical Documents

Emmanuel Ferrier, Marc Quiertant, Laurent Michel

The French Civil Engineering Association (AFGC) was created in 1998 following the merger of the AFPC and AFREM. It is a place for exchanges between engineers and researchers concerned with civil engineering activities. It aims to bring the world of materials of the structures, the world of teaching and research in the design and application. The Association offers its members numerous meetings during conferences, technical and scientific events and organizes tours of great achievements. It sets up Working Groups that host researchers, academics and engineers to take stock of the state of the art on important topics of Civil Engineering and to explore areas of innovation. These groups contribute to the development of technical documents published by the association, which enjoy a broad consensus at the national level and recognized internationally. The Association is a link to the French engineers and researchers working abroad and wishing to follow the evolution of the French technique, and maintain contact with the French Civil Engineering. In 2012 Emmanuel FERRIER and Marc QUIERTANT propose to open a working group on seismic retrofitting, after 3 years of work the working group hosting researchers academics and engineers proposed a document of 130 pages on seismic retrofitting using FRP materials.

In various countries, including France, the regulations concerning buildings and civil engineering structures contain recommendations aimed at achieving acceptable seismic performance, that is, the structures designed must withstand minor earthquakes without damage, moderate earthquakes with minimum non-structural damage and major earthquakes without collapsing. The seismic recommendations proposed in building regulations have thus been updated over the years to achieve this aim.

In France, the new earthquake zone map and changes in the regulations as a result of Eurocode 8 (EC 8) have contributed to defining the performance objectives of new structures. For existing structures, at least in certain cases, reinforcement is required to reduce seismic risks. This notion is introduced in Eurocode 8 Part 3 and in the implementing decrees and orders. Seismic retrofitting can therefore be either voluntary or compulsory. Based on the current construction rate, it would take one hundred years to completely replace France’s housing stock. Seismic retrofitting of existing structures therefore appears necessary to ensure the solidity of all building constructions and the safety and security of people and property. This document presents recommendations for the seismic retrofitting of concrete structures using fibre-reinforced polymers (FRP). Research results have been used to draw up recommendations and design rules in the case of quasi-static loading, taking serviceability limit state and ultimate limit state conditions into consideration (ACI 440.
Application of FRP materials for a renovation of steel railway bridges

Pavel Ryjáček, Kamila Cábová, Ludvík Kolpaský, Jan Vůjtěch, Ondřej Hráský, Vít Lojda

The steel bridges form a significant part of all bridge structures. In many cases, they were built many years ago and the age of hundred years is not an exception. That creates opportunities and necessities for the renovation of those structures. Most common renovation is focused on the bridge equipment, such as railing, footways and steel floors on the open decks. Although the traditional material for this purpose is steel, the maintenance costs are forcing the bridge operators to look for more durable and maintenance free solutions. The research reported in this paper is focused on the application of FRP (fibre reinforced polymers) for bridge equipment of railway bridges. Several FRP solutions were designed, fabricated and constructed on the test steel bridge and then exposed to the load test in order to verify the operator requirements. As the FRP is a fire sensitive material, the common fire scenarios were also tested, such as the fire of the rubbish between timber bridge sleepers and fire of the electric cables.

Presentation of the FASST-Bridge project (Fast and effective - solution for steel bridges life-time extension) in the framework of INFRAVATION ERA-NET program.

S. Chataigner, M. Quiertant, K. Benzarti

FASSTbridge aims at drastically reduce the economic and environmental costs of ownership of the steel bridges stock in Europe and the USA by providing a reliable preventive, cost-effective and sustainable solution for steel bridges life-time extension. The FASSTbridge solution will stand on two pillars:
- FASSTbridge methodology: an easy-to-apply methodology (fatigue life-time assessment, design, execution and maintenance guideline) to prevent the evolution of irreversible fatigue derived problems at a pre-failure scenario, and
- FASSTbridge strengthening system: a reliable, cost-effective CFRP strengthening system to preventively extend life-time of steel bridges.

The preventive nature of the solution is the key to cost-effectiveness and sustainability since it will allow the timely design and implementation of innovative, competitive CFRP-based strengthening actions that will reduce the overall cost and environmental impact of life-time extension.

The application of the FASSTbridge solution will entail the preservation of precious public assets increasing their remaining-life in safe conditions, which is strongly connected to the Challenge B “Enhanced durability and life-time extension” of the ERA-NET Plus Infravation 2014 Call. The solution application will encompass two steps. Firstly, the assessment of the residual life of existing bridges and, secondly, when the estimated value is below the designed life-time, the fatigue strengthening process (design, execution and maintenance) using CFRP strips in order to guarantee the initially expected life-time (or even more). This process will be supported by a demonstration of the complete FASSTbridge solution in a real composite steel bridge in Madrid (Spain).

Short- and long-term behaviour of bridge deck slabs strengthened in transverse direction with EB CFRP strips

Juan Manuel Gallego, Christoph Czaderski and Julien Michels

Reinforced concrete box-girder bridges with lateral cantilevers might have a lack of negative bending resistance in cross-direction due to the increase of traffic loads or the degradation along the time of the material properties. Externally Bonded (EB) Carbon Fiber Reinforced Polymer (CFRP) strips on the top side of these bridge slabs are a possible strengthening technique for such purpose. Strengthening of negative bending moments on the upper deck side implicates the exposure of the composite reinforcement to both...
short- and long-term elevated temperature scenarios. During the construction phase, the application of warm mastic asphalt induces elevated peak temperatures among others in the epoxy resin of about 80°C with a subsequent slow cooling phase over several hours. The short-term residual bond strength of the strengthened system after such an exposure has been checked with both lap-shear and large-scale beam tests performed at Empa. The long-term behaviour with the seasonal temperature fluctuation is another concern. For this purpose, cantilever plates with real mastic asphalt layers under sustained load are installed and continuously monitored in time.
Corrosion of steel reinforcement is one of the main causes leading to the degradation of reinforced concrete (RC) structures. In order to reduce the high maintenance cost associated with this problem, alternative reinforcing materials, such as Fibre Reinforced Polymer (FRP) reinforcements, have been investigated over the past three decades.

Despite the large amount of research that has been carried out to date on the use of FRP in concrete, one factor still hindering the widespread use of FRP bars in civil engineering applications is the lack of reliable data on their long-term in-service performance.

This paper investigates the durability of Glass FRP reinforcement exposed to severe environments and subjected to different levels of sustained load. The test matrix was designed to include 92 GFRP specimens exposed to temperatures varying from 20°C to 60°C for 0, 42, 90 and 270 days. A total of 69 specimens were embedded in concrete and submerged in water, whilst the remainders were submerged in alkaline solution with a pH of 12.8. Tensile tests were performed on reference samples and on all conditioned specimens to determine their initial and residual strength and stiffness.

The effect of different exposure conditions and sustained stress on the long term properties of the tested bars is examined and discussed in detail. Exposure to elevated temperatures seems to play a key role in triggering and accelerating the development of critical degradation mechanisms. On the basis of the experimental results presented in this paper, a comprehensive predictive model, based on the principles already adopted by T5.1 of fib, is developed and commented upon.

**Crack width in GFRP RC beams: an experimental study**

_Cristina Barris, Lluís Torres_

Serviceability Limit States (SLS) usually govern the design of FRP Reinforced Concrete (RC) elements, because of the mechanical and bond properties of the reinforcing bars. Many studies concerning deflections are found in the literature, but only few of them address the issue of cracking.

This contribution presents a study on the cracking behaviour of GFRP RC elements based on the results of an experimental programme involving 16 beams. The aim of the work is to study the influence of the reinforcing material, $\varphi/\rho_{\text{eff}}$ ratio, concrete cover, stirrups spacing and bond between the concrete and the reinforcement. For this purpose, two different types of GFRP and steel bars were used. The cracking behaviour (crack width and spacing) in the pure bending zone is analysed up to the service load. Crack width is consistently acquired by using a Digital Image Correlation (DIC) technique. The 2D full-field displacements of the pure flexural zone are registered by using 4 digital cameras and a commercial software that allowed analysing the evolution of the specimen cracks. Finally, coefficients are adjusted to different formulations regarding crack spacing and crack width.

**Finite element analysis of concrete beams strengthened with rods in basalt fiber**

_Todor Zhelyazov, Eythor Rafn Thorhallsson, Jónas Thór Snæbjörnsson_

A numerical study of the mechanical response of concrete beams with flexural reinforcement in basalt fiber is reported. An accurate finite element model of the beam is built and a four-point-bending test is simulated. The structural element is viewed as a multiple component system. Appropriate constitutive laws and failure criteria are defined for each component: concrete and basalt fiber. Non-linear concrete response is reproduced in the framework of theory which postulates coupling between linear elasticity and anisotropic
damage. Local failure takes place if a critical value of the damage variable is reached. Basalt fiber is modelled as an isotropic material of linear elastic behaviour until failure.

**Experimental investigation of the thin sandwich wall system reinforced with GFRP rebars**

*Marcin M. Haffke, Matthias Pahn*

Multi-layered concrete sandwich panels gain popularity in construction of commercial as well as residential buildings. Their good thermal properties, simplicity of assembly at the site and high level of prefabrication make them competitive solution in many cases. Such panels consists usually of two concrete wythes and insulation layer in between. Both concrete wythes, reinforced commonly with steel reinforcement, are joint together by use of connectors. Replacement of steel reinforcement by glass fibre reinforced polymers (GFRP) rebars enable the design of the much thinner panels, up to 4 cm, due to the reduction of required concrete cover for GFRP bars.

However changes in geometry of sandwich panel’s cross section comparing to commonly produced systems causes the so-called ‘sandwich effect’ to have more relevance in distribution of internal forces. As a result of that many different failure modes can occur at different stages of load. A four-point flex-ural test is adopted to fully understand the behaviour of sandwich panels under bending stress condi-tion. The experimental campaign includes instruments to measure the deflection along the beam, strains in the longitudinal reinforcement and shear deformation of insulation layer. Varying parameters are thickness of concrete and insulation layers as well as reinforcement ratio.

**Response to Thermo-Mechanical Loading of GFRP Reinforced Concrete Sandwich Panels**

*Andreas Schmitt, Marcin Haffke, Valter Carvelli, Matthias Pahn*

The thermo-mechanical behaviour of sandwich panels was experimentally investigated. The panels had two external concrete layers reinforced with E-glass fibres reinforced polymer (GFRP) rebars and an internal expanded polystyrene insulation layer. These are typical for low bearing panels in façade claddings. The investigation had three consecutive experimental phases. The first consisted in four point bending up to failure of two panels at room temperature to have the reference mechanical behaviour before heating. The second phase was dedicated to the application of a bending constant load and then heating with different rates and exposition times. The heating condition was such that internal GFRP rebars in one concrete layer were exposed to increasing temperature higher than the transition temperature of the resins. In the third phase, the heated panels were loaded in bending up to failure at room temperature for measuring the residual mechanical properties of the sandwich panels, in term of deformability and load carrying capacity.

**Vegetable fibres reinforced polymer: testing in progress**

*Francesca Giglio, Giulia Savoja*

The paper describes the research in progress of PhD thesis “Testing of components in composite materials reinforced with vegetable fibers for the construction sector” in Structural Engineering, conducted at the Università Mediterranea of Reggio Calabria (UNIRC). The research has a strong multidisciplinary nature and has as objective the study and testing of components for structural use and not, made from local natural fibers and epoxy based thermosetting resin. Research is carrying out various laboratory tests for material characterization and mechanical of some biocomposites, starting from the analysis of natural fibers, natural fabrics and epoxy resins bioderivate. In the most general organization of the theme, the research has the overall objective, the promotion of local production chains of materials from renewable sources, both contribute to the reduction of environmental impacts of composites. The local contextualization of the production and processing of the fibers is a focal point of the research, by virtue of scientific collaboration of some Departments of the Università della Calabria (UNICAL) which for many years deals with the study of the production chains of some plant fibers in the territory, and some Departments of Università Mediterranea.