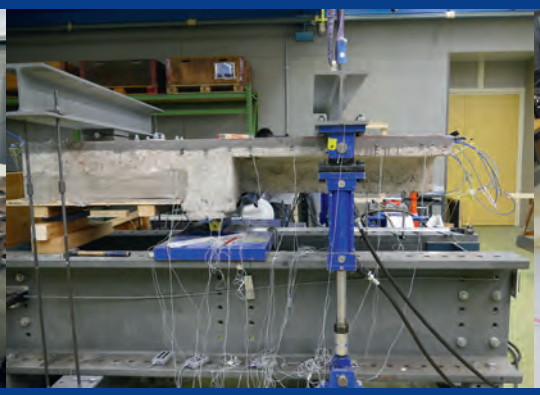
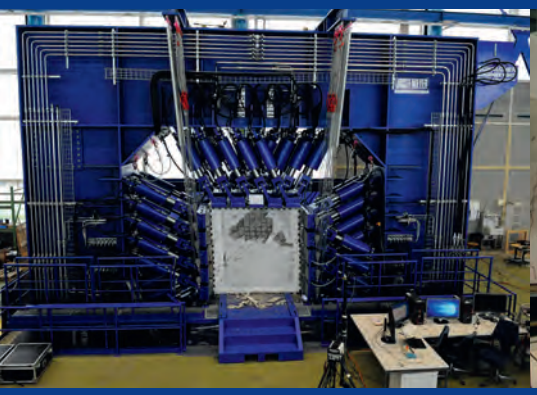
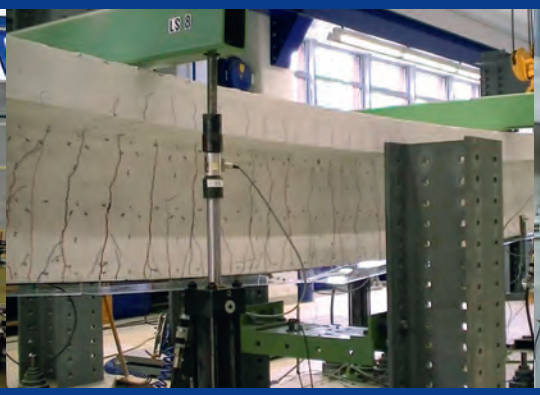




Forschung und Entwicklung

Recherche et développement

Research and Development


Foreword

Research efforts in the field of structural concrete have been intensively performed since its implementations as a building material more than one century ago. The aim of these researches has been to eventually provide comprehensive, consistent and safe design methods and to allow a continuous development of Structural Concrete. Despite the significant advances performed, many topics remain still under discussion. Also, the evolution in the material has opened a wide variety of new questions. There exists thus currently the need to continue with research initiatives in order to better understand the material and structural response of concrete works and to simplify them into sound and transparent design models.

In the following pages, an overview of the researches performed in Switzerland in the field of Structural Concrete during the last four years is presented. It shows the large diversity and richness of topics of interest.

In the name of all the researchers contributing in the following pages, I would also like to sincerely acknowledge the various sponsors for supporting these research efforts, from which society largely benefits.

Aurelio Muttoni

Head of *fib*'s Swiss National Member Group

Lausanne, August 2018

École Polytechnique Fédérale de Lausanne

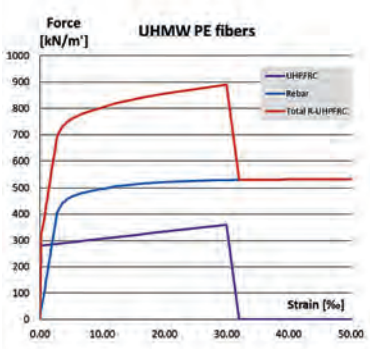
Laboratory for Maintenance and Safety of existing Structures (MCS)

Research is related to UHPFRC (Ultra-High Performance Fibre Reinforced Cementitious Composite Materials) produced from cement and other reactive powders, additions, fine hard particles, water, admixtures and a large number of short and slender steel fibres. The targeted addition of a thin layer of strain-hardening UHPFRC to an existing member in reinforced concrete (RC) enhances the structural resistance and the durability of existing RC structures. This concept has been implemented and applied in Switzerland since 2004 to enhance reinforced concrete structures and to make them durable and performant for future use.

Next generation of UHPFRC for sustainable construction

Main investigators: E. Denarié, A. Hajiesmaeili, H. Mohamed Abdul

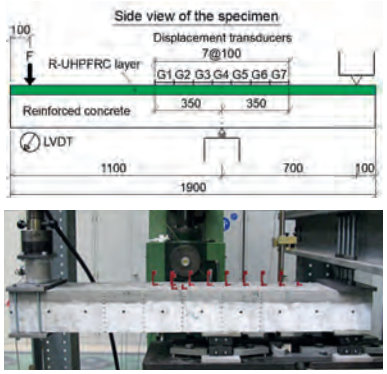
The embodied energy in UHPFRC is dominated by two components: steel fibres and clinker. In this project, UHPFRC mixes are developed by means of the massive replacement of clinker with limestone filler and of steel fibres with high-performance synthetic fibres. The novel mixes maintain or improve the tensile hardening and softening response and other mechanical properties, the time-dependent response and compactness when compared to current steel fibre reinforced UHPFRC materials. The environmental impact is significantly reduced.



Fatigue behaviour of UHPFRC – RC elements

Main investigators: E. Brühwiler, T. Makita, X. Shen, B. Sawicki

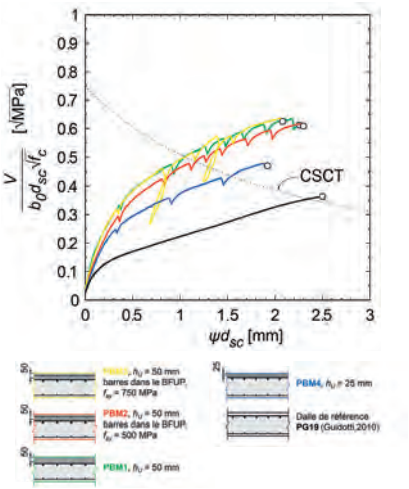
The fatigue behaviour of elements made of plain UHPFRC, R-UHPFRC (reinforced with rebars) and R-UHPFRC – RC under uniaxial and bi-axial stress states is investigated. The domain of very high numbers of fatigue cycles, i.e. more than 10 million cycles, is explored in order to simulate fatigue loading conditions relevant for bridges. Rules are established for the design of fatigue strengthening of bridge decks.



Punching shear strengthening of slabs using UHPFRC

Main investigators: E. Brühwiler, M. Bastien-Masse, P. Schiltz

To strengthen reinforced concrete (RC) slabs with deficient shear resistance, it is proposed to add a layer of 25 to 50 mm of UHPFRC with small diameter rebars (R-UHPFRC). The research reveals a monolithic composite element behaviour where the new UHPFRC layer acts as an external tensile reinforcement leading to a significant increase in the combined bending-shear and punching shear resistance of the strengthened element.



École Polytechnique Fédérale de Lausanne

Structural Concrete Laboratory

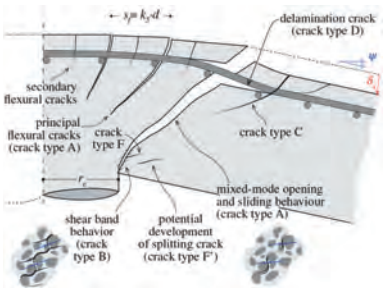
Punching of Concrete Slabs

Main investigators: A. Muttoni, M. Fernández Ruiz, J. Simões, J. Einpaul, F. Brantschen

An important experimental effort has been performed by the Structural Concrete Laboratory of EPFL, with more than 250 punching tests on full-size specimens since the year 2000.
On that basis, a mechanical model, the Critical Shear Crack Theory, has been developed.
This model has been adopted for punching shear design by the Swiss Concrete Code SIA 262 (2003 and 2013) and by the *fib's* Model-Code 2010. It is also incorporated in the draft for the next generation of Eurocode 2 (prEN 1992-1-1:2018).

Research (2014–2018) sponsored by:
Swiss National Science Foundation, project # 200021_137658/1

Additional information:
https://ibeton.epfl.ch/Recherche/punching/Default_e.asp



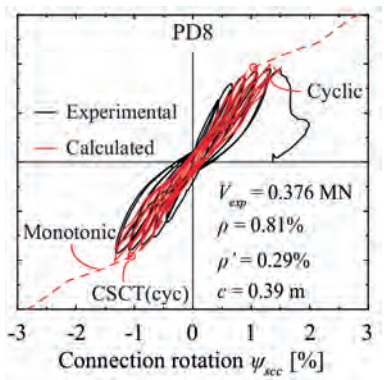
Seismic response of flat slabs

Main investigators: A. Muttoni, K. Beyer, I. Drakatos

The response of slab-column connections, particularly for members without transverse reinforcement, is typically associated with limited deformation capacities.
This issue has raised questions about the suitability and potential risks of the use of flat slabs relying on frame action as the primary bracing system of a structure (or when soft bracing systems are provided). This research, conducted by the Structural Concrete Laboratory in conjunction with the Earthquake Engineering and Structural Dynamics Laboratory of EPFL, is based on specific tests and has led to the extension of the theoretical framework of the Critical Shear Crack Theory to cover these cases.

Research (2014–2018) sponsored by:
– Cemsuisse, research project # 201201
– Swiss National Science Foundation, project # 143747
– Seismology and Earthquake Engineering Research Alliance for Europe, Project #2017-2

Additional information:
https://ibeton.epfl.ch/Recherche/sustainedloading/Default_e.asp



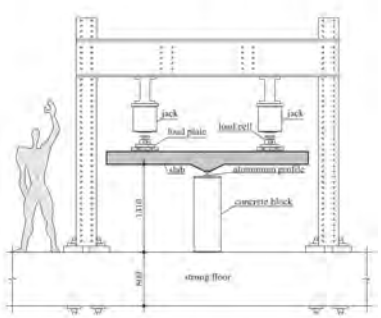
Fatigue response of concrete in shear

Main investigators: A. Muttoni, M. Fernández Ruiz, F. Natario

Many structural elements such as bridge deck slabs are subjected to cyclic actions such as those originating from traffic loads. This issue might be decisive for the design and verification of these elements. However, conventional design methods have been questioned as many phenomena influencing potential redistributions of internal forces (such as shear and flexural cracking) are usually neglected.
The Structural Concrete Laboratory has performed a detailed investigation of this topic combining experimental and analytical research, leading to practical design guidelines.

Research (2014–2018) sponsored by:
Swiss Federal Roads Office, project # AGB 2009/008

Additional information:
https://ibeton.epfl.ch/Recherche/shearslabsshells/Default_e.asp



École Polytechnique Fédérale de Lausanne

Structural Concrete Laboratory

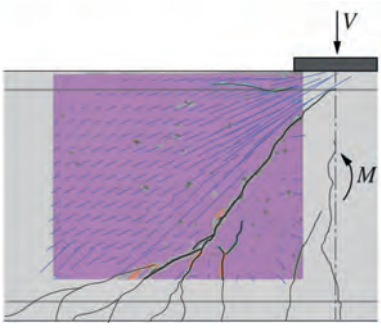
Shear resistance of beams and slabs without shear reinforcement

Main investigators: A. Muttoni, M. Fernández Ruiz, F. Cavagnis, R. Cantone

The topic of the shear resistance of slabs without transverse reinforcement such as the deck slabs of bridges or the top and bottom slabs of cut-and-cover tunnels is decisive in many cases for the dimensions and economic efficiency of these members.
Related to this topic, the Structural Concrete Laboratory has performed detailed testing programmes with innovative test setups and measurement devices. The results have allowed for consistent progress in the understanding of the various contributions of the potential shear-transfer actions.

Research (2014–2018) sponsored by: -
– Swiss Federal Roads Office, project # AGB 2015/011
– Swiss Federal Roads Office, project # AGB 2011/015

Additional information:
https://ibeton.epfl.ch/Recherche/shearslabsshells/Default_e.asp



Shear Transfer in Cracked Concrete

Main investigators: M. Fernández Ruiz, A. Muttoni, M. Tirassa

The consistent understanding of the capacity of cracked concrete to transfer shear forces requires an accurate description of the engagement of aggregate interlock stresses for crack kinematics corresponding to those observed in shear failures.
To this end, the Structural Concrete Laboratory is carrying out research in collaboration with the Computational Solid Mechanics Laboratory of EPFL where refined experimental measurements are performed. The results are used in combination with the concept of the scales of roughness to provide a consistent framework for the modelling of the phenomenon.

Research (2014–2018) sponsored by:
Swiss National Science Foundation, project # 200021_1169649

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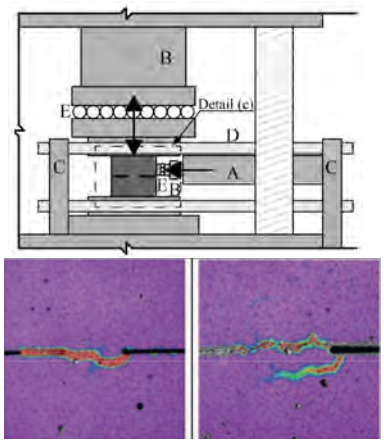
https://ibeton.epfl.ch/Recherche/shear/Default_e.asp



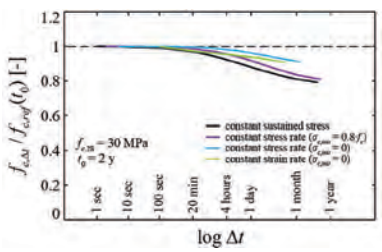
Strength of concrete under sustained loads

Main investigators: A. Muttoni, M. Fernández Ruiz, D. Tasevski

Concrete may be locally subjected to high level of stress in many situations. As a consequence, microcrack development and growth may occur in a phenomenon called non-linear creep, potentially reducing the effective concrete strength, but also producing beneficial stress redistributions and therefore reducing the stress concentrations.
This phenomenon has been investigated by the Structural Concrete Laboratory by developing a constitutive model of concrete that includes the development of microcracking in concrete. This model has been validated by several specific experimental programmes and has allowed for the development of simplified design approaches.

Research (2014–2018) sponsored by:
Swiss Federal Roads Office, project # AGB 2013/001

Additional information:
https://ibeton.epfl.ch/Recherche/sustainedloading/Default_e.asp



École Polytechnique Fédérale de Lausanne

Structural Concrete Laboratory

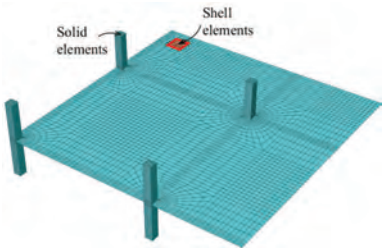
Non-linear analysis of slabs

Main investigators: A. Muttoni, M. Fernández Ruiz, R. Cantone, M-R. Backes

An accurate analysis of the response of concrete slabs is required to suitably estimate the opening of the cracks and therefore their ability to transfer shear stresses. This analysis is however relatively complex as it needs to account for the stiffness and redistributions on the internal forces after flexural and shear cracking.
A number of suitable strategies for such modelling is being developed at the Structural Concrete Laboratory, allowing for the performance of refined analysis and also providing guidelines for simplified analyses.

Research (2014–2018) sponsored by: - Swiss Federal Roads Office, project # AGB 2015/011

Additional information: https://ibeton.epfl.ch/Recherche/shear/Default_e.asp



Textile Reinforced Concrete

Main investigators: M. Fernández Ruiz, A. Muttoni, P. Valeri

Textile Reinforced Concrete consists of a material where a non-metallic reinforcement (normally carbon or glass fabric) is arranged within a cementitious matrix. This reinforcement is insensitive to corrosion and therefore allows for the use of cements with low clinker content and the provision of low concrete covers.
Within this frame, the Structural Concrete Laboratory is carrying out research to characterise the mechanical performance and potential applications of this material for building sustainable and lightweight structures.

Research (2014–2018) sponsored by:
– Cemsuisse, research projects # 201407 and # 201801
– Gerber Rüf foundation, project # KP-290/18

Additional information: https://ibeton.epfl.ch/Recherche/textile/Default_e.asp

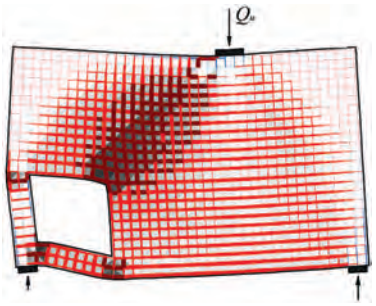
Stress fields for design and assessment of structural concrete

Main investigators: A. Muttoni, M. Fernández Ruiz, F. Niketic

The stress fields method, as the strut-and-tie method, has been very successful in the design and dimensioning of new structures, as well as for checking existing structures. They have inspired numerous codes and international recommendations.
On this basis, the elastic-plastic stress field method has been developed by the Structural Concrete Laboratory. This topic has been the subject of a number of research studies, which involved verifying it systematically in tests and checking the applicability of the method for complex details.

Research (2014–2018) sponsored by: Swiss Federal Roads Office, project # AGB 2009/009

Additional information: https://ibeton.epfl.ch/Recherche/stressfields/Default_e.asp



École Polytechnique Fédérale de Lausanne

Structural Concrete Laboratory

Shear strength of girders and beams with transverse reinforcement

Main investigators: A. Muttoni, M. Fernández Ruiz, M. Rupf, M-R. Backes

Design of girders and can be consistently performed by using equilibrium-based models. Yet, a number of specific issues such as the amount of shear transferred by the compression chord, the transverse bending of the webs or the activation of the prestressing tendons require accurate approaches to suitably assess the various potential load-carrying actions.
A series of research studies has been carried out on this topic by the Structural Concrete Laboratory, by applying and extending the elastic-plastic stress field method. As a result, a number of design recommendations and guidelines for practice have been produced.

Research (2014–2018) sponsored by: -
– Swiss Federal Roads Office, project # AGB 2006/015
– Swiss Federal Roads Office, project # AGB 2009/009

Additional information:
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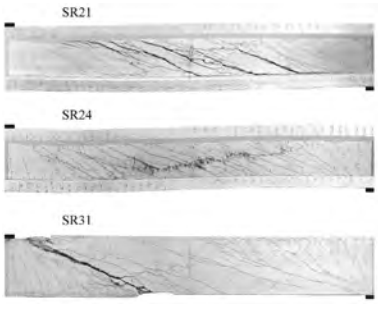

Bond, anchorage and reinforcement detailing

Main investigators: A. Muttoni, M. Fernández Ruiz, F. Moccia

The Swiss practice with respect to anchorage and detailing has been traditionally very much inspired by a rigid-plastic bond response. This approach has shown consistent results in many cases, but does not account for a number of specific issues such as size effect, the influence of poor bond conditions or the influence of cracking parallel to the bar axis.
Following these observations, the Structural Concrete Laboratory is leading an effort to develop more comprehensive models to consistently account for the phenomenon of bond and its influence on detailing. The final aim will be to update current code provisions, thereby extending their validity and applicability.

Research (2014–2018) sponsored by:
Swiss Federal Roads Office, project # AGB 2018/001

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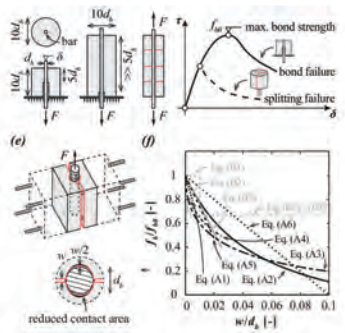


Reliability analysis

Main investigators: A. Muttoni, M. Fernández Ruiz, F. Niketic, P. Valeri, Q. Yu

The topic of reliability analysis and safety format is becoming one of capital importance for design for a number of reasons, such as the possibility of using non-linear analysis methods as well as the need to use new materials (for instance textile concrete) with different responses in terms of deformation capacity and potential redistribution of forces.
Within this framework, the Structural Concrete Laboratory is investigating the suitability and consistency of classical safety formats and how they can be tailored or extended to other cases.

Research (2014–2018) sponsored by:
– Swiss Federal Roads Office, project # AGB 2009/009
– Cemsuisse, research project # 201801

Additional information:
https://ibeton.epfl.ch/Recherche/codes/Default_e.aspp

$$\gamma_C = \frac{f_{ck}}{f_{cm} \cdot e^{-\alpha \cdot \beta \cdot (COV)_{fc}}} \geq 1.00$$

$$\gamma_S = \frac{f_{sk}}{f_{sm} \cdot e^{-\alpha \cdot \beta \cdot (COV)_{fs}}} \geq 1.00$$

Eidgenössische Technische Hochschule (ETH) Zürich

Chair of Concrete Structures and Bridge Design

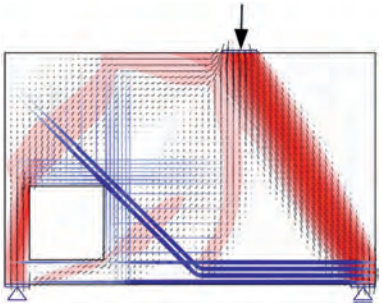
Computer-Aided Design of Discontinuity Regions

Main investigators: J. Mata-Falcón, D. T. Tran, T. Galkovski, W. Kaufmann

Strut-and-tie models and stress fields are powerful design tools, but often tedious and of limited use for serviceability and deformation capacity checks. Discontinuity Region Design, a computer-aided stress field tool, overcomes these limitations. Similar to the EPSF method developed at EPFL, it only requires basic material properties known at design stage and computes compression softening automatically. Further, it accounts for tension stiffening (using the Tension Chord Model) and strain limitations of concrete and reinforcement to cover all ULS and SLS checks, including crack widths and deformation capacity.

Research (2016–2018) sponsored by:
Eurostars-2 (Horizon 2020 EU research and innovation programme), #10571
In collaboration with IDEA StatiCa.

Additional information:
http://www.kaufmann.ibk.ethz.ch/en/research/DR.html



DRD stress field for deep beam with opening.

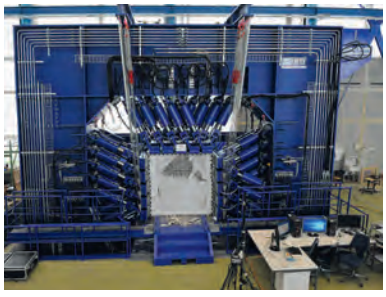
Large Universal Shell Element Tester

Main investigators: W. Kaufmann, A. Beck, D. Karagiannis, D. Werne

The Large Universal Shell Element Tester is a worldwide unique testing facility. Combining the concepts of the University of Toronto's panel and shell element testers, it enables large-scale tests on reinforced concrete elements with dimensions of 2.0·2.0 m and a variable thickness. Precise, general load combinations (8 stress resultants) can be introduced at the edges of the specimen by means of 100 actuators (–1.6/+1.2 MN each), controlled by 20 control channels. The setup can also be used for the testing of e.g. fibre reinforced concrete or subassemblies of larger structures under multiaxial loading.

Research (2015–2018) sponsored by:
– ETH Zurich
– industry

Additional information:
http://www.kaufmann.ibk.ethz.ch/en/research/LUSET.html



Failed specimen of Pilot Test 1 in the LUSET at ETHZ.

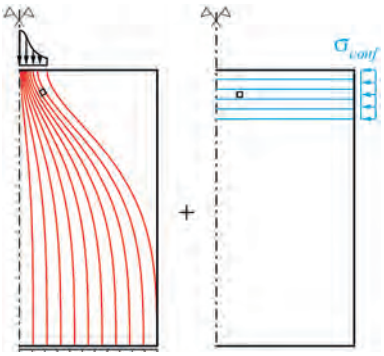
Concrete hinges/partially loaded areas

Main investigators: T. Markić, W. Kaufmann

Despite having been studied and used for more than a century, there is still a remarkable knowledge gap regarding the behaviour of concrete hinges and partially loaded areas in reinforced concrete. The project aims at developing consistent mechanical models for these structural elements, and their subsequent validation by means of large-scale experiments. Based on the outcomes, a new set of design rules and recommendations will be proposed. In a first step, stress fields for partially loaded blocks, accounting for the beneficial effect of confinement (active, passive and geometrical) have been developed.

Research (2016–2018) sponsored by:
cemsuisse (project number 201501)

Additional information:
http://www.kaufmann.ibk.ethz.ch/en/research/betongelenke.html



Bottle-shaped stress field for partially loaded reinforced concrete blocks.

Eidgenössische Technische Hochschule (ETH) Zürich

Chair of Concrete Structures and Bridge Design

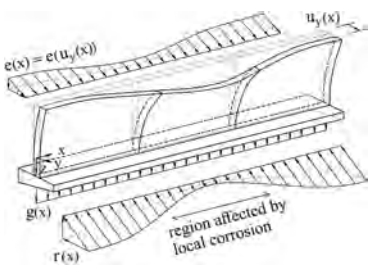
Structural behaviour of retaining walls affected by local corrosion

Main investigators: S. Haefliger, W. Kaufmann, U. Angst

Many existing cantilever retaining walls are affected by severe local pitting corrosion of the main reinforcement in the construction joint above the footing. This leads to a strong reduction of both deformation capacity and ultimate load. Furthermore, the missing ductility inhibits a pronounced decrease of earth pressure by deformation of the wall (as typically assumed in design), leading to higher loads. Hence, serious concerns about the safety of these structures arise. The project addresses this issue, accounting for the effects of local corrosion and deformation-dependent loading in collaboration with the Chairs of Durability of Engineering Materials and Geomechanics at ETHZ.

Research (2016–2018) sponsored by:
– Federal Roads Office (FEDRO)
– Federal Office of Transport (FOT)

Additional information:
http://www.kaufmann.ibk.ethz.ch/en/research/verformungsverhalten_winkelstuetzmauern.html



Principle sketch of retaining wall affected by local corrosion.

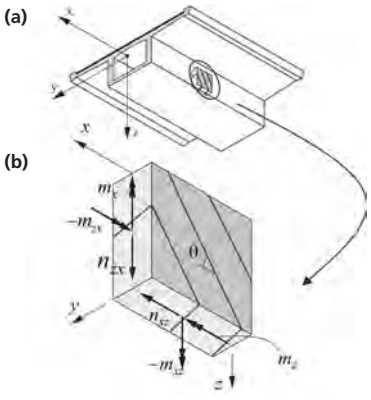
Effect of transverse bending on the shear capacity of concrete bridges

Main investigators: D. Karagiannis, W. Kaufmann

Increasing traffic loads and deck widening projects often require the assessment of the webs of existing box girder bridges against combined loading by longitudinal shear and transverse bending. Due to the presumed conservatism of current design models for this type of loading, strengthening is required in many cases. Through a combination of theoretical investigations, large-scale experiments and numerical simulations, this research project aims at developing a mechanically consistent model that will enable a more realistic assessment of the load-bearing capacity under combined in-plane shear and transverse bending, including checks of the deformation capacity.

Research (2015–2018) sponsored by:
Federal Roads Office (FEDRO)

Additional information:
http://www.kaufmann.ibk.ethz.ch/en/research/querbiegung_schub.html



a) Segment of a box girder bridge and b) isolated web element.

Chair of Structural Mechanics

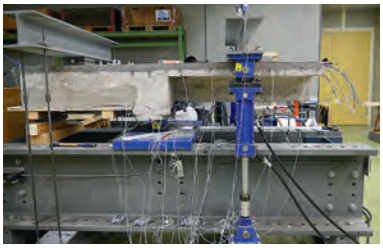
Strengthening a ribbed slab with UHPFRC

Main investigators: H. Martín-Sanz García, B. Herraiz, E. Chatzi, E. Brühwiler

The Du Pont building, erected in 1913, is an existing and historic reinforced concrete structure in the city of Zurich. As part of the renovation of the building, the slabs are to be strengthened by adding a 40 mm UHPFRC layer. A series of experiments took place at the IBK Structures Lab (ETH Zurich), using an embedded fiber optic measurement system, to assess the actual capacity of the slabs, and investigate failure mechanisms. The project is a collaboration between the Chair of Structural Mechanics (ETH Zurich), the Structural Maintenance and Safety Laboratory (EPFL) and Dr. Lüchinger+Meyer Bauingenieure AG.

Research (2015–2018) sponsored by:
– Swiss National Science Foundation, project # 407040_154060
– PSP Properties AG

Additional information:
http://www.chatzi.ibk.ethz.ch/people/research-staff/henar-martin-sanz.html



UHPFRC strengthened ribbed slab, extracted from the Du Pont building and prepared for testing at the IBK Structures Lab.

Empa, Swiss Federal Laboratories for Materials Science and Technology

Structural Engineering Research Laboratory

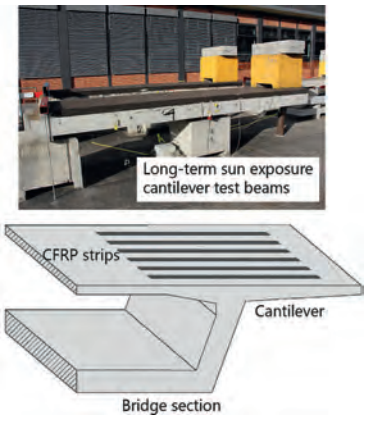
Temperature stability of CFRP strips in bridges

Main investigators: J. M. Gallego, M. Breveglieri, C. Czaderski, J. Michels

In bridge construction, externally bonded carbon fibre reinforced polymer (CFRP) strips can be used for the flexural strengthening of cantilevers in the transverse direction of box girder bridges. Experiments were performed to examine the temperature stability and durability of this type of installation during mastic asphalt application. Tests on cantilevers exposed to sun exposure over several years are still ongoing. Furthermore, thermo-mechanical models to estimate temperatures in the adhesive, models for the resistance of the bonded system and practical recommendations will be developed.

Research sponsored by: Swiss Federal Roads Office (FEDRO), Research Project AGB 2012/001 (2013–2017) and AGB 2016/003 (2017–2019)

Additional information:
https://www.empa.ch/de/web/s303/strenghening-concrete-structures



CFRP strip strengthening on top of a RC box-girder bridge and its simulation on cantilever test beams subjected to long-term sun exposure.

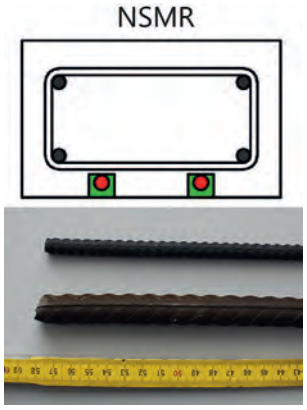
Near-surface mounted memory steel strengthening

Main investigators: B. Schranz, C. Czaderski, M. Shahverdi

A cost-effective, iron-based shape memory alloy (memory steel) was developed at Empa for application in civil engineering structures. The memory steel can be produced in the form of standard geometry ribbed reinforcement bars. The unique properties of the material can be utilized in a pre-stressed form of the near-surface mounted (NSM) strengthening technique using grooves in the concrete cover for building components in flexure. A PhD project at Empa aims at acquiring in-depth knowledge about the characteristics of the material, its bond in the grooves and its application by means of small to large-scale experiments as well as numerical investigations.

Research (2017–2021) sponsored by: Swiss National Science Foundation (SNF), Project No. 200021_175998/1

Additional information:
https://www.empa.ch/web/s303/advanced-structural-materials



Above: principle of near-surface mounted reinforcement (NSMR), Below: ribbed memory steel bars.

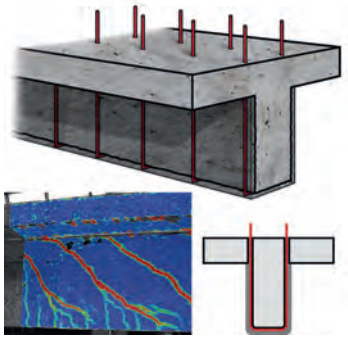
Prestressed shear strengthening of RC beams

Main investigators: M. Shahverdi, C. Czaderski, J. Michels (Company re-fer)

In this project, ribbed memory steel bars produced by the company re-fer are used in combination with shotcrete for shear strengthening of reinforced concrete (RC) structures. The prestressing has the advantage that the shear cracks width can be reduced and new shear cracks occur under higher loads. The results so far show the feasibility of memory steel shear reinforcement. Large-scale experiments on T-beams with a length of 5.2 m are performed in order to study the practical application and effectiveness of memory steel for the prestressed shear strengthening of concrete beams.

Research (2016–2019) sponsored by: Innosuisse, CTI Project No. 18528.1 PFIW-IW, Industry Partner: re-fer, Brunnen, Switzerland

Additional information:
https://www.empa.ch/web/s303/advanced-structural-materials



Schematic illustration of ribbed memory steel bars in shotcrete application for shear strengthening of RC beams and the shear cracks of the reference test beam measured with DIC.

Haute école d'ingénierie et d'architecture Fribourg HEIA-FR

institut des Technologies de l'Environnement Construit iTEC

Construction with wood-cement compounds and timber

Main investigators: D. Zwicky, N. Macchi, A. Fridez, V. Sciboz, M. Maeder, M. Medziti

Pourable lightweight wood-based concretes (or wood-cement compounds, WCCs, respectively) were developed and assessed with respect to structural properties, targeting their structural combination with timber.
Composite slab and wall elements were conceived and evaluated experimentally and analytically in full-scale tests up to rupture and for long-term behaviour. Practical structural design approaches were also derived.
Further assessments targeted properties of thermal and fire protection, recyclability, eco-balance and economic competitiveness. Possible use in residential, office and school buildings was proven.

Research (2012–2017) sponsored by:
– Swiss National Science Founda-tion, project 4066-40_136918
– Univ. of Applied Sciences and Arts of Western Switzerland
– ERNE Holzbau AG
– Vial Charpentes SA

Additional information:
– www.nfp66.ch > project Zwicky
– researchgate.net/profile/Daia_Zwicky

Timber-WCC slab in full-scale test.

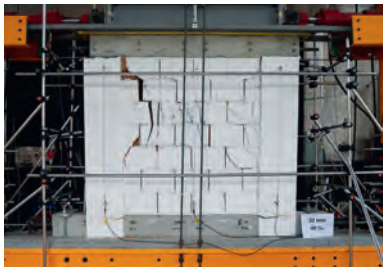
Thin UHPC layers to improve the seismic behaviour of structures

Main investigators: M. Devaux, D. Redaelli, M. Hayek, J. Moix

Ultra-High Performance Fibre-Reinforced Concrete (UHPFRC) allows for very thin (20–30 mm) but extremely resistant, robust and durable layers to be cast.
With their strength and ductility, cast-in-place or precast UHPC layers can be efficiently used as local reinforcement to improve the seismic behaviour of existing and new structural elements made of traditional materials (concrete, masonry and steel).
Experimental and theoretical research is ongoing to identify structurally and constructively optimized UHPC configurations, in order to provide engineers with practical design guidelines.

Research (2015 to date) sponsored by:
– Univ. of Applied Sciences and Arts of Western Switzerland
– Industrial partners

Additional information:
itec.heia-fr.ch/FR/Projets



Cyclic test on masonry wall element with U-shaped corner strengthening made of thin UHPFRC layers.

Lucerne University of Applied Sciences and Arts

Competence Centre for Structural Engineering (CC KI)

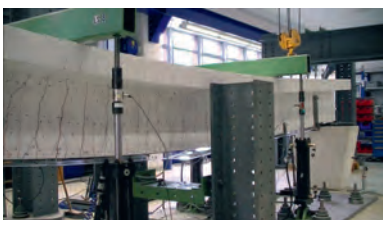
New development of a CRFP tensioning system

Main investigators: H. Stempfle, L. Abächerli, G. Borkowski

The tensioning system developed in the past by StressHead AG and Lucerne University, was well received nationally and to an extent internationally in the area of component reinforcement. The anchors used to date required at times that existing reinforcement to be severed. For this reason, the tensioning system with anchors was further developed for beams and slabs so that force can be applied without damaging the existing reinforcement. In addition, a design concept for the system was developed.

Research (2012–2015) sponsored by:
– Innosuisse
– Stresshead AG

Additional information:
https://www.hslu.ch/de-ch/hochschule-luzern/forschung/projekte/detail/?pid=3927



Four-point bend test of the untensioned beam strengthened with CRFP tensioning system.

Post-tensioning anchor with highly resilient load introduction zone

Main investigators: H. Stempfle, M. Switalla, E. Schurtenberger

The challenges involved in pretensioning systems include force introduction and their mechanical constraints and engineering design while at the same time managing to find an economic solution. The objective of the project was to develop post-tensioning anchors for flat slabs that would allow for the post-tensioning of concretes with a lower early strength, for the benefit of good construction progress. The load introduction zone was to be optimised at the same time. As part of the work, a model for force introduction in concrete was developed, taking compressive stress and tensile stress into consideration.

Research (2013–2016) sponsored by:
– Innosuisse
– VSL AG

Additional information:
https://www.hslu.ch/de-ch/hochschule-luzern/forschung/projekte/detail/?pid=3930

Pre-tensioned double-span slab: injection of tension cables.

Fatigue of bridge decks subjected mainly to bending forces

Main investigators: K. Thoma, G. Borkowski, P. Roos

Within the framework of an FEDRO project (Swiss Federal Roads Office), a fatigue test on reinforced concrete components was planned, carried out and analysed taking into consideration the membrane state of stress (CMA) . In addition, the influence of a CMA on the steel stress amplitudes using non linear finite elements analysis of case studies and samples was discussed. In a parameter study, the influence of key parameters (bond stiffness, flexural strength, etc.) on the CMA and the resulting steel stresses were demonstrated.

Research (2011–2018) sponsored by:
Swiss Federal Roads Office

Additional information:
https://www.hslu.ch/de-ch/hochschule-luzern/forschung/projekte/detail/?pid=767

Fatigue test of bridge deck.

Lucerne University of Applied Sciences and Arts

Competence Centre for Structural Engineering (CC KI)

Efficient construction of frame corners in reinforced concrete

Main investigators: D. Heinzmann, K. Thoma, H. Stalder, A. Jäger

The research project aims at developing a simple, efficient reinforcement layout for frame corners, which should enable a complete transfer of the load-bearing resistance of the adjacent components. The load-bearing behaviour of these frame corners is verified experimentally with component tests and an associated design concept is developed based on the Stringer table model.
The result is an economical and practical reinforcement layout for reinforced concrete construction. In further research projects, financed by Innosuisse, prefabricated discontinuity reinforcement elements are developed for more productive and efficient use in reinforced concrete construction.

Research (since 2017) sponsored by:
cemsuisse

Fracture pattern of the test of a closing frame corner.

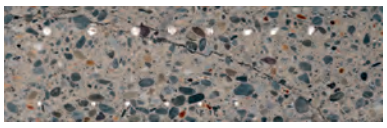
Punching of reinforced concrete slabs made from recycled concrete from mixed demolition waste

Main investigators: A. Kenel, M. Laurent, A. Jäger

The concrete building method is very common in Switzerland (and in all industrialised countries). To conserve gravel resources, concrete can be produced with recycled (mixed) demolition waste.
In the leaflet SIA 2030:2010, the punching of slabs made of recycled concrete from RC-M mixed granulate is treated very conservatively or as lightweight concrete due to the lack of test results.
This project is intended to enable the increased use of recycled concrete from mixed RC-M demolition waste in building construction, in particular for the slabs, and therefore to conserve the resource (primary) gravel.

Research (since 2017) sponsored by:
– City of Zurich
– F.J. Aschwanden AG
– Kibag AG
– Toggenburger AG

Additional information:
https://www.hslu.ch/de-ch/hochschule-luzern/forschung/projekte/detail/?pid=3870



Section of a tested punching slab.