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1 ANNUAL REVIEW OF THE INSTITUTE

1.1 EDITORIAL AND ANNUAL REVIEW OF THE INSTITUTE

Dear friends and partners of the Institute of Concrete and Masonry Structures,

Dear Sir or Madam,

This 33rd edition of "Darmstadt Concrete" informs you about the activities of the institute in research, teaching and committee work in the past year 2018 in a good tradition at the turn of the year. At the same time we would like to inform you about current personnel changes at the Institute of Concrete and Masonry Structures and thank all persons and institutions who have supported us in research and teaching in the past year. We hope you will find this overview of our activities interesting and enjoy reading it.

In the field of teaching, we can report that a total of 12 courses were offered in 2018 and that we taught more than 930 students the basics of concrete structures, masonry, prestressed concrete and bridge construction. Lectures and exercises were also offered on the contents of building service engineering, life cycle assessment of buildings, facility management as well as on questions of safety and reliability of buildings and structural dynamics. This broad range of our courses would not have been possible without the active support of a number of highly qualified lecturers and external speakers. We would like to take this opportunity to thank them all for their extraordinary, honorary commitment. In order to introduce students to scientific work, more than 25 bachelor theses and over 35 master theses were supervised in 2018. Our congratulations this year go especially to our graduates Ms. Melanie Stöcker, M.Sc. and Mr. Dominik Hiesch, M.Sc., who were awarded as best graduates of their year by the Department of Civil and Environmental Engineering in the spring and autumn of 2018. In addition, other graduates were able to win prestigious prizes. In this context, Ms. Olivia Schneider, B.Sc. and Mr. Marcel Killian, B.Sc. should be mentioned, who received this year's Dreßler Bau Award for their bachelor theses. Furthermore, Ms. Christina Dallinger, B.Sc. was awarded the Implenia Award 2018 for the best bachelor thesis in the category building construction.

Mr. Dominik Hiesch, M.Sc., received the sponsorship award of the “Freunde-Verein” for the best master thesis in the field of concrete and masonry construction. Mr. Lukas Bujotzek, B.Sc. received the prize of the “Fachvereinigung Deutscher Betonfertigteilbau e. V.” for academic achievements in the field of prefabricated concrete structures, which was awarded for the second time.

Dr.-Ing. Moien Rezvani was awarded the Kurt-Ruths-Prize for his outstanding dissertation on the subject "*Shrinkage model for concrete made of limestone-rich cements*", which he received at a ceremony on 14th February 2018 in the Georg-Christoph-Lichtenberg-Haus. The prize of the “Freunde-Verein” for the best dissertation went to **Dr.-Ing. Claudia Weißmann** for her work "*Effizienter Einsatz erneuerbarer Energieträger in vernetzten Wohnquartieren*". We congratulate both winners and thank cordially all prize donators.

In 2018 our team worked on numerous research projects. The project "Entwicklung einer thermischen Entkoppelung von Stahlbetonwänden im Wand-Deckenknoten" was completed. However, a number of new research proposals were also successfully approved. In this context, we are very proud of the joint acquisition of the major project "E4Q - Einbindung erneuerbarer Energieträger in die Energieversorgung vernetzter Quartiere" at the Federal Ministry for Economics and Energy, which we implemented together with the IWU Institute. As part of the large-scale project C³ Carbon Concrete Composite of the Federal Ministry of Education and Research, we were commissioned to work on the research project "C³-V4.19 - Carbonbewehrte Parkhausdeckenplatten". The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) has entrusted us with two new projects on the "Entwicklung von basaltbewehrten Deckenplatten für den Wohnungsbau" and on the topic "Modifizierte Teilsicherheitsbeiwerte für Mauerwerkswände im Bestand", the processing of which has just started. Together with the Federal Institute for Materials Research and Testing in Berlin, we were successful with an application at the German Federal Environmental Foundation (DBU) for "Schaffung von Bemessungsgrundlagen für Lehmmauerwerk auf Basis von DIN EN 1996/NA mittels experimenteller und numerischer Untersuchungen".

We would like to inform you that in January 2018, on the decisive initiative of Prof. Graubner, the German Masonry Committee (Deutscher Ausschuss für Mauerwerk e. V. / DAfM) was founded. The purpose of the association is to promote scientific research of masonry, in particular by drawing up guidelines, exchanging and publishing research results and participating in

standardization projects in the department 06 of the NABau in DIN e. V. Prof. Graubner was elected Vice Chairman of the DAfM and appointed Chairman of the Research Advisory Board of the DAfM.

Since April 2018, our employee Ms. Marleen Fischer, M.Sc., has been involved in the Kopernikus research project "Energiewende-Navigationssystem ENavi" (Federal Ministry of Education and Research) under the direction of Professor Oechsner of the Material- und Prüfanstalt of TU Darmstadt. Ms. Marleen Fischer, M.Sc. is also an associate member of the “Darmstadt Graduate School of Excellence Energy Science and Engineering”. In this context, we would like to thank the Darmstadt Graduate School for the fact that two of its scholarship holders are currently able to do their research at our institute.

In addition to presenting what we have achieved, this annual review should also serve to thank our employees for their work and commitment. Without the high quality and the untiring commitment with which our scientists, as well as our employees in the secretariat, in the technical service and in the laboratories approach their tasks and projects, the achievements and success of our institute in 2018 would not have been possible.

In the past year, two former institute employees completed their doctorates. We congratulate them on this:

Dr.-Ing. **Valentin Förster**:	*Tragfähigkeit unbewehrter Beton- und Mauerwerksdruckglieder*
Dr.-Ing. **Jaroslav Kohoutek**:	*Zuverlässigkeit integraler Straßenbrücken in Massivbauweise*

Dr.-Ing. Kohoutek has already been working in a responsible position at Deutsche Bahn since 2015, while Dr.-Ing. Förster moved to an engineering office in Frankfurt am Main as a structural engineer at the beginning of 2018. Dr.-Ing. Claudia Weißmann, who now works for a consulting firm, has also left the Institute of Concrete and Masonry Structures, while Larissa Krieger, M.Sc. returned to the institute after her parental leave to continue her doctoral project.

This year, **Dr.-Ing. habil. Ngoc Linh Tran** successfully completed his habilitation and received the venia legendi for concrete structures. His habilitation thesis is entitled "Shear strength of slender RC members without shear reinforcement". Dr.-Ing. habil. Ngoc Linh Tran will stay at the Institute of Concrete and Masonry Structures as a postdoctoral researcher.

We welcome our new employees:

Mr. **Christian Herget, M.Sc.** as of 01st March 2018

Mrs. **Dipl.-Ing. Martina Lohmeier** as of 01st October 2018

Mr. **Dominik Hiesch, M.Sc.** as of 01st April 2019

At this point we would like to congratulate **Prof. Eric Brehm** on his professorship for reinforced concrete and masonry structures at the Hochschule Karlsruhe - Technik und Wirtschaft and **Prof. Christian Glock** on his professorship for concrete and masonry structures at the Technische Universität Kaiserslautern. Now five former research assistants of the Institute of Concrete and Masonry Structures under direction of Professor Graubner hold a professorship at a German university:

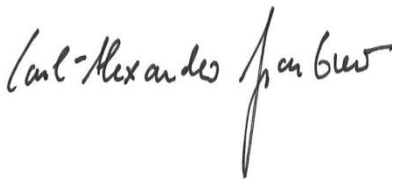
Prof. Dr.-Ing. **Eric Brehm**	Hochschule Karlsruhe - Technik und Wirtschaft
Prof. Dr.-Ing. **Andreas Garg**	Hochschule Mainz
Prof. Dr.-Ing. **Christian Glock**	Technische Universität Kaiserslautern
Prof. Dr.-Ing. **Eric Simon**	Technische Hochschule Nürnberg
Prof. Dr.-Ing. **Benjamin von Wolf-Zdekauer**	Hochschule Mainz

Last but not least, we would also like to take this opportunity to thank the Verein der Freunde des Instituts für Massivbau der TU Darmstadt e.V., without whose support many small but also large projects at and for the institute and the students would not have been possible. We would like to take this opportunity to thank the Chairman of the Board, Dr.-Ing. Michael Six, the Treasurer, Dipl.-Ing. Dieter Hanek, as well as the members of the Board, Prof. Dr.-Ing. Katharina Klemt-Albert, Dr.-Ing. Gert Riegel and Dr.-Ing. Gerd Simsch, who constantly advise and support us in many ways.

The following short reports in both German and English give you a brief insight into the scientific activities of our employees. If you are interested, please contact us. A compilation of the scientific publications of our staff in 2018 as well as further information can be found on the homepage of the institute:

http://www.massivbau.tu-darmstadt.de/massivbau

On behalf of the entire Institute for Concrete and Masonry Structures, we wish you and your relatives a Merry Christmas and a Happy New Year.



Univ.-Prof. Dr.-Ing. Carl-Alexander Graubner



Dr.-Ing. Tilo Proske

1.2 COLLABORATION IN STANDARDISATION COMMITTEES

In 2018, Prof. Graubner will continue his occupation as the chairman of the standardisation committee NA 005-06-01 AA “Masonry Structures”, the leading national standards committee dealing with issues of standardisation in the field of masonry structures. In addition, Prof. Graubner will act as Vice Chairman of the Steering Board NABau Fachbereich 06 “Masonry Structures”. This board is the top level DIN standardisation committee in the field of masonry structures and coordinates all national and international standardisation activities. Prof. Graubner also acts as the German delegate on the European level and is member of the European standardisation committees Scientific Committee 6 and Working Group 1 as well as director of Project Team 2 for the revision of DIN EN 1996-3. Furthermore, Prof. Graubner is an elected member of the standardisation committee NA 005-07-01 AA “Design and Construction of Reinforced Concrete”. As a long-standing member of several expert committees of the German Centre of Competence for Construction (DIBt) in Berlin and of several subcommittees of the German Committee for Structural Concrete DAfStb, he also contributes his expertise in the approval of construction products and in the drafting of guidelines.

Prof. Graubner is member of the editorial advisory board of the journal "Mauerwerk" since 2012 and author of the chapter "Mauerwerk" in the well-known "Schneider Bautabellen" since 2016 as well as editor and co-author of the book "Mauerwerksbau - Praxishandbuch für Tragwerksplaner", in which the latest developments in research and practice in the field of masonry construction are published.

In 2018 Prof. Graubner was elected Vice Chairman of the German Masonry Committee (DAfM) and appointed Chairman of the Research Advisory Board of the DAfM.

Further on, Prof. Graubner is a representative expert of the “Graduate School of Energy Science and Engineering”.

To establish research in the field of fibre-reinforced polymer reinforcement, employees represent the Institute of Concrete and Masonry Structures in the subcommittee "Non-Metallic Reinforcement" of the German Committee for Structural Concrete.

Overview of committee work at the Institute of Concrete and Masonry Structures:

Deutsches Institut für Normung e.V. (DIN)

- NA 005-01-31 AA Nachhaltiges Bauen (Sp ISO/TC 59/SC 17 und CEN/TC 350)
- NA 005-51 FBR Fachbereichsbeirat KOA 01; Mechanische Festigkeit und Standsicherheit
- NA 005-06 FBR Lenkungsgremium Fachbereich 06 – Mauerwerksbau
- NA 005-06-01 AA Mauerwerksbau (Spiegelausschuss CEN/TC 125, CEN/TC 250/SC 6)" (Obmann)
- NA 005-06-33 AA Mauerwerk; Bauten aus Fertigbauteilen (Obmann)
- NA 005-07-01 AA Bemessung und Konstruktion (Sp CEN/TC 250/SC 2)

Deutsches Institut für Bautechnik (DIBt)

- SVA „Beton-, Stahlbeton und Spannbetonbauteile“ A (413) und B1 (413 a)
- SVA „Bewehrungselemente“ B3 – (413c)
- SVA „Stahlfaserbeton“ A (449) und B (449a)
- SVA „Wandbauelemente, Mauerwerk“ B1 und B2
- SVA „Bauteile aus Faserbeton und textilbewehrtem Beton“ (71A und 71B)

Deutscher Ausschuss für Stahlbeton (DAfStb) im DIN

- TA Bemessung und Konstruktion (Sp CEN/TC 250/SC 2)
- TA Bemessung und Konstruktion „Unterausschuss Stahlfaserbeton“
- TA Bemessung und Konstruktion „Unterausschuss Nichtmetallische Bewehrung“

Féderation International du Béton (fib)

- C2 „Safety and performance concepts“

Comitée Européen de Normalisation (CEN)

- CEN/TC 250/SC 6 „Design of masonry structures“
- CEN/TC 250/SC 6/WG 1 „Evolution of EN 1996-1-1 – General rules for reinforced and unreinforced masonry structures“
- CEN/TC 250/SC 6/WG 2 „Simplified calculation methods“
- CEN/TC 250/SC 6/WG 2/PT 2 „Revised version of EN 1996-3“

Weitere Ausschüsse

- JCSS – Joint Committee on Structural Safety
- Forschungsbeirat der Deutschen Gesellschaft für Mauerwerksbau (DGfM)
- American Concrete Institute (ACI)
- Réunion International de Laboratoire et de Matériaux (RILEM)
- Verband Deutscher Betoningenieure e.V. (VDB)

1.3 SEMINARS AND EVENTS

1.3.1 TRAINING SEMINAR FOR STRUCTURAL ENGINEERS

Like the last years before the Institute of Concrete and Masonry Structures again cordially invited structural engineers to the 2018 seminar series "Training seminar for structural engineers - from practice for practice". 21 referents in six seminars could show some exiting notes from praxis and also from the current status of research and standardisation to over 500 participants over the year. The seminar series in 2018 gave an overview of the latest technical developments in civil engineering. In spring the issues of energy efficient buildings according to EnEV 2016 and GEG, innovative reinforcement for concrete elements and the indirect action in concrete structures were treated. In autumn the lectures dealt with fire protection, Building Information Modeling (BIM) and design of formwork. Below you find all six individual seminars:

- Energy efficient buildings according to EnEV 2016 and GEG | 28th February 2018
- Innovative reinforcement for reinforced concrete members | 07th March 2018
- Indirect action in concrete structures | 21st March 2018
- Fire protection | 12th September 2018
- Building Information Modelling (BIM) | 26th September 2018
- Design of formwork | 10th October 2018

Due to the positive feedback and high attendance in the past years, we will organise the seminar again in 2019. We are confident that the combination of interesting topics and renowned speakers will again attract many structural engineers. The topics of the seminars in 2019 are shown below:

- Interpretation questions of the Eurocode 2 | 27th February 2019
- Special dimensioning problems | 13th March 2019
- Planning law and planning liability | 27th March 2019
- Cracks - mechanical background, calculation, repair | 28th August 2019
- Innovative construction products | 18th September 2019
- FE-calculation and modelling | 25th September 2018

Seminar updates as well as the registration can be found on the homepage of the Institute of Concrete and Masonry Structures (www.massivbau.tu-darmstadt.de) under the section „Veranstaltungen". In case of questions, please do not hesitate to contact Mr. Christian Herget, M.Sc.

1.3.2 DARMSTADT SEMINAR FOR CONCRETE AND MASONRY

The “Verein der Freunde des Instituts für Massivbau der TU Darmstadt e. V.” in 2019 also cordially invites to the 40th Darmstadt Seminar for Concrete and Masonry Structures (Darmstädter Massivbauseminar) in the MERCK Innovation centre under the heading: “Frankfurt Skyscraper Conference”. The Frankfurt Skyscraper Conference will deal with the challenges, chances and risks during construction and operation of skyscrapers. Planners, executives and operators report from praxis, present innovations and create a bridge between common and new strategies in building a skyscraper.



Figure 1 Darmstadt seminar for concrete and masonry structures

For the presentation sessions we are proud to present you some notable lecturers out of practice and research and development, who use examples to illustrate the challenges and opportunities of high-rise construction. Integrated discussions and conference breaks offer the opportunity for personal and professional exchange as well as for establishing new networks.

The following speakers could be won for the 40th Darmstädter Massivbauseminar:

Frankfurter Hochhauskonferenz **04. April 2019**

Programm

08:30 **Anmeldung**

09:00 **Begrüßung**
Dr.-Ing. Michael Six
Vorsitzender des Vorstandes der Freunde des Instituts für Massivbau der TU Darmstadt e.V.

09:15 **Hochhausboom in Frankfurt - Trends und Herausforderungen**
Simone Zapke, leitende Magistratsdirektorin
Amtsleiterin Bauaufsicht Frankfurt am Main

09:45 **Resiliente Hochhausstrukturen: urban, langlebig, wandlungsfähig**
Dipl.-Ing. Architekt S.M. Arch./MIT Jürgen Engel
KSP Jürgen Engel Architekten

10:30 **Kaffeepause**

11:00 **Entwicklung von Hochhäusern in Frankfurt**
Prof. Dipl.-Ing. Volkmar Agthe
Tishman Speyer Properties

11:40 **Digitalisierung: Innovative Betriebskonzepte**
Dr.-Ing. Gert Riegel
Apleona HSG Facility Management

12:10 **Höher, schneller – Fertigteile? Rationelle Hochhauskonstruktionen**
Dr.-Ing. Hubert Bachmann
Ed. Züblin AG

12:45 **Mittagspause**

13:30 **3D-Modellierung kombinierter Pfahl-Platten-Gründungen am Beispiel des Projektes FOUR**
Prof. Dipl.-Ing. Hubert Quick
Quick und Kollegen - Ingenieure und Geologen

14:00 **Zeitgemäße Hochhaus-Tragwerke: Entwurf und Berechnung**
Dr.-Ing. Gerd Remmel
RSP Remmel + Sattler Ingenieurgesellschaft

14:45 **Besonderheiten bei der statischen Prüfung räumlich modellierter Tragkonstruktionen von Hochhäusern**
Univ.-Prof. Dr.-Ing. Carl-Alexander Graubner
Dr.-Ing. Guido Hausmann
König und Heunisch Planungsgesellschaft

15:30 **Kaffeepause**

16:00 **Internationale Trends im Hochhausfassadenbau**
Dr.-Ing. Andreas Bachmann
Seele GmbH & Co. KG

16:30 **Brandschutztechnische Bemessung hoher Gebäude – Stand der Technik und normative Entwicklung**
Univ.-Prof. Dr.-Ing. Jochen Zehfuß
Technische Universität Braunschweig

17:00 **MULTI: Ein innovatives, seilloses Aufzugskonzept für moderne Hochhäuser**
Prof. Dipl.-Ing. Michael Cesarz
MULTI thyssenkrupp Elevator

17:30 **Schlusswort**
Dipl.-Ing. Dieter Hanek
Mitglied des Vorstandes der Freunde des Instituts für Massivbau der TU Darmstadt e.V.

Figure 2 Schedule of the Frankfurt Skyscraper Conference

For up-to-date informations or registration visit the homepage of the Institute of Concrete and Masonry Structures **www.massivbau.tu-darmstadt.de**. Mr. Christian Herget, M.Sc. and Dr.-Ing. Moien Rezvani are at your disposal as contact persons.

1.3.3 DARMSTADT DAYS OF PREFABRICATED CONCRETE ELEMENTS

Due to our cooperation with the professional association “Fachvereinigung Deutscher Betonfertigteilbau e. V. (FDB)” and the “InformationsZentrum Beton”, we were able to host the renowned seminar series “Darmstadt Days for Prefabricated Concrete Elements” in 2018 for the 11th time. The presented topics varied from the characteristics of prefabricated constructions, which already begin with the initial sketch, to special construction elements and corresponding methods, such as job-mixed additions or prestressed constructions. Further, stability considerations define a focal point with examples, such as lateral buckling and the design and construction of the connections. In this year, about 80 structural engineers and students participated in the event. The seminars were complemented by an exhibition of renowned manufactures of construction products related to the topic of precast construction.

In the upcoming year, the seminar series with interesting lectures, practical examples and our well-attended exhibition is going to be celebrated for the 12th time. We are confident to attract a highly diversified audience with a combination of interesting topics and renowned speakers form science and practice. The following topics will be discussed in the upcoming seminar series in spring 2019:

14th March 2019 | Basic Principles of Planning and Trends

15th March 2019 | Prefabricated Concrete Structures

21st March 2019 | Fire Protection Requirements und Connections

22nd March 2019 | Concrete and Façade

Generally speaking, the seminar content is tailored towards engineers from practise. However, a separate “student day” takes place in which the design of precast concrete elements will be treated. Thus, the lecture “Prefabricated Constructions”, which takes place in the context of the Darmstadt days of prefabricated concrete elements, can be incorporated into the student’s study design. Since 2017, the FDB sponsors the "FDB Förderpreis". This prize is awarded to the best graduate of the lecture “Prefabricated Constructions”. In 2018 the prize, which was awarded during the summer party of the “Verein der Freunde des Instituts für Massivbau”, went to Mr. Lukas Bujotzek, B.Sc.

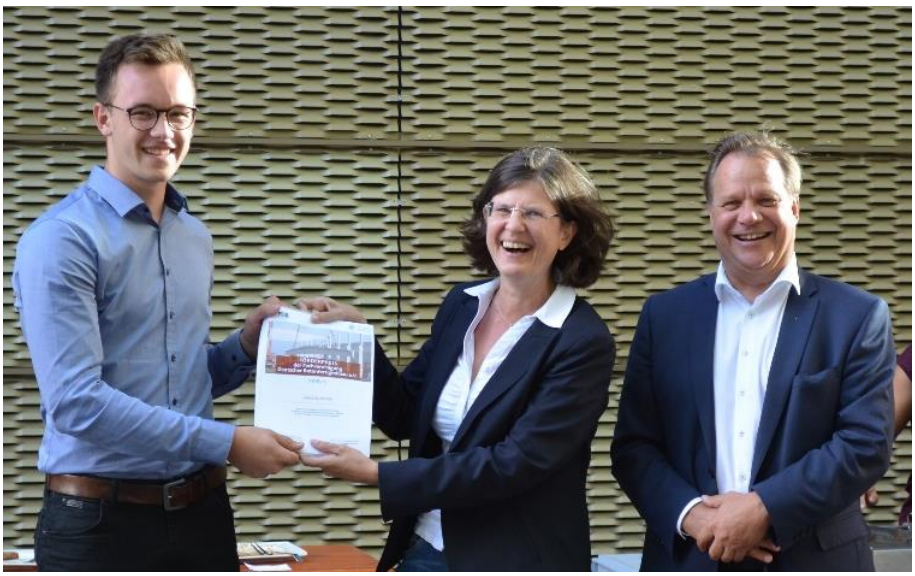


Figure 3 Awarding of the "FDB Förderpreis" 2018 (from left to right: Lukas Bujot-zek, Elisabeth Hierlein (FDB e.V.), Prof. Graubner (TU Darmstadt))

Update on the event can be found on the homepage of the Institute of Concrete and Masonry Structures (www.massivbau.tu-darmstadt.de). Enter the section named „Veranstaltungen“. In case of questions, please don’t hesitate to contact Mr. Jonas Klein, M.Sc.

1.4 EXCURSIONS

1.4.1 ANNUAL WHIT EXCURSION OF TU DARMSTADT AND TU KAISERSLAUTERN

This year again the joint excursion of the Institute of Concrete and Masonry Structures of the TU Darmstadt (Professor Graubner) and the Institutes of Steel Structures and Concrete Structures of the TU Kaiserslautern (Professors Kurz and Glock) took place. In the week after Whitsun, from 22nd May 2018 to 25th May 2018, this year's excursion took us to the neighbouring Netherlands. Besides many technical and architectural impressions, the cultural program was not neglected.

On the first day of the excursion, the group visited the construction site of the Gateway Gardens in Frankfurt am Main. It is a new industrial area which is going to be connected by a new S-Bahn tunnel. After an informative morning, we went on to the TU Eindhoven in the Netherlands, where we listened to exciting lectures on damage cases and 3D concrete printers and were allowed to visit the testing laboratories and technical facilities. Afterwards the group let the evening end at the Delft Beestenmarkt.

On day 2, the group headed towards The Hague, where the Rotterdamsebaan tunnel construction project was visited. Christoph Hennings and Kersten Dengler (Wayss&Freytag Ingenieurbau AG) explained both the technical and infrastructural aspects of the megaproject as well as the structural design implementation. Afterwards we visited the company FiberCore in Rotterdam. After an interesting lecture in the Rotterdam Science Tower on the composition and properties of fibre-reinforced polymer structures, we were allowed to visit the factory halls. Here the different production steps as well as finished products could be examined. On day 3 it was possible for us to visit a glass fibre reinforced bridge of the company FiberCore.

On the third day the group departed to Amsterdam. At first there was a very interesting city tour. HOCHTIEF then invited the travel group to a snack in the Campus Café. After a refreshment, an impressive presentation was given on their recently completed SAAone project. Two engineering structures could be approached and inspected together with the responsible site manager by bus. After the return trip to Delft, we went to dinner at Het Koningshuys in the evening. After a relaxed dinner with our guest of honour, Professor Walraven, the group moved on and celebrated together until the early hours of the morning.

On the last day we went to Hamm to Goldbeck's precast factory. After a safety briefing, the group was guided through the factory, which consists of four halls and storage areas. After the

tour, the company was presented before the group returned home. We would especially like to thank the organising committee as well as all involved persons and companies, who welcomed us not only with great background information, lectures, videos, snacks and drinks, but also with guided tours and gifts!



Figure 4 Participants of the excursion on the construction site of Gateway Gardens

Redouan El Ghadioui

1.4.2 EXCURSION OF BSE AND SFM & SD

As part of the lectures Building Service Engineering I and Strategic Facility Management & Sustainable Design a study trip to the Energy Campus and production site of Stiebel Eltron took place on Friday, 15th December 2017. Fifteen students accompanied by three research assistants and Mr. Dipl.-Ing. Thomas Heß visited Stiebel Eltron, which is a leading manufacturer of heating systems and industrial energy systems with its headquarter in Holzminden.

First, the company´s history was presented as well as the products and background information on Stiebel Eltron's strategy to manufacture most of its product in Germany and Europe. After this introduction, leading technologies for heat supply, air ventilation and domestic hot water supply were presented in several showrooms. As part of this, the students had the chance to gain a deeper understanding of the principles of operation of these systems. Finally, a guided tour to the production lines of heat pump systems and instantaneous water heaters enabled students and research assistants to understand the complexity of manufacturing processes for technical systems for heat and domestic hot water supply.



Figure 5 Participants of the study trip visiting the Energy Campus of Stiebel Eltron, Holzminden

On behalf of all participants, the Institute of Concrete and Masonry Structures thanks Mr. Engelmann and Mr. Riemenschneider (both employees of Stiebel Eltron) for organizing the study trip and guiding the interesting tour onsite. This trip was possible only due to the generous support of the company Stiebel Eltron and the "Freunde des Instituts für Massivbau der TU Darmstadt e.V.", to whom we express our sincere thanks.

André Müller

1.5 PERSONAL MATTERS



Since January 2018, **Ms. Marleen Fischer, M.Sc.** is employed at the Institute of Concrete and Masonry Structures. Ms. Fischer studied civil engineering with the specialization in facility management, building physics and building construction and geotechnical engineering at the TU Darmstadt. During her studies, she worked as a student assistant at the Institute and Laboratory of Geotechnics and at the Institute KGBauko. At this institute, she worked as a second supervisor of the course “Green Building II” exemplarily. As part of her doctorate at the Institute of Concrete and Masonry Structures, Ms. Fischer will initially be responsible for the courses “Strategic Facility Management and Sustainable Design” and “Building Service Engineering II”. Later on, she will participate in the research project “E4Q” which will be processed from December 2018 in cooperation with the Institute for Housing and Environment. Topic of this project is to analyse the integration of renewable energies into the energy supply of residential and mixed districts energetically, ecologically and economically. Since August 2018 Ms. Fischer has been associate member of the Graduate School of Energy Science and Engineering of the TU Darmstadt.



Mr. Jonas Klein, M.Sc. has been working at the Institute of Concrete and Masonry Structures since 1st January 2018. Mr. Klein studied civil engineering at the TU Darmstadt, specialising in structural engineering. During a stay abroad in Hanoi, Vietnam, he wrote his master thesis "Research on the structural behaviour of reinforced concrete members strengthened with TRC" concerning the subsequent strengthening of reinforced concrete members with textile reinforced concrete. After completing his studies, Mr. Klein worked as a project engineer at bauart Konstruktions GmbH in Darmstadt. His work included the planning of construction tasks in the field of structural engineering as well as the evaluation of existing structures. As part of his activities at the Institute of Concrete and Masonry Structures, Mr. Klein will be in charge of the lectures "Concrete Structures I/II" and "Prefabricated Concrete Structures".



Since April 1st 2018 **Mr. Christian Herget, M.Sc.** is employed at the Institute of Concrete and Masonry Structures. Mr. Herget studied civil engineering with specialisation in concrete an masonry structures, traffic and transportation and geotechnical engineering at the Technical University Darmstadt. In his master thesis about shrinkage of concrete for application in infrastructural constructions he already dealt with the topic of shrinkage and the ecological improvement of concrete as a mass building material. At the institute he is working on a research project about shrinkage of concrete with a low clinker content made of limestone rich cements. Cements are to be made more ecological and thus more environmentally friendly through improved concrete technology and the replacement of the main component cement clinker by ground limestone. Besides his research project he is organising the seminar „Training seminar for structural engineers - from practice for practice“. This annual series of six seminars with changing topics attract more than 500 participants in the field of structural engineering and architecture every year.



Since 1st October 2018, **Dipl.-Ing. Martina Lohmeier** works at the Institute of Concrete and Masonry Structures as an external employee and doctoral candidate.

As part of her tasks at the Institute of Concrete and Masonry Structures, Mrs. Lohmeier will supervise the course "Strategic Facility Management and Sustainable Design".

1.6 AWARDS

1.6.1 AWARDS OF THE „FREUNDE-VEREIN“

The annual award of the „Verein der Freunde des Instituts für Massivbau der TU Darmstadt e.V.“ for the outstanding dissertation at the Institute in 2018 was awarded to **Dr.-Ing. Claudia Weißmann**. She wrote her doctoral thesis on " *Effizienter Einsatz erneuerbarer Energieträger in vernetzten Wohnquartieren* ".

We congratulate Dr.-Ing. Claudia Weißmann very much to this success!

In addition to the award for the outstanding dissertation at the Institute of Concrete and Masonry Structures, the „Freunde-Verein“ also awards a prize to the student with the best master thesis at the institute, which is donated by the GOLDBECK company. The prize was awarded this year to **Ms. Melanie Stöcker, M.Sc.** for her thesis titled "*Untersuchungen zum Nachweis gegen Ermüdung vorgespannter Straßenbrücken im Bestand*“. This work was supervised by Mr. Redouan El Ghadioui, M.Sc.

We congratulate **Ms. Stöcker** very much!



Figure 6 Awarding the prizes of the „Freunde-Verein“ on the annual summer party

1.6.2 DREßLER BAU AWARD

The Dreßler Bau Award was awarded for the sixth time on 14th November 2018 for outstanding bachelor theses in the fields of concrete and masonry structures and construction management. This year, the award was divided between two students of the Institute for Concrete and Masonry Structures:

- **Award winner:** **Ms. Olivia Schneider, B.Sc.**
  Title of Bachelor Thesis: Research on the bending-behavior and shear force resistance of carbon-fiber and steel-reinforced concrete
  Betreuer: Mrs. Larissa Krieger, M.Sc.
  Mr. Sebastian Hofmann, M.Sc.
- **Award winner:** **Mr. Marcel Kilian, B.Sc.**
  Title of Bachelor Thesis: Comparison of different methods to determine deformations of reinforced slabs under long-term loading
  Betreuer: Mr. Redouan El Ghadioui, M.Sc.

We congratulate to this success!



Figure 7 Olivia Schneider (Award winner IfM), Tobias Mann (Dreßler Bau), Marcel Kilian (Award winner IfM) und Anna-Lena Schmidt (Award winner Institut for Concrete Management); Picture: Gregor Rynkowski

1.6.3 REAL ESTATE RESEARCH AWARD

Dr.-Ing. Claudia Weißmann was awarded 2nd place in the real estate research award 2018 of the “Gesellschaft für Immobilienwirtschaftliche Forschung (gif)” for her dissertation "*Efficient Use of Renewable Energy Sources in Networked Residential Quarters*", endowed with €2,500.

The real estate research award has been awarded since 1995 and serves to network science and research in the real estate sector.

The work, which has now received an award, was created during Dr. Weißmann's work at the Institute of Concrete and Masonry Structures.

We congratulate Dr.-Ing. Claudia Weißmann on this award and wish her all the best for her future career!

1.6.4 IMPLENIA AWARD

Together with universities, Implenia promotes sciences and students. For this reason, the Implenia Award was awarded between 15th and 16th November 2018 at the "Neue Messe Essen" project. Committed students from the field of civil engineering were honoured for their outstanding bachelor theses.

This year, **Ms. Christina Dallinger, B.Sc.** received the Implenia Award in the building construction category for her Bachelor Thesis "*Untersuchung praxisgerechter Ansätze zur Bewertung der Robustheit von Tragwerken*". The Bachelor Thesis was supervised by Mr. Dominik Müller, M.Sc.

We congratulate very much to this success.

1.6.5 KURTH-RUTHS-AWARD

On 14th February 2018, **Dr.-Ing. Moien Rezvani** was awarded with Kurt-Ruths prize 2018 with a value of 20,000 € for his dissertation "*Shrinkage model for concrete made of limestone-rich cements*". The Kurt-Ruths prize is awarded annually by families Dr. Harald Ruths and Andrea Ruths-Tillian for outstanding dissertations of faculties architecture, civil and environmental engineering and chemistry of Technische Universität Darmstadt.



Figure 8 Group photo (left to right): Award winner Dr.-Ing. Moien Rezvani, award sponsor Andrea Ruths-Tillian, president of TU Darmstadt Professor Hans Jürgen Prömel and award sponsor senator E.h. Dr. Harald Ruths (Photo: Gregor Rynkowski)

We would like to congratulate Dr.-Ing. Moien Rezvani on this outstanding success and are delighted that he has been appointed to a postdoctoral position at the Institute of Concrete and Masonry Structures.

1.7 ACKNOWLEDGEMENTS

Without the support of the following organisations we would not have been able to perform our work in research and education in its entirety during the past year:

Apleona HSG GmbH
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Birco GmbH
BT3 Betontechnik GmbH
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Bundesanstalt für Straßenwesen
Bundesministerium für Bildung und Forschung
Bundesministerium für Verkehr und digitale Infrastruktur
Bundesministerium des Innern, für Bau und Heimat**B**undesverband der Deutschen Ziegelindustrie
Bundesverband der Kalksandsteinindustrie e.V.
Bundesverband Porenbetonindustrie e.V.
Bundesverband Deutsche Beton- und Fertigteilindustrie e.V.
Bundesverband Leichtbetonzuschlagindustrie e.V.
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Deutsche Bundesstiftung Umwelt (DBU)
Deutsche Forschungsgemeinschaft (DFG)
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Deutsche Poroton GmbH
Deutscher Ausschuss für Stahlbeton
Deutscher Beton- und Bautechnik-Verein e.V.
Deutsches Institut für Bautechnik
Dreßler Bau GmbH
Dyckerhoff AG
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Forschungsinstitut der Zementindustrie (FiZ)
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InformationsZentrum Beton GmbH
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Ingenieurconsult Cornelius Schwarz Zeitler GmbH
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König und Heunisch Planungsgesellschaft mbH & Co KG
LCEE Life Cycle Engineering Experts GmbH
Liapor GmbH & Co.
LohrElement GmbH
mako GmbH & Co. KG Schalungstechnik**M**APEI Betontechnik GmbH
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We want to express our gratitude for this support and hope for a successful cooperation in the future.

In teaching, a support by experts from the private sector, the industry, administration and organisations is necessary and highly appreciated, especially in order to include all practical aspects of civil engineering. For their personal commitment as visiting lecturers at our Institute we would like to thank the following persons:

Dr.-Ing. Herbert Duda	Applied Structural Dynamics
Dipl.-Ing. Thomas Heß	Building Service Engineering I + II
Dr.-Ing. Gert Riegel	Strategic Facility Management & Sustainable Design
Dr.-Ing. Georg Geldmacher	Concrete Bridges and Falsework

Furthermore, we would like to thank the following persons for their lectures as well as for their commitment.

Applied Structural Dynamics
Dr.-Ing. Markus Spengler

Prefabricated Concrete Constructions
Dipl.-Ing. Mathias Tillmann
Dr.-Ing. Christoph Schmidhuber
Dipl.-Ing. Heinz Eberherr
Dipl.-Ing. Tanja Skottke
Dipl.-Ing. Ralf Niehüser
Dipl.-Ing. Erwin Scholz
Dr.-Ing. Diethelm Bosold
Dipl.-Ing. Werner Hochrein
Dipl.-Ing. Dipl.-Wirt. Ing. Elisabeth Hierlein
Dipl.-Ing. Dipl.-Wirtsch.-Ing. Mike Richter
Dipl.-Wirt.-Ing. (FH) Peter Schermuly
Dr.-Ing. Matthias Molter
Dipl.-Ing. Jürgen Glaesle

Concrete Bridges and Falsework
Dr.-Ing. Gerhard Zehetmaier
Dr.-Ing. Stefan Kempf

Masonry and special topics of concrete structures
Dipl.-Ing. (FH) Oliver Keil
Dipl.-Ing. (FH) Michael Pröll
Dipl.-Ing. Georg Flassenberg

Prestressed Concrete Structures
Dr.-Ing. Stefan Daus

Strategic Facility Management & Sustainable Design
Thilo Kälberer
Dr.-Ing. Torsten Mielecke
Dr.-Ing. Sebastian Pohl

Building Service Engineering
Dipl.-Ing. Herbert Schäfer
Prof. Dr.-Ing. Benjamin von Wolf-Zdekauer
Dipl.-Ing. Olaf Pielke
Dipl.-Ing. Frank Bieber
Dipl.-Ing. Robin Engelmann
Dipl.-Ing. Patrik Bös
Dr.-Ing. Leif Pallmer

1.8 PUBLICATIONS

Selected papers and book chapters:

Müller, D.; Graubner, C.-A.: Uncertainties in the assessment of existing masonry structures, In: Sixth International Symposium on Life-Cycle Civil Engineering (IALCCE 2018), 28.-31. Oktober 2018, Taylor & Francis, London, S. 369-376, ISBN: 978-1-138-62633-1.

Graubner, C.-A.; Mazur, R.; Purkert, B.: Bemessung von Ziegelmauerwerk - Effizient auch im Brandfall, In: Bauplaner - Supplement im Deutschen IngenieurBlatt, 2018, Schiele & Schön, Berlin, S. 14-15.

Rezvani, M.; Proske, T.; Herget, C.; Graubner, C.-A.: Schwindverhalten von Beton aus kalksteinreichen Zementen, In: Beton- und Stahlbetonbau, Heft 113, 2018, Ernst & Sohn Verlag, S. 1-11, DOI: DOI: 10.1002/best.201800065.

Tran, N.; Graubner, C.-A.: Uncertainties of concrete parameters in shear capacity calculation of RC members without shear reinfor, In: In: Strauss, A. et al. (Eds.) Extended Abstracts of the 16th International Probabilistic Workshop 2018 (IPW 2018) in Vienna 12 - 14 September 2018, Beton- und Stahlbetonbau 113, Issue S2: 16th International Probabilistic Workshop, September 2018, Ernst & Sohn Verlag, DOI: https://doi.org/10.1002/best.201800059.

Tran, N.; Graubner, C.-A.: Influence of material spatial variability on the shear strength of concrete members without stirrups, In: In: Strauss, A. et al. (Eds.) Extended Abstracts of the 16th International Probabilistic Workshop 2018 (IPW 2018) in Vienna 12 - 14 September 2018, Beton- und Stahlbetonbau 113, Issue S2: 16th International Probabilistic Workshop, September 2018, Ernst & Sohn Verlag, DOI: https://doi.org/10.1002/best.201800059.

Baldermann, A.; Rezvani, M.; Proske, T.; et al.: Effect of very high limestone content and quality on the sulfate resistance of blended cements, In: Construction and Building Materials, Vol. 188, 2018, Elsevier, Amsterdam, S. 1065-1076, ISBN: https://doi.org/10.1016/j.conbuildmat.2018.08.169.

Rezvani, M.; Proske, T.; Herget, C.; Graubner, C.-A.: Drying shrinkage behaviour of cement paste and concrete made with eco-friendly limestone-rich cements, In: Proceedings of the 20. Internationale Baustofftagung (ibausil), 12.-14. September 2018, Weimar, S. 561-568, ISBN: ISBN 978-3-00-059950-7.

El Ghadioui, R.; Proske, T.; Graubner, C.-A.: Load-bearing capacity and deformation behaviour of carbon-textile reinforced concrete members, In: Proceedings of the 12th fib International PhD Symposium in Civil Engineering, 29.-31. August 2018, Prag (Tschechien), S. 363-370, ISBN: 978-80-01-06401-6.

Hofmann, S.; Graubner, C.-A.; Proske, T.: Load-bearing performance of concrete beams with basalt fibre reinforced polymer (BFRP) rebars, In: Proceedings of the 12th fib International PhD Symposium in Civil Engineering, 29.-31. August 2018, Prag (Tschechien), S. 419-426, ISBN: 978-80-01-06401-6.

Graubner, C.-A.; Schmitt, M.: Nichttragende Wände, In: Kalksandstein: Planungshandbuch. Planung, Konstruktion, Ausführung (PKA) – 7. Auflage, 2018, Bau+Technik GmbH, Hannover.

Graubner, C.-A.; Schmitt, M.: Bemessung, In: Kalksandstein: Planungshandbuch. Planung, Konstruktion, Ausführung (PKA) – 7. Auflage, 2018, Bau+Technik GmbH, Hannover.

Palm, S.; Müller, C.; Proske, T.; Rezvani, M.; Graubner, C.-A.: Concrete application of clinker-efficient cements, In: Advances in Cement Research, Vol. 30, Issue 8, 2018, ice Publishing, S. 1-24, DOI: https://doi.org/10.1680/jadcr.17.00217.

Mazur, R.; Graubner, C.-A.: Out-of-plane bending moments in masonry walls – Analysis of different calculation methods, In: Mauerwerk, Vol. 22, Issue 3, 2018, Ernst & Sohn Verlag, Berlin, S. 139-150, DOI: 10.1002/dama.201800006.

Wörner, P.; Müller, A.; Fischer, M.; Graubner, C.-A.: Gut gemeint - auch gut gemacht? Die Nachhaltigkeit der deutschen Energiewende auf dem Prüfstand, In: Energiewirtschaftliche Tagesfragen, Band 68, Heft 6, 2018, S. 40-44.

Steiner, S.; Lothenbach, B.; Borgschulte, A.; Proske, T.; Winnefeld, F.: Effect of relative humidity on the carbonation rate of portlandite, calcium silicate hydrates and ettringite, In: Proceedings of the 20. Internationale Baustofftagung (ibausil), 2018, Weimar, S. 2-963-2-968.

Proske, T.; Steiner, S.; Graubner, C.-A.: Diffusion of CO2 and water vapor in clinker-reduced concretes, In: Proceedings of the 20. Internationale Baustofftagung (ibausil), 2018, Weimar, S. 2-145-2-152.

Proske, T.; Rezvani, M.: Shear Behavior of Fresh Concrete under variable Pressure – Development of a specific Testing Device, In: Proceedings of International RILEM Workshop on Rheological Measurements of Cement-Based Materials (IRWRMC), 2018.

Müller, D.; Tran, N.; Graubner, C.-A.: Stochastische Simulation der Nutzlasten in Gebäuden, In: Vielfalt im Massivbau - Festschrift zum 65. Geburtstag von Prof. Dr.-Ing. Jürgen Schnell, 2018, Ernst & Sohn, S. 91-107, ISBN: 978-3-00-058653-8.

Proske, T.; Rezvani, M.; Palm, S.; Müller, C.; Graubner, C.-A.: Concretes made of efficient multi-composite cements with slag and limestone, In: Cement and Concrete Composites, Vol. 89, 2018, Elsevier, Amsterdam, S. 107-119, DOI: https://doi.org/10.1016/j.cemconcomp.2018.02.012.

Rezvani, M.; Graubner, C.-A.; Proske, T.: Klinker raus, Kalksteinmehl rein! Vorhersage des Schwindverhaltens von Beton aus kalksteinhaltigen Ökozementen, In: Vorfertigung - Zukunft des Bauens, Kongressunterlagen 62. Betontage, 20-22. 2. 2018, Neu-Ulm.

Förster, V.; Graubner, C.-A.: Tragfähigkeit unbewehrter Betondruckglieder bei zweiachsig exzentrischer Beanspruchung, In: Beton- und Stahlbetonbau, Heft 2, 2018, Ernst & Sohn, Berlin, S. 136-146, DOI: 10.1002/best.201700083.

Selected presentations:

Rezvani, M.; Proske, T.; Herget, C.; Graubner, C.-A.: Ökobeton – Ein umweltfreundlicher und leistungsfähiger Baustoff? Farbe und Lack Konferenz, Kassel, 28.11.2018.

Wörner, P.; Graubner, C.-A.; Müller, A.; Fischer, M.; Weißmann, C.: Gut gemeint – auch gut gemacht? Gedanken zur Nachhaltigkeit der deutschen Energiewende, Hauptversammlung des Instituts für Stahlbetonbewehrung e.V., Düsseldorf, 18.10.2018.

Müller, D.; Graubner, C.-A.: Uncertainties in the assessment of existing masonry structures, Sixth International Symposium on Life-Cycle Civil Engineering (IALCCE 2018), Gent, 29.10.2018.

Steiner, S.; Proske, T.; Graubner, C.-A.: Diffusionsverhalten von CO2 und Wasserdampf in klinkerreduzierten Betonen, 20. Internationale Baustofftagung (ibausil), Bauhaus-Universität Weimar, Weimar, 13.09.2018.

Rezvani, M.; Proske, T.; Herget C.; Graubner, C.-A.: Drying shrinkage behaviour of cement paste and concrete made with eco-friendly limestone-rich cements, 20. Internationale Baustofftagung (ibausil), Bauhaus-Universität Weimar, Weimar, 13.09.2018.

Hofmann, S.: Load-bearing performance of concrete beams with basalt fibre reinforced polymer (BFRP) rebars, 12th fib International PhD Symposium, Prag (Tschechien), 29.-31.08.2018

El Ghadioui, R.: Load-bearing capacity and deformation behaviour of carbon-textile reinforced concrete members, 12th fib International PhD Symposium, Prag (Tschechien), 29.-31.08.2018

Rezvani, M.; Proske, T.; Herget, C.; Graubner, C.-A.: Ökobeton – Ein umweltfreundlicher und leistungsfähiger Baustoff? VDB Regionaltagung, Wiesbaden, 26.06.2018.

Graubner, C.-A.; Mazur, R.: Mauerwerk - Einfach und Effizient, 12. Akademischer Mauerwerkstag, Mainz, 21.06.2018

Rezvani, M.; Herget, C.: Ökobeton, "17:30 SAT.1 LIVE“, Regionalmagazin für Hessen und Rheinland-Pfalz , SAT1 Fernsehsender, 23.03.2018. Hier anschauen

Graubner, C.-A.; El Ghadioui, R.: Carbonbeton - Ein Werkstoff der Zukunft?, Darmstädter Betonfertigteiltage 2018, Darmstadt, 08.03.2018

Rezvani, M.; Graubner, C.-A..; Proske, T.: Klinker raus, Kalksteinmehl rein! Vorhersage des Schwindverhaltens von Beton aus kalksteinhaltigen Ökozementen, 62. Betontage, Neu-Ulm, 21.02.2018.

Graubner, C.-A.; Wörner, P.; Müller, A.; Fischer, M.; Weißmann, C.: Gut gemeint - auch gut gemacht? Gedanken zur Nachhaltigkeit der deutschen Energiewende, Eröffnungsvortrag der 62. BetonTage, Neu-Ulm, 20.02.2018.

1.9 STUDENT FINAL THESES AT THE INSTITUTE

Last year, the following final theses were written at the Institute of Concrete and Masonry Structures:

Editor	**Title of final thesis**	**Supervisor**	**Type of thesis**
Almeroth, Christian	Analyse eines alternativen Ansatzes zur kombinierten Bemessung für Biege- und Torsionslängskräfte	Redouan El Ghadioui	Bachelorthesis
Arndt, Vanessa	Carbonfaserverstärkte Kunststoffbewehrung – Vergleich der Bemessungsansätze internationaler Regelwerke	Redouan El Ghadioui	Bachelorthesis
Arnoldi, Susanne Daniela	Anwendung und Weiterentwicklung des Zertifizierungssystems Eco Protocol für Bestandsgebäude in Panamá	Marleen Fischer, Patrick Wörner	Masterthesis
Beck, Vanessa	Ertüchtigung von Stahlbetonbauteilen mit Öffnungen	Sebastian Hofmann	Masterthesis
Bensch, Milena	Konzeption, Durchführung und Auswertung von Zugfestigkeitsprüfungen faserverstärkter Kunststoffbewehrung	Redouan El Ghadioui	Bachelorthesis
Bieger, Max	Nachrechnung von schiefwinkligen Eisenbahnbrücken im Bestand mit Vollplattenquerschnitt	Redouan El Ghadioui	Masterthesis
Bueno Sánchez, Rebeca	Analyse eines Zertifizierungssystems für bestehende Bürogebäude in Panama und Entwicklung eines praxisorientierten Leitfadens für die Kategorien Energie und Wasser	Patrick Wörner	Masterthesis
Cepo, Daniel	Toleranzen im Hochbau – Untersuchungen zu normativen Regelungen zulässiger Abweichungen	Redouan El Ghadioui	Bachelorthesis
Dallinger, Christina	Untersuchung praxisgerechter Ansätze zur Bewertung der Robustheit von Tragwerken	Dominik Müller	Bachelorthesis
Dehnbostel, Jonas	Vergleich verschiedener Möglichkeiten zur Berücksichtigung der Wandsteifigkeit bei der Schnittgrößenermittlung im Mauerwerksbau	René Mazur	Bachelorthesis
Dingeldein, Lukas	Schubtragfähigkeit von Wand-Decken-Anschlüssen mit thermischer Entkopplung	Jochen Zeier, Sebastian Hofmann	Masterthesis
Duruöz, Nazif	Einfluss von Bewehrung auf die Haftscherfestigkeit in der Lagerfuge bei bewehrtem Mauerwerk	Benjamin Purkert	Masterthesis
Eckel, Maike	Experimentelle Untersuchung der Schubtragfähigkeit von Wand-Decken-Anschlüssen mit thermischer Entkopplung	Sebastian Hofmann	Masterthesis
Farid, Opjani	Tragfähigkeit von Mauerwerkswänden bei teilaufliegender Decke – Bemessungsansätze im Vergleich	Benjamin Purkert	Bachelorthesis
Fischer, Simon	Vergleichende Untersuchungen zur Verstärkung von Spannbeton-Brücken im Bestand	Redouan El Ghadioui	Masterthesis
Fleckhammer, Jan	Entwicklung eines geeigneten Stabwerkmodells zur Ermittlung der Traglast von Außenwänden aus Mauerwerk	René Mazur	Masterthesis
Fritzsche, Max	Mitwirkende Breite bei einachsig gespannten Platten mit elastischer Auflagerung	Jochen Zeier	Masterthesis

Editor	**Title of final thesis**	**Supervisor**	**Type of thesis**
Gaul, Alexander	Entwicklung eines aktualisierten Ansatzes zur Bewertung der gebäudebezogenen Lebenszykluskosten für Büro- und Verwaltungsgebäude	Sarah Steiner	Masterthesis
Gliemroth-Brübach, Lisa	Diskussion von Erdhäusern nach dem Cradle-to-Cradle-Prinzip und ökologische Bewertung möglicher Gebäudehüllenkonzepte	Marleen Fischer	Bachelorthesis
Grimm, Niklas Nils	Analyse und Optimierung der Betriebsweise des Wärme- und Kältekonzepts des Klinikums Darmstadt	Patrick Wörner	Masterthesis
Grün, Stefan	Reliability analyses of unreinforced masonry basement walls under lateral earth pressure	Dominik Müller	Masterthesis
Haus, Michael Matthias	Entwicklung und Validierung von nutzerabhängigen Stromlastprofilen für ausgewählte repräsentative Haushalte in Deutschland	Patrick Wörner	Bachelorthesis
Herget, Christian	Schwindarme Betone für Bauteile im Infrastrukturbereich	Moien Rezvani, Sarah Steiner	Masterthesis
Hiesch, Dominik	Carbonbewehrte Betonbauteile unter statischer Dauerbeanspruchung – Experimentelle und theoretische Untersuchungen	Redouan El Ghadioui	Masterthesis
Hohl, Florian	Schnittgrößenverteilung und Verformung am Außenwand-Decken-Knoten im obersten Geschoss eines Mauerwerksgebäudes	Benjamin Purkert	Masterthesis
Hutterer, Dennis	Erstellung eines Gebäudehüllen- Konzepts für Erdhäuser nach Cradle-to-Cradle-Prinzipien und Evaluierung deren ökologischen Potentiale	Marleen Fischer	Bachelorthesis
Kara, Hakan	Vergleich von Strategien zur Erhöhung der Robustheit von Tragwerken	Dominik Müller	Bachelorthesis
Keppler, Juliane	Analyse der Materialkennwerte zur Beschreibung des Dauerstands- und Ermüdungsverhaltens carbonbewehrter Deckenplatten unter einaxialer Druckbeanspruchung	Redouan El Ghadioui	Bachelorthesis
Kilian, Marcel	Vergleich unterschiedlicher Verfahren zur Ermittlung von Verformungen bewehrter Deckenplatten unter Dauerlast	Redouan El Ghadioui	Bachelorthesis
Kiziltoprak, Medet	Softwaregestützte Untersuchung zum Tragverhalten textilbewehrter Flachstürze in Verbindung mit aufgeklebten Hochlochziegeln	René Mazur	Masterthesis
Klein, Adrian	Windbeanspruchte Außenwände aus Mauerwerk mit geringer vertikaler Auflast – Bemessungsansätze im Vergleich	Benjamin Purkert	Bachelorthesis
Kleinhenz, Christin	Bemessung und Konstruktion von wasserundurchlässigen Betonbauteilen	Sebastian Hofmann	Masterthesis
Knau, Julia	Sicherheitsformate für die Mauerwerksbemessung – Vergleich internationaler Regelwerke	Dominik Müller	Bachelorthesis
Koert, Johannes	Analyse des deutschen Strommarkts und Entwicklung einer zeitvariablen Tarifstruktur für den Haushaltsstrompreis unter Berücksichtigung wetterbedingter Einflussfaktoren	Patrick Wörner, André Müller	Studienarbeit (i.R.d. Interdisziplinären Projekts)

Editor	**Title of final thesis**	**Supervisor**	**Type of thesis**
Kühnl, Vivian	Experimentelle Untersuchungen zum Trag- und Verformungsverhalten carbonbewehrter Betonbauteile unter Kurzzeitbeanspruchung	Redouan El Ghadioui	Masterthesis
Liang, Pupu	Strategische Chancen und Risiken von Wärmepumpentechnologien hinsichtlich der Treibhausgasemissionen über den Lebenszyklus	André Müller	Masterthesis
Metzger, Simon	Untersuchung der dynamischen Tragwerksreaktionen carbonbewehrter Fußgängerbrücken	Redouan El Ghadioui	Masterthesis
Möllers, Reinhild	Analyse von Energiewandlungs- technologien im Wärmesektor und deren systematische Einbindung im zukünftigen deutschen Energiesystem	André Müller	Masterthesis
Müller, Linda-Fee	Analyse des deutschen Strommarkts und Entwicklung einer zeitvariablen Tarifstruktur für den Haushaltsstrompreis unter Berücksichtigung wetterbedingter Einflussfaktoren	Patrick Wörner, André Müller	Studienarbeit (i.R.d. Interdisziplinären Projekts)
Müller, Sina	Experimentelle und theoretische Untersuchungen zum Verbundverhalten unterschiedlicher Bewehrungselemente	Redouan El Ghadioui	Masterthesis
Nader, Henrik	Experimentelle Untersuchung zum Trag- und Verbundverhalten von textilbewehrten Bauteilen	Sebastian Hofmann	Masterthesis
Prediger, Bastian	Untersuchungen zum Tragverhalten eines textilbewehrten Flachsturzes in Verbindung mit aufgeklebten Mauerziegeln	René Mazur	Masterthesis
Preuschoff, Karen	Experimentelle Untersuchung zum Querkrafttragverhalten von basaltbewehrten Bauteilen	Sebastian Hofmann	Masterthesis
Rehn, Johannes	Analyse des deutschen Strommarkts und Entwicklung einer zeitvariablen Tarifstruktur für den Haushaltsstrompreis unter Berücksichtigung wetterbedingter Einflussfaktoren	Patrick Wörner, André Müller	Studienarbeit (i.R.d. Interdisziplinären Projekts)
Rothermel, Swenja	Versuchsgestützte Untersuchungen zur Querkrafttragfähigkeit carbonbewehrter Betonbauteile unter Kurzzeitbeanspruchung	Redouan El Ghadioui	Masterthesis
Rudeloff, Kevin	Untersuchung von vorgespannten Eisenbahnbrücken im Bestand hinsichtlich der Spannungsrisskorrosionsgefährdung	Redouan El Ghadioui	Masterthesis
Schneider, Marvin	Einfluss der Normalkraft auf das Tragverhalten am Außenwand-Decken-Knoten bei teilaufliegender Decke	Benjamin Purkert	Masterthesis
Schäpe, Patrick	Tragverhalten bewehrter Mauerwerkswände unter Scheibenbeanspruchung	Benjamin Purkert	Masterthesis
Stöcker, Melanie	Untersuchungen zum Nachweis gegen Ermüdung vorgespannter Straßenbrücken im Bestand	Redouan El Ghadioui	Masterthesis
Valipoor, Soheil	Tragfähigkeit von normalkraftbeanspruchtem Mauerwerk mit T-förmigem Querschnitt	Benjamin Purkert	Masterthesis
Vogler, Julian	Vergleich verschiedener Möglichkeiten zur Bemessung nichttragender Mauerwerkswände	René Mazur	Bachelorthesis

Editor	**Title of final thesis**	**Supervisor**	**Type of thesis**
Volz, Lisann	Schnittgrößenermittlung im Mauerwerksbau bei teilaufliegender Decke – Berechnungsansätze im Vergleich	Benjamin Purkert	Bachelorthesis
von Goertzke, Vincent	Einfluss der Permeabilität textiler Schalungen auf die Sichtbetonqualität und die Dauerhaftigkeit von Betonbauteilen	Moien Rezvani Tilo Proske	Masterthesis
Wiese, Kai	Einfluss der Nachbehandlung auf das Gefüge und das CO2-Diffusionsverhalten von Feinbeton	Sarah Steiner	Masterthesis

2 DARMSTADT CONCRETE 2018: ARTICLES

2.1 FIELDS OF RESEARCH AT THE INSTITUTE

Our research objectives are based on the common idea of constructing our buildings safer, more durable, more economical and more environmentally friendly. For this reason, the Institute of Concrete and Masonry Structures deals with a wide variety of topics within six research areas.



Figure 9 Research Fields at the Institute of Concrete and Masonry Structures

The scientific articles in this journal are divided into the following categories:

- Construction and Design

  Construction and Design, Masonry, Risk and Safety
- Mineral and ecological building materials
- Energy and Sustainability

  Energy Research, Sustainable Design

The illustrations in the scientific papers are renumbered in each article.

2.2 RESEARCH FIELD: CONSTRUCTION AND DESIGN

Research Field: Construction and Design

The research area "Construction and Design" takes a central role at the Institute of Concrete and Masonry Structures. It includes all questions concerning the planning and design of concrete and masonry structures. The focus is on innovations in the design and construction of reinforced concrete and prestressed concrete members that meet the high requirements of modern buildings.

Research Field: Masonry

Increased demands on modern buildings in terms of economy and comfort as well as the great economic importance of masonry as a traditional building material require sustainable innovations for this type of construction. Increased requirements with regard to heat, sound and fire protection, the need for rationalisation and improved material properties lead to optimised masonry constructions, which pose a wide variety of challenges to practical research in the field. In this context, new products are scientifically accompanied in order to be taken into account in masonry standardisation. In addition, improved dimensioning methods are being developed which make optimum use of the potential of masonry and thus increase its economic efficiency.

Research Field: Risk and Safety

Safety and reliability are among the most important characteristics of structural and technical systems. In this context, the concept of safety demands the absence of dangers to the life and limb of people in the direct vicinity of buildings or technical systems.

For several years, the Institute of Concrete and Masonry Structures has been conducting intensive research work in the field of safety and reliability of structural systems. The research projects to be carried out deal with the modelling of actions and resistances, the calibration of safety and combination factors as well as the consideration of extraordinary actions in structural engineering.

MONTE CARLO SIMULATION OF UNREINFORCED MASONRY WALLS CONSIDERUNG SPATIALLY VARIABLE MATERIAL PROPERTIES

Lukas Bujotzek, Dominik Müller

The Institute of Concrete and Masonry Structures is currently investigating the influence of spatially variable material properties on the load-bearing capacity of unreinforced masonry walls. Within a recently completed master thesis, masonry walls were modelled using the software DIANA FEA and Monte Carlo simulations were carried out applying a tool, which was developed for this purpose, cf. (1).

Figure 1 shows exemplary results of the investigations. The load-bearing capacity of walls with different slenderness λ was stochastically simulated using a coefficient of variation of 25 % for the modulus of elasticity and 20 % for the compressive strength of masonry. The simulation was carried out both with spatial variability of the material properties from unit to unit, i.e. a variability of the material properties within a wall, and without spatial variability, i.e. with the same random material properties at each point of the wall. From 100 simulation runs per wall, the mean values and the design values were determined. According to EN 1990, the design values are defined as the approximate 0.1 % quantile of the load-bearing capacity and were calculated using a lognormal distribution with mean value and standard deviation of the simulation results. For walls with low slenderness, which fail due to a stress problem, a smaller mean value of the load carrying capacity is obtained if spatial variability is considered. This can be explained by the fact that in this case the load capacity of the wall is determined by the weakest course. It is worth noting that, despite the lower mean value, an increase in the design value can be observed. The key factor for this is the significant reduction in the variation of the load-bearing capacity, which is made possible by a load redistribution due to different strengths within the wall. For walls of higher slenderness, which fail due to a stability problem, spatial variability does not cause a decrease of the mean value of the load-bearing capacity, since the load-bearing capacity depends on an average stiffness of the wall and no longer on the weakest course. The positive effect of spatial variability is therefore much more pronounced for walls failing due to stability than for walls with low slenderness.

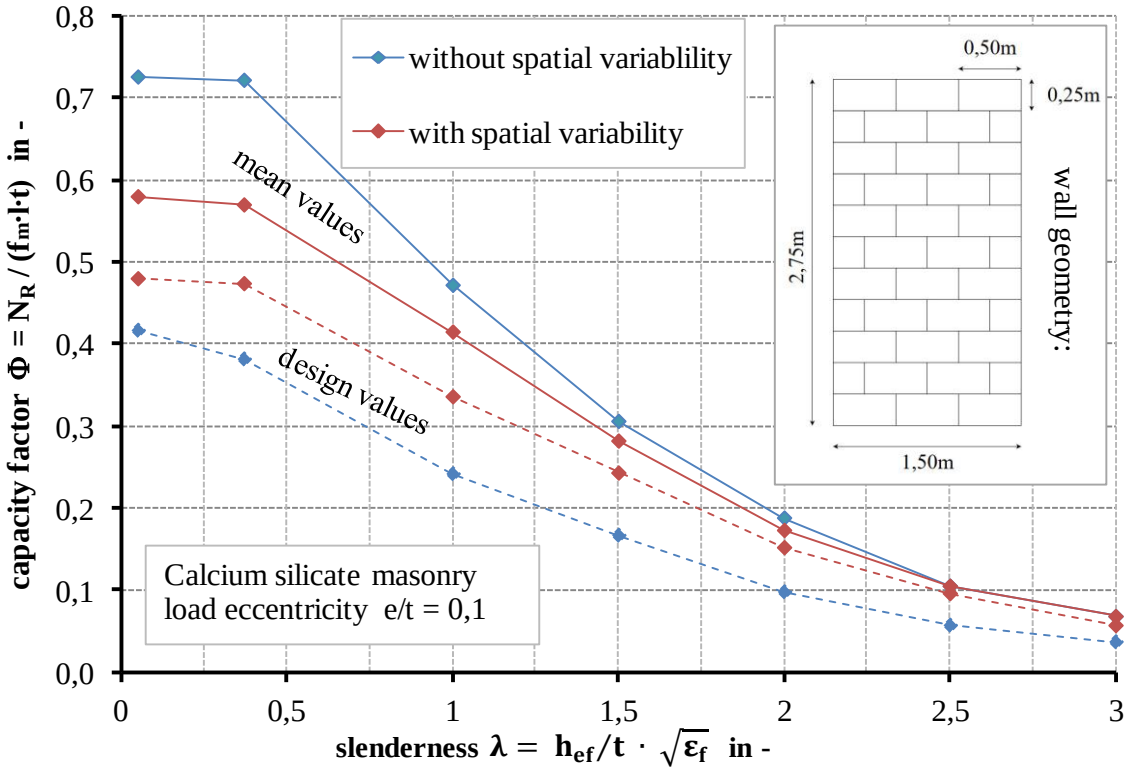

Figure 1: Influence of spatial variability as a function of wall slenderness

The investigation of other boundary conditions also mainly shows a positive effect of considering the spatial variability of material properties. One of the few exceptions are very short walls (masonry pillars). In the upcoming year further investigations of this phenomenon will be carried out at the Institute of Concrete and Masonry Structures. The particular emphasis will then be on existing masonry, as in this case the spatial variability of material properties is especially pronounced.

(1) Bujotzek, Lukas (2018): Monte-Carlo-Simulation unbewehrter Mauerwerkswände unter Berücksichtigung räumlich streuender Materialeigenschaften. Master thesis at the Institute of Concrete and Masonry Structures, Technische Universität Darmstadt.

ANALYSIS OF CRACK SPACING OF TEXTILE-REINFORCED CONCRETE MEMBERS

Redouan El Ghadioui

The force-deflection behaviour of a reinforced concrete rod subjected to tensile stress is characterised by the phases state I (non-cracked), state IIa (crack formation phase) and state IIb (final crack pattern), compare Figure 1. When the concrete tensile strength is reached, a separating crack is formed in whose cross-section the tensile force is only ascribed to the reinforcement, while the concrete strain drops to zero. In the areas on both sides of the crack, tensile stresses are transferred into the concrete due to the bond stresses. If these tensile stresses exceed the concrete tensile strength, further cracks will occur. The length between the crack and the point where the concrete tensile strength is reached is referred to as the transfer length l_t.

On this basis, the minimum, maximum and mean crack spacing ($s_{r,min} = l_t$, $s_{r,max} = 2\ l_t$, $s_{r,m} \approx 1.5\ l_t$) are derived. This transfer length can be determined as follows by forming a force equilibrium:

$$A_{c,eff} \cdot f_{ct,eff} = \tau_{bm} \cdot l_t \cdot u_s \qquad \text{(a)}$$

These relationships are transferred to beams subjected to bending using an effective height of the tension area.

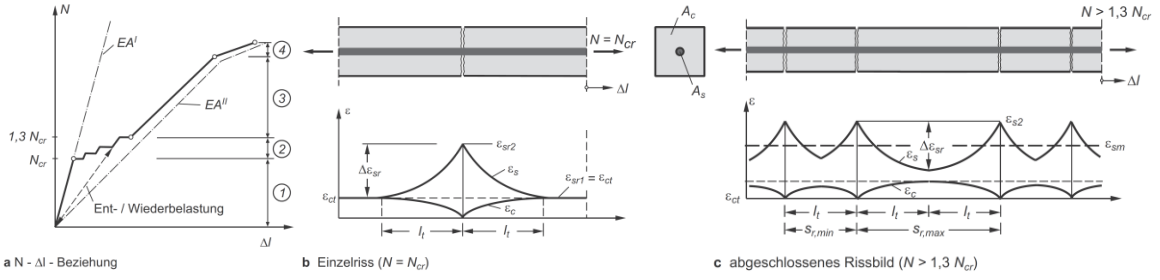

Figure 1: Crack phases of a reinforced concrete rod subjected to tensile stress, cf. (1)

Based on experimental investigations on carbon- and steel-reinforced concrete members with equivalent mechanical ratio of reinforcement (based on the mean values of the strengths) subjected to bending, the crack patterns in the ultimate limit state were digitized and the crack spacings were evaluated, cf. Figure 2.

According to DIN EN 1992-1-1, it can be assumed that the ratio of the mean bond stresses to the concrete tensile strength is $k_b = \tau_{bm} / f_{ct} = 1.8$. On the basis of the experimentally determined crack spacings, this ratio was analysed, cf. Figure 2. It was determined that the mean bond stresses of the ribbed steel reinforcement are higher ($k_{b,Stahl} > k_{b,Carbon}$), but the crack spacings are of a similar order of magnitude. Due to the elliptical cross-section of the textile carbon reinforcement, the total circumference of the reinforcement is comparable in size despite the significantly higher geometric ratio of reinforcement of the steel-reinforced concrete members.

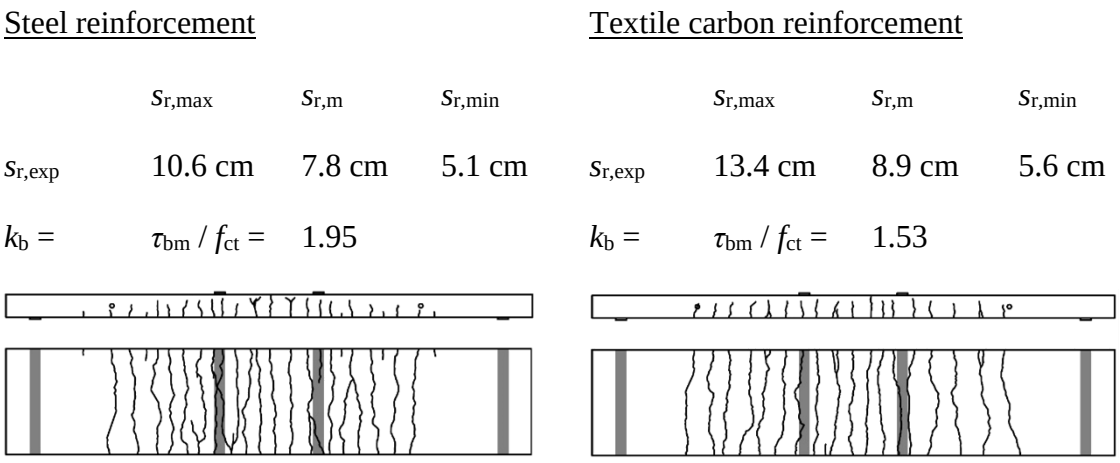

Figure 2: Crack patterns and crack spacings of the concrete members

In addition to the bond behaviour of the fibre strands aligned in the longitudinal direction, the transverse reinforcement has a decisive influence on the crack behaviour. Due to the generally close-meshed arrangement of the transverse reinforcement, smaller crack spacings can occur. The resulting effects on the deformation behaviour at the serviceability limit state will be investigated in more detail within the framework of further research.

(1) Zilch, Konrad; Zehetmaier, Gerhard (2010): Bemessung im konstruktiven Betonbau. Nach DIN 1045-1 (Fassung 2008) und EN 1992-1-1 (Eurocode 2). 2., neu bearb. und erw. Aufl. Berlin, Heidelberg: Springer.

EXPERIMENTAL INVESTIGATION OF THE BOND BEHAVIOUR OF BFRP REINFORCEMENT BARS

Sebastian Hofmann

For the verification and the development of design models for basalt fibre reinforced polymer reinforcement bars, the knowledge about the bond behaviour in concrete structures is indispensable. The bond stresses acting along a reinforcing element embedded in concrete can be experimentally determined by so-called pull-out tests (1). For this purpose, a total of 46 small-scale test specimens with rod-shaped BFRP reinforcement bars and conventional reinforcing steel as reference as well were produced and tested as part of a research project. The reinforcement diameter, the compressive strength and the composite length were varied to analyse their influence on the bond stress-slip relationship. Figure 2 illustrates the test results for a bar diameter of $\phi = 8$ mm and the composite lengths $l_b = 6 \times \phi$. The left diagram in Figure 2 shows the results for a concrete compressive strength of 35 N/mm² and the right diagram in Figure 2 for a concrete compressive strength of 64 N/mm².

The experiments showed that the average bond stress (Figure 1) increases, for steel and as well for BFRP reinforcement, with larger bond lengths. Furthermore, it could be observed that the qualitative course of the bond-stress-slip behaviour of the performed experiments with the same configuration is very analogical to each other. This circumstance is very important for the development and / or the verification of a mechanical bond model. A slip of 0.2 mm for example, results to a mean crack width of $w_{cr,m} = 0.4$ mm in a concrete member. This crack width marks an important reference for the proof of serviceability e.g. in building construction.

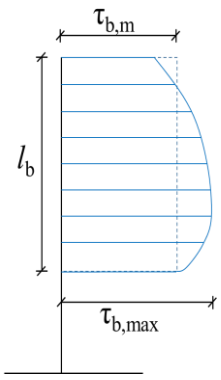

Figure 1: Mean bond stress (2)

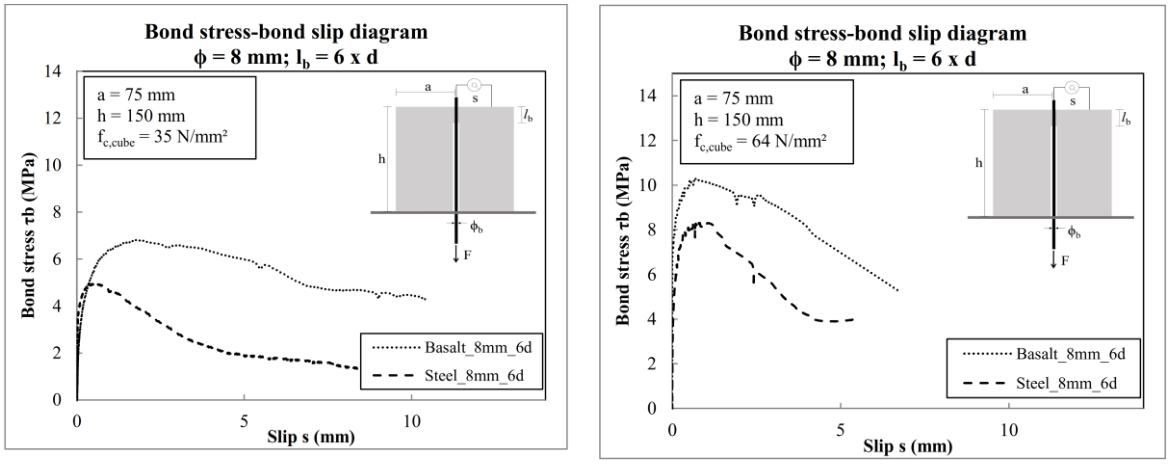

Figure 2: Bond-stress-slip-diagram of ϕ = 8 mm, l_b = 6 x ϕ, $f_{c,\,cube}$ = 35 MPa (left), $f_{c,\,cube}$ = 64 MPa (right)

Based on the experimentally determined bond stress, a limit value of the permissible stress $\sigma_{SLS,\,perm}$ in the limit state of serviceability for BFRP reinforcement bars can be derived. If the stresses remain below the limit value, the crack width requirement can be achieved. The permissible stress in the reinforcement can be determined by the following equation:

$$\sigma_{SLS,perm}\,(w_{cr}) = \frac{F_b(s = 0{,}5\;x\;w_{cr})}{A_{reinforcement}} \qquad \text{(a)}$$

F_b in equation (a) refers to the pull-out force with a slip of half the crack width w_{cr} to be limited. This permissible stress for limiting the crack width in case of FRP reinforced concrete must be determined separately for each bar diameter and each manufacturer, since a different bond stress-slip relationship is depending on the surface type and geometry.

(1) RILEM. Technical Recommendations for the Testing and Use of Construction Materials. Internal Union of Testing and Research Laboratories for Materials and Construction. London (UK): E & Fn SPON 1992

(2) Leonhardt, F., Mönnig, E.: Vorlesung über Massivbau - Teil 1: Grundlagen zur Bemessung im Stahlbetonbau. Berlin: Springer-Verlag 1984

CARBON REINFORCED CONCRETE SLABS UNDER POINTED LOADS (PREPARATORY TESTS)

Larissa Krieger

Multi-storey car parks seems predestined for the use of carbon reinforced concrete members due to penetration of chlorides. By using high strength reinforcement, extremely resistant to corrosion, the required concrete cover can be reduced to a minimum value for transferring bond stresses. In a large-scaled research project, carbon reinforced concrete slabs for multi-storey car parks will be analysed regarding to their load-bearing and deformation behaviour under pointed loads. The design loads for multi-storey car parks includes not only uniformly distributed loads but also pointed loads (wheel loads). The diagram in figure 1 shows the moment-deformation graphs of three bending tests on 0.5 m wide carbon-reinforced concrete plates with a span of 2.2 m. Furthermore different thicknesses were examined.

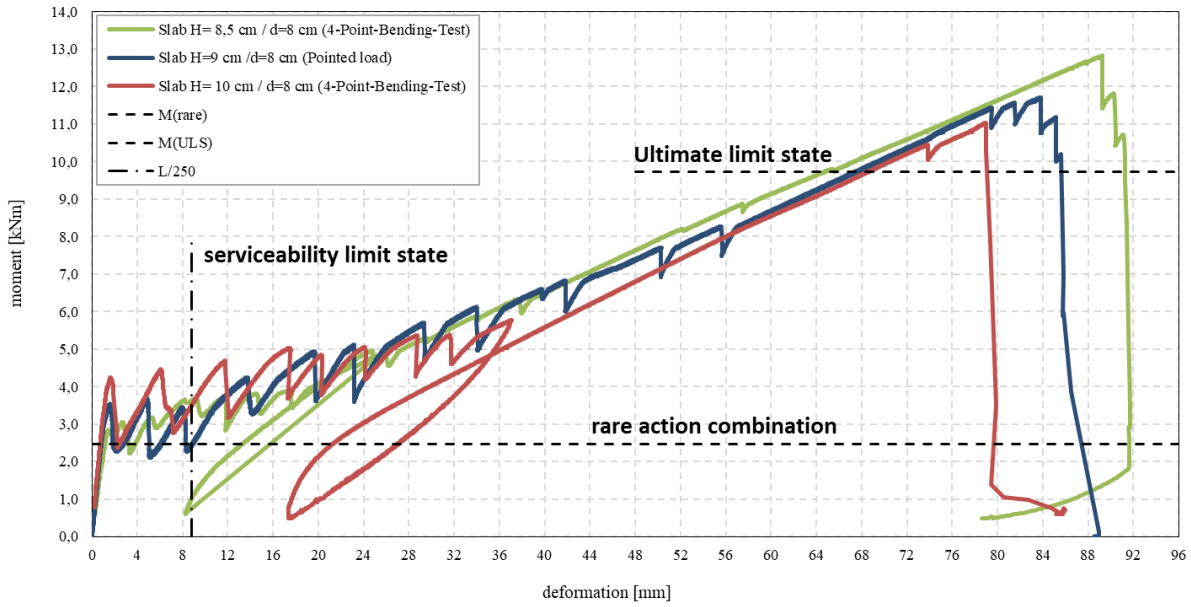

Figure 1: moment-deformation graphs

In the preparatory tests, slabs with effective depths of 8.0 cm but different component heights (8.5 cm; 9.0 cm; 10.0 cm) were analysed. Consequently the concrete cover various from 0.5 cm to 2.0 cm. Here a grid made of carbon fibres with epoxy resin impregnation and an oval roving form with a cross-section a_{tex} = 0.78 cm²/m was used. The results show that, because of the high

concrete flexural strength (f_{ctm} = 10 MPa), all slabs under service load are non-cracked. The slabs will comply with the permissible deformation of $w_{L/250}$ = 8.8 mm even within creep deformation.

Outlook / research activities:

Before the end of 2019 extensive tests on large-sized carbon reinforced concrete slabs under pointed load (load area: 20 x 20 cm) will be investigated concerning the load-bearing capacity and the shear force resistance. Based on the test results, the normative regulations regarding the "effective width" for steel reinforced concrete will be analysed. Furthermore the transferability of the results to carbon reinforced concrete has to be checked. In accordance with the DAfStb-Heft 240 (1) only the load area as well as the load position is taken into account by the calculation of the "effective width" for bending and shear force. However, we also know, that especially the transverse reinforcement has an influence on the load distribution (2). In addition, the small grid spacing of only 5 cm may also have an effect on the load distribution in transverse direction. The resulting effects on the load behaviour and deformation behaviour will be investigated in further research.

(1) Deutscher Ausschuss für Stahlbeton: DAfStb-Heft 240 Hilfsmittel zur Berechnung der Schnittgrößen und Formänderungen von Stahlbetonwerken nach DIN 1045, Ausgabe Juli 1988, Beuth-Verlag

(2) Leonhardt, Fritz (1984): Vorlesungen über Massivbau Teil 1: Grundlagen zur Bemessung im Stahlbetonbau, Springer-Verlag, 3. Auflage

SHEAR TRANSFER AT THE INTERFACE BETWEEN CONCRETE CAST AT DIFFERENT TIMES

René Mazur

For the calculation of the shear force capacity at the interface between concrete cast at different times, design equations are given, inter alia, in DIN EN 1992-1-1/NA and in fib Model Code 2010. In both standards a distinction is made between very smooth, smooth, rough and very rough or rather indented joint surfaces. The design equations do not differ for different roughness or geometry of the surface. Only the coefficients for friction and mechanical interlock have to be selected according to the boundary conditions. Surfaces with shear keys, which are shaped and manufactured by formwork for example, have to be designed – according to the standards – with the same coefficients as very rough surfaces.

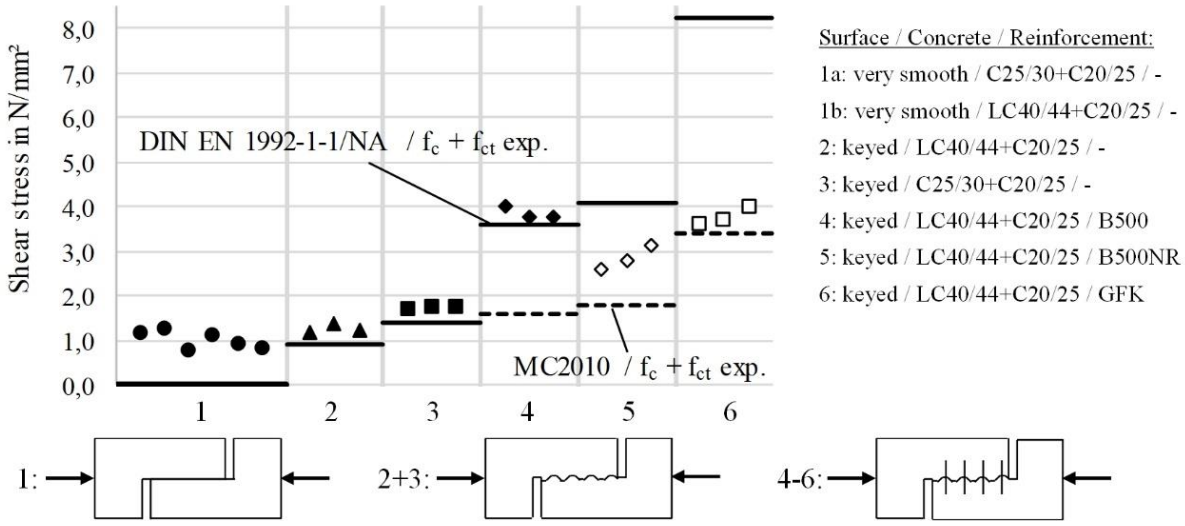

Figure 1: Comparison of experimental results with DIN EN 1992-1-1/NA and fib Model Code 2010

In Figure 1, the results of some experiments are compared with the calculative mean values according to DIN EN 1992-1-1/NA and fib Model Code 2010. In the case of unreinforced joints (test series 2 and 3), the experimental results are in good agreement with the estimations according to the already mentioned standards. Based only on these few experimental results, it is not possible to determine the influence of a change in the geometry of the shear keys on the shear capacity.

In both above-mentioned standards an additive approach of the three components of the load transfer (adhesion or rather mechanical interlock, friction and reinforcement) is used to determine the overall shear force capacity. This approach is very practical because no distinction of cases is necessary depending on the governing failure mode. A good agreement can be found when comparing the results of the experimental tests with the approaches of the technical codes, even though the addition of the different load bearing components does not correctly represent the real mechanical load bearing behavior. Therefore, these approaches should be critically scrutinized. Figure 1 shows the results of some experimental tests of reinforced joints (test series 4 to 6). While for the test series 4 and 5 a moderate to good agreement of the results can be found, the results of test series 6 vary widely from the calculative mean values according to DIN EN 1992-1-1/NA.

Further experimental tests as well as analytical and numerical investigations on the shear transfer between concrete cast at different times will carried out with special focus on shear keys. In initial numerical investigations the experimental results could be reproduced with good arrangement. Additional experimental tests can be performed to validate the analytical and numerical calculations.

STATISTICAL UNCERTAINTIES IN THE DETERMINATION OF MATERIAL PROPERTIES FOR THE ASSESSMENT OF EXISTING STRUCTURES

Dominik Müller

Material properties of existing structures are often determined by tests if a change of use requires a new verification of structural safety and no documents from the planning phase are available or the structural verification cannot be achieved without a more precise determination of the material properties that are actually existent in the structure. Since all material properties scatter and the sample size is limited due to economic reasons, the arithmetic mean and the empirical standard deviation of the test results are random variables as well. This so-called statistical uncertainty must be taken into account when evaluating the test results.

A material-independent procedure for the determination of characteristic values and design values under consideration of statistical uncertainties is described in EN 1990, Annex D. The procedure is based on a Bayesian method with non-informative prior distributions. For a log-normally distributed material property the p-quantile X_p is given as:

$$X_p = \exp\left(m_{\ln X} - k_{p,n} \cdot s_{\ln X}\right) \qquad \text{with} \quad k_{p,n} = -t_{n-1,p} \cdot \sqrt{1+\frac{1}{n}} \tag{a}$$

Here, m_{lnX} and s_{lnX} are the arithmetic mean and the empirical standard deviation of the natural logarithms of the test results. The coefficient $k_{p,n}$ depends on the number of tests n and is tabulated in EN 1990 for characteristic and design values. Alternatively, $k_{p,n}$ can be determined using Students' t-distribution with n-1 degrees of freedom. According to EN 1990, the probability p of the material property being lower than the specified value is 5 % for characteristic values and about 0.1 % for design values. Figure 1 shows an evaluation of equation (a) assuming a coefficient of variation of the test results of V_X = 20 %. It can be seen that the influence of statistical uncertainty on the design values X_d is much more pronounced than for the characteristic values X_k, which can be explained by the significantly lower probability p for design values X_d.

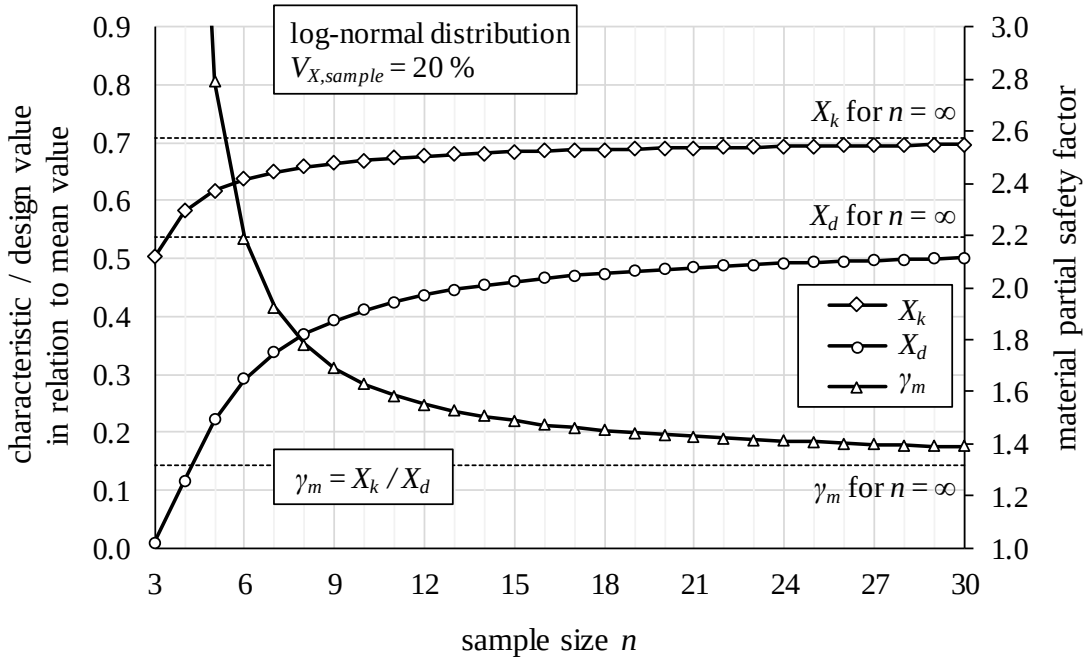

Figure 1: Influence of statistical uncertainty on characteristic values, design values and partial safety factors for material properties

The quotient of characteristic and design value shown in Figure 1 represents the required partial safety factor for material properties γ_m. Since the design values converge more slowly than the characteristic values with increasing number of samples, the required partial safety factor also depends on the sample size. This consideration of this effect is particularly important when partial safety factors for existing structures shall be modified depending on test results, cf. (1).

(1) Müller, Dominik; Graubner, Carl-Alexander (2018): Uncertainties in the assessment of existing masonry structures. In: Proceedings of the Sixth International Symposium on Life-Cycle Civil Engineering (IALCCE 2018). 28-31 October 2018. Ghent, Belgium.

INTERACTION BETWEEN BENDING MOMENT AND NORMAL FORCE AT JOINTS OF MASONRY WALLS AND PARTIALLY SUPPORTED FLOOR SLABS

Benjamin Purkert

Bending moments occurring due to the fact that the slab rotation is restrained by the rising walls have to be considered in the design of exterior masonry walls. In Germany, these moments can be determined according to DIN EN 1996-1-1/NA, Annex NA.C. This method is based on linear elasticity theory and determines the internal forces using a simplified frame system. Thereby, the moment, which would occur in case of fully clamped support of a slab, is allocated to the adjacent components according to their bending stiffnesses. For simplification purposes, cracks in the cross section as well as the resulting reduction of the stiffness are taken into account by a reduction factor. However, the influence of the acting normal force on the distribution of the moment is not considered at all.

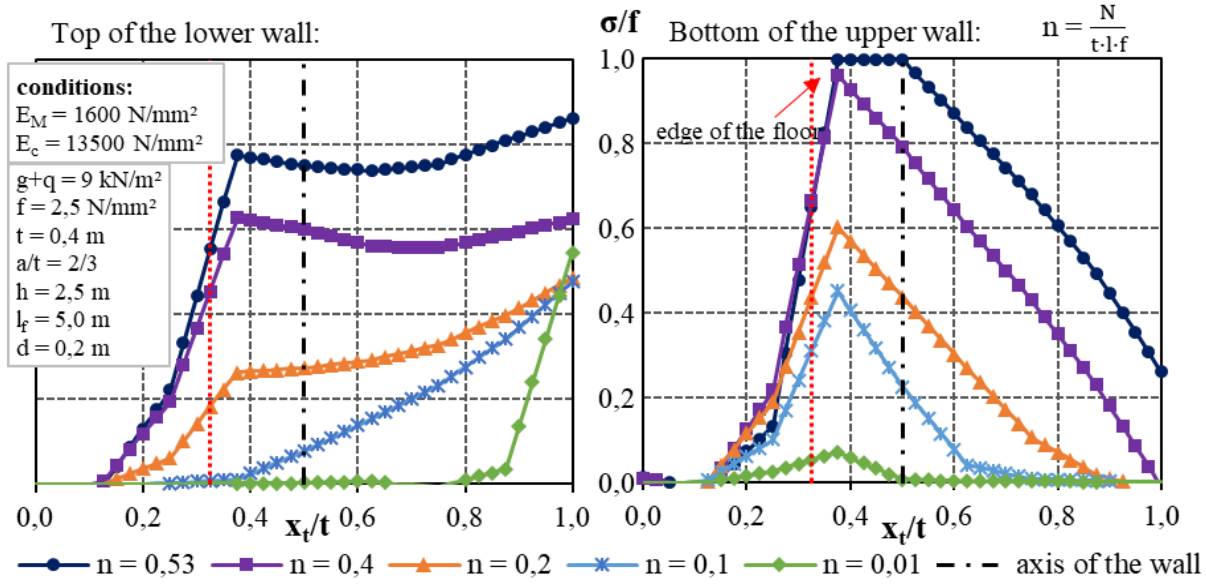

Figure 1: Distribution of the stress in the cross section of the masonry wall

From a more realistic investigation on the load bearing behaviour of a wall slab joint using a numerical model, it can be seen that it is hardly possible to display the realistic material behaviour using linear elasticity theory. In particular, the assumption of a linear strain distribution among the cross section according to Bernoulli's theorem is not true anymore, as an evaluation

of the strain values shows (see Figure 1). Moreover, it can be seen that the normal force has an influence on the acting bending moment at the top or bottom of a wall which should not be neglected.

In Figure 2, the bending moments according to the normative method referring to the axis of the wall are compared to those resulting from the numerical calculation and the influence of the normal force is shown. As it gets obvious, normatively a linear relationship between bending moment, normal force, and eccentricity is assumed which is not the case from a realistic point of view. In particular, substantial differences can be identified at the bottom of the wall.

Apart from that, it can be concluded that the normative calculation method always results in higher eccentricities – with the exception of low acting normal forces at the top of the wall – than resulting from the more realistic numerical model. Therefore, the normative design method is conservative in most cases.

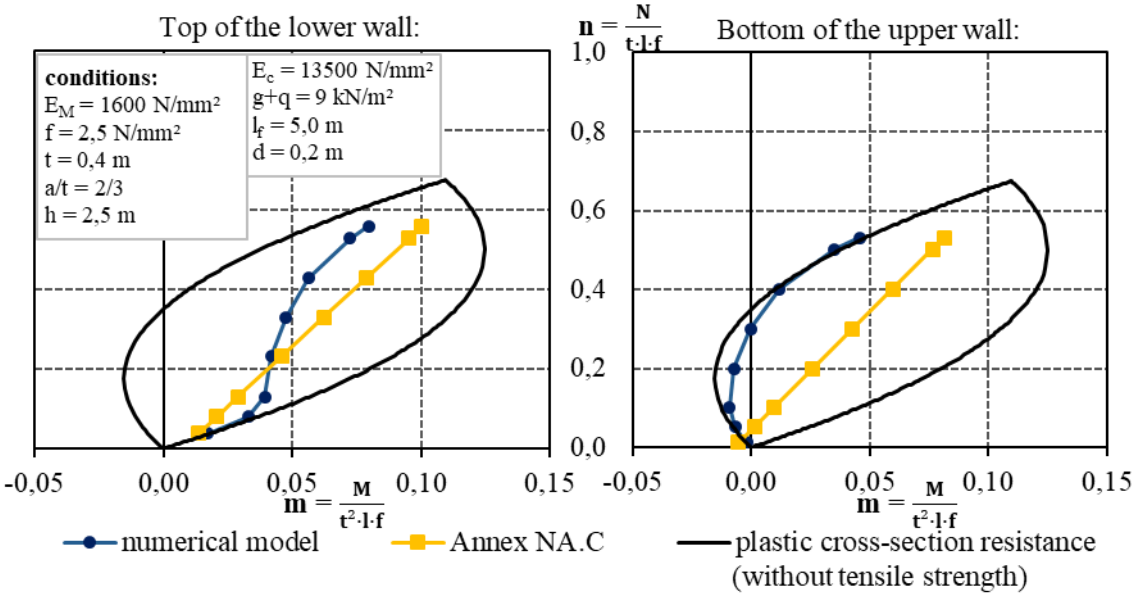

Figure 2: Comparison of the normatively and numerically determined M-N-Interaction

UNIFIED SHEAR MODEL FOR SLENDER RC MEMBERS WITHOUT SHEAR REINFORCEMENT

Ngoc Linh Tran

In more than one hundred years since the first use of reinforced concrete, research on shear strength of reinforced concrete members without shear reinforcement has remained a big challenge in the development of a general mechanical shear model that is consistently valid for all practical cases. Existing shear models were developed with the use of certain empirical parameters, in which some mechanical aspects could not be clearly explained. Therefore, these shear models can be only applied to a limited range of application and are strongly dependent on the shear test databases used to calibrate the models.

In contrast to the existing shear models, the newly developed shear model considers all necessary physical parameters with realistic values. The derivation of the model is based on the mechanical principles. Taking the tensile fracture energy into account in the model, the shear stress transmission over the cracks is considered. In combination with an analysis of the crack width and crack spacing, the size effect is automatically taken into account. Using basic parameters of concrete and reinforcement materials, the model works not only for the design of new concrete members but also for the recalculation of existing structures. The model offers a wide range of application, including conventional steel-reinforced concrete members as well as the new reinforced concrete systems. The first formulation of the new shear model has been introduced in (1) and presented in (2) in detail. According to the new model, the mean value of shear strength of a slender reinforced concrete member without shear reinforcement is calculated as follows:

$$V_{cm} = \frac{2}{3} \cdot f_{ctm} \cdot b \cdot d \cdot \left(k_x + 1.25 \cdot \frac{G_F}{f_{ctm} \cdot w_m} \cdot (1 - k_x) \right) \tag{1}$$

Here, f_{ctm} and G_F are the mean tensile strength and fracture energy of concrete; b and d are the width and static depth of the concrete member; $k_x = x/d$ is the relative depth of the compression zone; w_m is the mean primary crack width corresponding to the considered section. If concentrated loads are applied, the control section is set at a distance d from the load point. The calculation of shear strength V_{cm} is iterative, generally. The parameters are explained and determined in detail in Section 9.1.3 of literature (2). A comparison between experimental and calculated results

for a large range of reinforced concrete members shows that the new shear model exhibits consistently high prediction accuracy, see Tab. 1.

Table 1: Comparison between experimental and calculated shear strengths (2)

No.	Test group	number of beams	mean value of V_{exp} / V_{cal}	CoV (%)
	concentrated load			
1	normal concrete	1086	0.99	14.9
2	recycled aggregate concrete	131	1.02	13.0
3	lightweight aggregate concrete	49	1.01	16.9
4	normal concrete + pre-stressed load	113	0.99	12.2
5	steel fibre-reinforced concrete	60	1.06	14.5
6	normal concrete + FRP reinforcement	207	1.09	14.4
	distributed load			
7	normal concrete	16	0.99	11.2
8	normal concrete + pre-stressed load	12	1.03	9.6

A new validation of the shear model for textile-reinforced concrete members, sandwich concrete members, and members made of foam concrete, geopolymer concrete, concrete with considerable shrinkage, swell and creep effect, also shows positive results of prediction accuracy. The new model can therefore be described as a **U**nified **S**hear **M**odel (USM) for slender reinforced concrete members without shear reinforcement.

(1) Tran, N.L.: A new model for shear strength of fibre-reinforced concrete members without shear reinforcement. fib Symposium 2017, Maastricht, The Netherlands, June 12-14, 2017.

(2) Tran, N.L.: Shear strength of slender reinforced concrete members without shear reinforcement – A mechanical model. Habilitation. Technische Universität Darmstadt, 2018.

THERMAL DECOUPLING OF REINFORCED CONCRETE WALLS

Jochen Zeier

Reducing thermal bridges can make a significant contribution to meeting future requirements for energy-efficient construction. The aim of this research project is to develop the scientific basis for the development of thermally decoupled connections for reinforced concrete walls. The wall-slab-connection to be developed should enable sufficient thermal decoupling of the reinforced concrete wall from the reinforced concrete slab and at the same time fulfill the static requirements in particular from the temperature deformation of the wall. The main application area is seen in multi-storey residential and office buildings with underground garages.

The building physics and static requirements for the thermally decoupled wall connection were compiled based on a previous research project (1). The wall-slab-connection must be made of "non-combustible" materials in the load-bearing parts and cause less heat loss than the structural solution with insulation on the wall head. From a static point of view, the forces resulting from the temperature deformation are the decisive factors.

Based on the composition of the material, a full-surface lightweight concrete element was identified as being most suitable on the basis of static, building physics and economic criteria.

Using thermal modeling, the required heat transfer coefficient λ could be determined for the wall-slab-connection. It was found that the heat loss at the thermal bridge using the wall-slab-connection compared to the monolithic construction could be significantly reduced without additional insulation. At the same time, the heat losses are lower than in the constructive solution with insulation on the wall head.

The load-bearing behavior of the wall-slab-connection made of a full-surface lightweight concrete element was investigated experimentally, whereby the shearing resistance was determined by means of small-body experiments (see Figure 1). The recalculation of the experiments using FE software showed a good agreement.

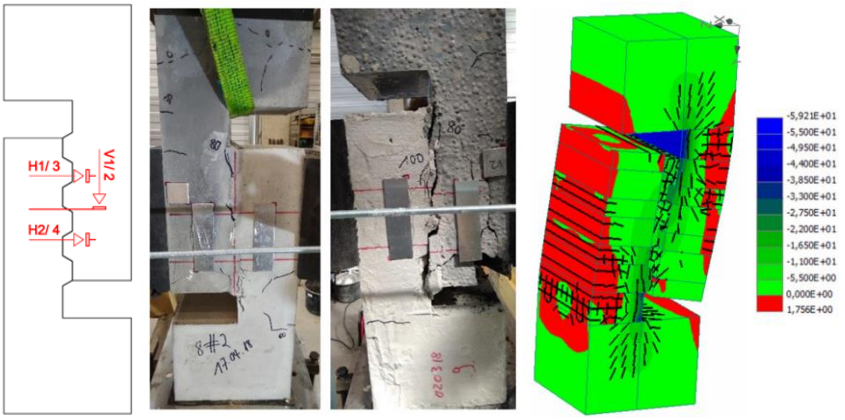

Figure 1: Small-scale test specimens

On the basis of large-scale test specimens, the combined load of a bending moment and a shear force on the joint was investigated. Due to the interaction, a reduced shearing load capacity has to be considered.

The novel wall-slab-connection made of a lightweight concrete element with tooth-shaped surface and joint reinforcement to ensure a sufficient bond showed in the experiment on a sufficiently high load capacity for many applications is cost effective and also reduces the heat loss at the thermal bridge significantly.

(1) Graubner, C.-A.; Proske, T.; Zeier, J.; Bröse, C. (2016): Entwicklung thermisch entkoppelter Druckanschlüsse für Stahlbetonstützen. Research Paper, TU Darmstadt, Institut für Massivbau, Darmstadt, 2016.

2.3 RESEARCH FIELD: BUILDING MATERIALS

The research area "Mineral and ecological building materials" focuses on ecologically optimised structural concretes, ecologically optimised cements, self-compacting concretes and fresh concrete pressure on formwork.

The aim of the research area "Ecologically optimised structural concretes" is the development of so-called "Green Concretes" or "Eco-Concretes". These concretes are composed in such a way that the environmental impact resulting from the production of the raw materials and the concrete production is as low as possible. In several research projects, Eco-Concretes are currently being developed with the participation of the precast concrete industry and ready-mix concrete producers, with which load-bearing concrete members can be produced in the near future.

By reducing the water content, switching to a high-performance superplasticizer and significantly increasing the limestone powder content, a significant reduction in the clinker content was achieved while maintaining the concrete compressive strength. All in all, the cement-reduced Eco-Concretes have a global warming potential that is reduced by approx. 30 % to 60 % compared to conventionally used concretes.

SHRINKAGE OF CONCRETE FOR APPLICATION IN INFRASTRUCTURAL CONSTRUCTIONS

Christian Herget, Tilo Proske

The production of cement and concrete is responsible for about 5-8% of the annual anthropogenic CO_2-emissions. By reducing the cement clinker in cement, concrete could be produced much more ecologically. Particularly in road construction, special requirements are forced on the cements and the concretes produced from them due to the strong environmental attacks such as frost-thaw cycles, de-icing agent attack, alkali-silica reaction and mechanical stress. Therefore, Portland- or composite cements with only small quantities of substituent materials are usually used. Especially in non-reinforced components, such as concrete road pavements, or prestressed concrete components in bridge superstructures, the deformation properties such as creep and shrinkage influence the load-bearing behaviour and durability significantly.

Within the scope of this research work, the creep and shrinkage of concretes with a similar compressive strength (C30/37) for infrastructural constructions made of clinker reduced cements was investigated. Based on conventional concrete compositions, both the cement clinker content of the laboratory cements and the water-cement ratio were varied. The compressive strength and the shrinkage and creep deformations of the concretes made of clinker-reduced cements were determined. It was found that by adjusting the concrete technology by reducing the water content and partially substituting the cement clinker with limestone powder and ground blast furnace slag in the concrete, comparable strengths can be achieved as reference concretes from pure CEM I with a usual w/c-ratio. Concrete made of CEM II/B-LL with 35 wt.-% limestone powder causes a significant reduction in shrinkage deformation (see Figure 1 left). Blast furnace slag seems to have only a minor influence on the shrinkage behaviour of concrete with w/c = 0.5 and a slag content of 46 wt.-% (see Figure 1 right). The lowest shrinkage was achieved in concretes with a multicomposite cement containing cement clinker, ground blast furnace slag and limestone powder in a ratio of 35/30/35 wt.-%. The creep behaviour was positively influenced by ground blast furnace slag. In addition, the shrinkage and creep values measured were compared with calculated values from standard. It was found that the prediction model for shrinkage and creep in Eurocode 2 is clearly on the safe side for concretes made of cements containing ground blast furnace

slag. An adaptation of the current standard with regard to shrinkage and creep deformations is considered necessary.

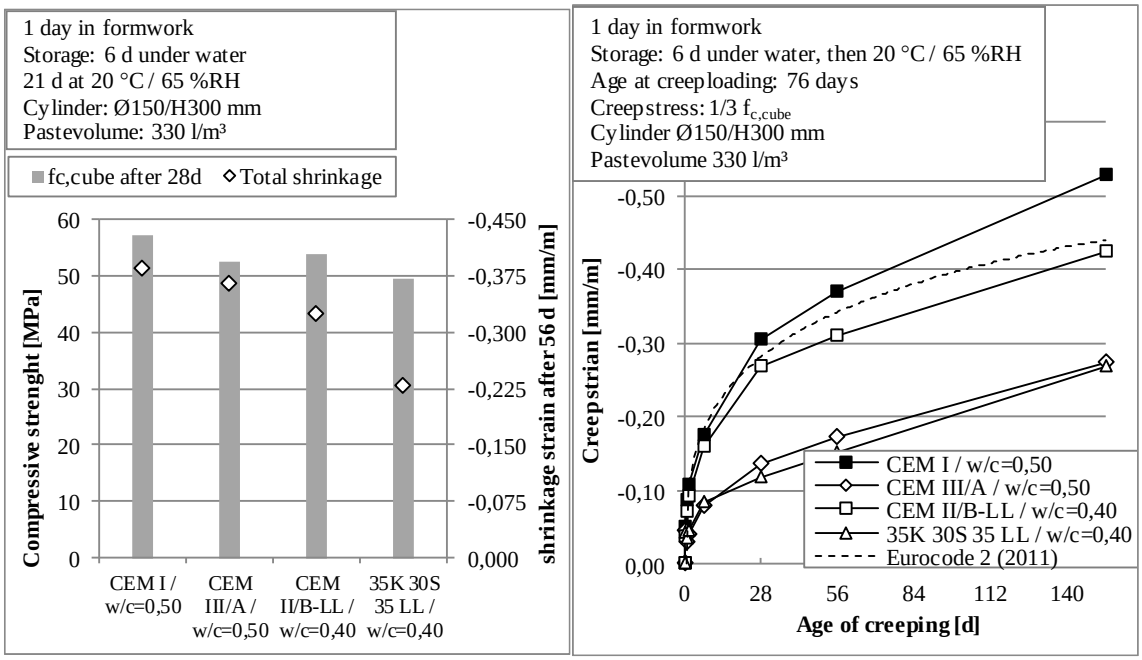

Figure 1: Compressive strength, shrinkage strain (left) and creep strain (right) of concretes made of clinker reduced cements

INFLUENCE OF THE PERMEABILITY OF TEXTILE FORMWORK ON THE DURABILITY OF CONCRETE ELEMENTS

Moien Rezvani, Tilo Proske, Sascha Hickert, Vincent von Goertzke

Properties of concrete are significantly affected by the water-cement-ratio of the mixture. In general, a lower water-cement-ratio leads to a higher compressive strength and a more durable concrete. The properties of concrete cover layer is essential for the durability of the entire concrete element. It can be expected that a reduced water-cement-ratio in the concrete cover by using permeable formworks results in an improved density of this region. In contrast to conventional impermeable formwork, the excessive water can drain through the permeable textile formwork.

Within present inter-discipline research of the Institute of Concrete and Masonry Structures and Institute of Structural Mechanics and Design, it was attempt to understand to what extent the permeability of textile formworks influences the mechanical characteristics and durability of concrete and concrete elements. Four different textile formworks, namely Covertec (impermeable reference material), Polyester, Cotton and Sefitec, with various permeability and material properties were used). Compressive strength, shrinkage deformation, carbonation resistance, water vapour diffusion, frost resistance and the surface hardness of two concrete mixtures with different strength levels were tested for each textile type. Meanwhile, the aforementioned experiments were conducted exemplarily for eco-friendly concrete with reduced water and Portland cement clinker content.

The test results regarding the carbonation resistance and compressive strength are shown in Figure 1. Figure 1 confirms that the carbonation resistance and the compressive strength of concrete is notably affected by the type and the permeability of textile formwork.

Independent from concrete composition, the samples made with permeable textile, exhibited a higher carbonation resistance and compressive strength than the reference sample made in impermeable formwork. Furthermore, a lower shrinkage deformation and a higher surface hardness was observed for samples made with permeable textile formworks.

The conducted study showed that a significant improvement of the mechanical and durability properties is achievable by application of permeable textile formworks in comparison to the con-

ventional impermeable formworks. This can be attributed mainly to the reduction of the water-cement-ratio and porosity in the layer of concrete in vicinity of formwork.

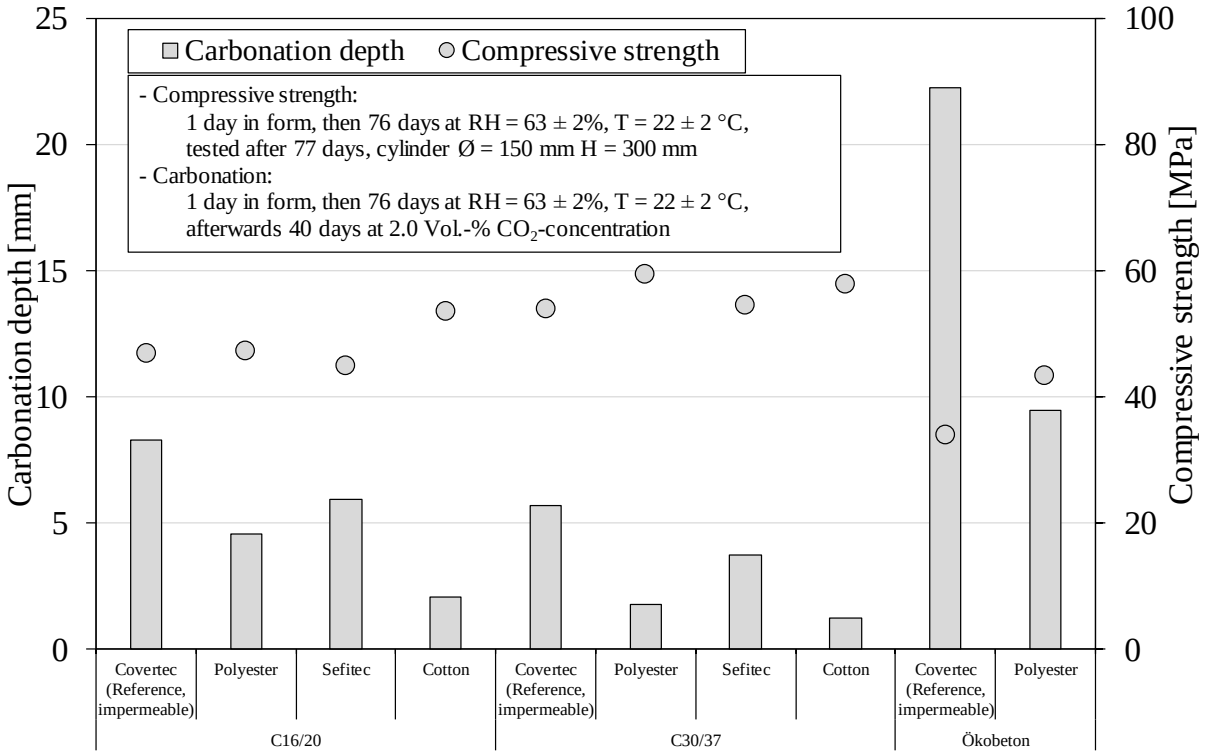

Figure 1: Influence of permeability of textile formwork on the carbonation resistance and compressive strength

INFLUENCE OF HUMDITY ON CARBONATION OF ETTRINGITE, PORTLANDITE AND C-S-H-PHASES

Sarah Steiner, Tilo Proske

The carbonation behavior of ettringite, portlandite and calcium-silicate-hydrate phases (C-S-H) is highly important for durability issues of concrete, especially regarding carbonation induced steel corrosion. Relative humidity (RH) is an important influencing factor regarding the carbonation process. Therefore, the influence of humidity on the carbonation of single phases was studied.

Calcium-Silicate-Hydrates (C-S-H) with initial Ca/Si molar ratios of 0.7, 1.2 and 1.6 were synthesized by mixing silica fume with calcium oxide. For carbonation, defined quantities of C-S-H phases as well as powdered portlandite (Por) and ettringite (Ett) were loosely filled into sample containers. Carbonation took place in climate chambers at 20 °C, 57% RH and 1 vol-% CO_2 for 1, 4, 7, 28, 92 and 183 days. In addition, samples were stored in 91% RH (20 °C and 1 vol-% CO_2) for 1, 4, 7 and 28 days. The direct impact of short-term changes in humidity conditions were investigated by exposing samples, which were already carbonated for 183 days at 57% RH, to an atmosphere containing 1 vol-% CO_2 and 91%RH for further 21 days. X-ray diffraction (XRD) measurements and Fourier-transform infrared spectroscopy (FTIR) were conducted to analyse the partially and completely carbonated samples. Additionally, Thermogravimetric analyses (TGA) were carried out. The amount of $CaCO_3$ was quantified using the tangential method.

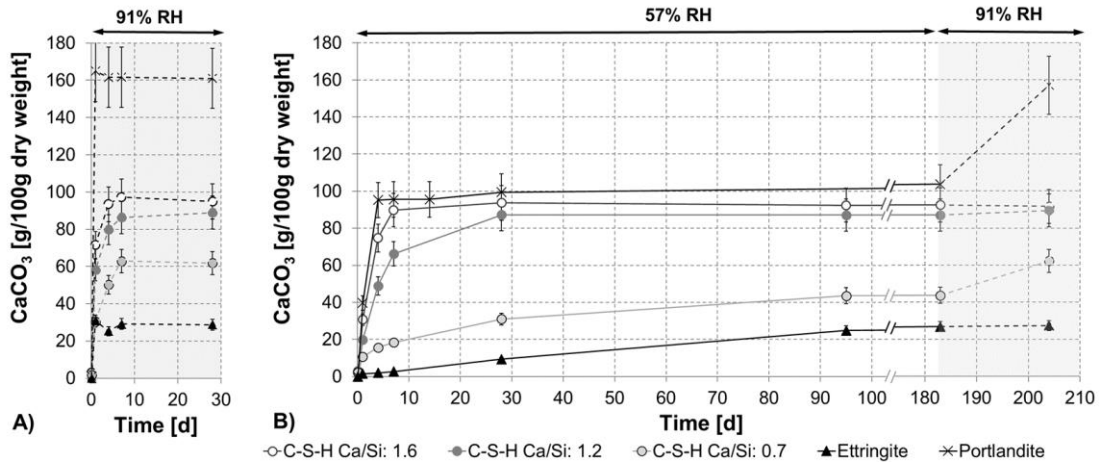

Figure 1: $CaCO_3$ content while carbonation of Ettringite, Portlandite and C-S-H phases at 1 vol.-% CO_2, 91% RH (A) and 57% RH (B) determined by TGA data.

Figure 1 shows the amounts of $CaCO_3$ determined from TGA as a function of carbonation time. Generally, the measurements indicate higher reaction rates at 91% RH (Fig. 1A) compared to 57% RH (Fig. 1B). The measurements of ettringite show faster (Fig. 1B) and complete carbonation at 91% RH, whereas the reaction rate at 57% RH was significantly slower (Fig. 1A). Furthermore, analyses of portlandite under changing moisture conditions (Fig. 1B) suggest that only partial carbonation took place at 57% RH. However, at 91% RH the entire material seems to have reacted after one day.

The reaction rates of the C-S-H phases decrease with a decreasing Ca/Si ratio, while a high relative humidity induces an accelerated carbonation. The reaction rate of C-S-H with an initial Ca/Si ratio of 0.7 is strongly influenced by the relative humidity. After 92 days of carbonation at 57% RH the determined mass fraction of $CaCO_3$ remained almost constant. The rearrangement of the samples into an atmosphere with high humidity (91% RH) resulted in a sudden increase of the reaction rate (Fig. 1A). C-S-H with initial Ca/Si ratios of 1.6 and 1.2, seemed to be almost completely carbonated at 57% RH as well as at 91% RH after 28 days.

2.4 RESEARCH FIELD: ENERGY AND SUSTAINABILITY

Research Field: Energy Research

The German federal government has set ambitious climate protection targets until 2050: At least 80 % of the gross electricity consumption and 60 % of the gross final energy consumption shall be covered by renewable energies. Buildings play a key role in this project as the building stock not only accounts for a quarter of annual final energy consumption, but also forms a central interface between the electricity, heating and mobility sector. Innovative energy technologies can be used efficiently, ecologically and economically, especially on the urban scale, and can lead to a stronger coupling of these sectors.

The Institute of Concrete and Masonry Structures makes an essential contribution to the energy system of tomorrow mapping energy requirements in high temporal resolution, conducting dynamic simulations of energy concepts or developing concepts for the utilisation of excess energy.

Research Field: Sustainable Design

In the context of the progressive destruction of our environment, aspects of sustainable development are becoming increasingly important. In regard to this, the field of civil engineering offers great potential for development. Factors such as a high commitment of resources, complex emissions and the still often limited application of integral planning are only some of the elements of a wide field of action, which is equally of economic, ecological and social importance.

Research in the field of sustainable development has been one of the central fields of work of the Institute of Concrete and Masonry Structures since 1997. A number of software tools have been developed in recent years to carry out a holistic analysis and assessment of buildings over their entire life cycle. From the planning phase to the construction, operation and disposal phases, all relevant economic and ecological features of a building can be recorded and evaluated over its entire life cycle.

ECOLOGICAL AND ECONOMIC ASSESSMENT OF BATTERY ELECTRIC VEHICLES

Marleen Fischer

The ongoing climate change can be stopped by reducing greenhouse gas (GHG) emissions. Future scenarios, for instance those published in the study "Climate Paths for Germany" (1), see great potential in battery electric vehicle (BEV): In 2050, a share of 73 percent of electric mobility is expected in the vehicle fleet, of which about two-thirds will have a battery-electric drive. It is questionable, whether traveling by today's electricity mix has an ecological advantage compared to conventional vehicles. Furthermore, the high-emission production of the additionally required batteries has to be noted. Against this background, an ecological analysis is carried out for the production and operation of BEVs as well as an additional economic study regarding consumption costs.

The research project compares greenhouse gas emissions, investment costs and operating costs of a battery electric vehicle of the type Renault ZOE with those of a Renault CLIO (73 PS) with gasoline engine and a Renault CLIO (90 PS) with diesel engine.

Table 1: Overview of the motor vehicles according to manufacturer`s instructions (2), (3)

	Renault ZOE	**Renault CLIO gasoline vehicle**	**Renault CLIO diesel vehicle**
consumption	13.0 kWh/100 km	5.6 l/100 km	3.5 l/100 km
fuel costs	0.27 €/kWh	1.43 €/l plus inflation	1.25 €/l plus inflation
GHG emissions			
operation	64 g CO_2-eq./km	235 g CO_2-eq./km	178 g CO_2-eq./km
manufacturing engine	248 kg CO_2-eq.	1,087 kg CO_2-eq.	1,269 kg CO_2-eq.
manufacturing battery	10,988 kg CO_2-eq.	-	-
investment costs			
vehicle	29,900 €	11,990 €	17,290 €
battery	8,000 €	-	-

Table 1 provides an overview of the examined motor vehicle types. Both ecological and economic analysis assume a maximum driving distance of 200,000 km. Figure 1 depicts the results of the ecological study on the left side. Based on the current electricity mix, the battery electric vehicle amortizes after 59,500 kilometers compared to a gasoline vehicle. Due to a battery change after 160,000 kilometers, the actual amortization compared to the diesel vehicle takes place after about 186,000 kilometers. The economic analysis has shown that traveling with a battery electric vehicle has much higher investment costs (see figure 1, right). Despite the lower running costs, the battery electric vehicle cannot amortize during the entire scope of consideration. In the case that the battery change occurs within the prescribed warranty period of 8 years (< 160,000 kilometers), the significant increase in the graphic at 160,000 kilometers can be minimized; *Traveling with electricity* still remains the most cost-intensive.

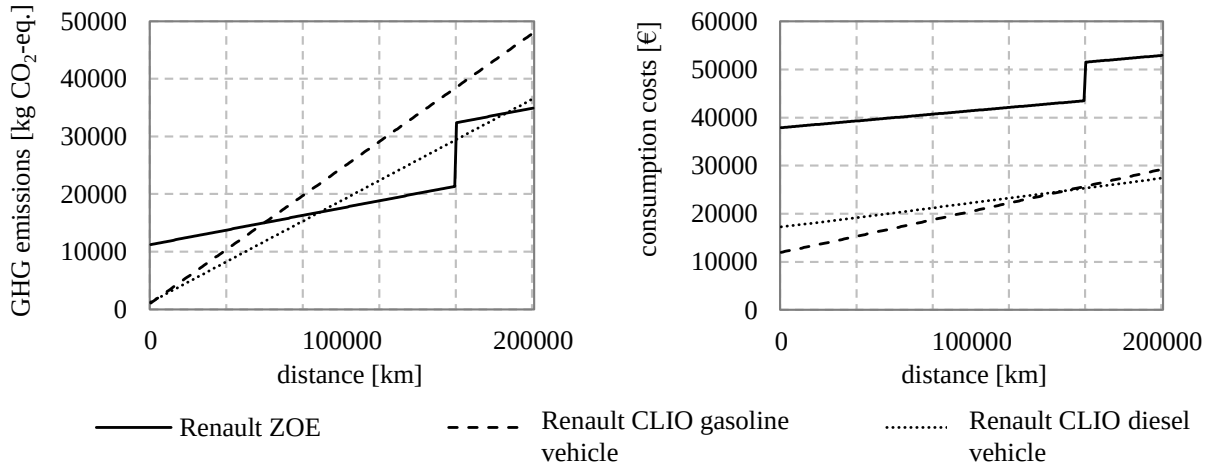

Figure 1: Greenhouse gas emissions (left) and consumption costs (right) of a small battery electric vehicle compared to a gasoline and a diesel engine

(1) Gerbert, P.; Herhold, P.; Burchardt, J.; Schönberger, S.; Rechenmacher, F; Kirchner, A.; Kemmler, A. und Wünsch, M. (2018): Klimapfade für Deutschland. BCG und Prognos (Ed.).

(2) BMI (2017): ÖKOBAUDAT 2017-I. Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Ed.), Berlin.

(3) MWV (2018): Verbraucherpreise. Mineralölwirtschaftsverband e.V. (Ed.), Berlin.

POTENTIALS OF ENERGY-EFFICIENT REFURBISHMENTS TO REDUCE CARBON EMISSIONS IN THE GERMAN BUILDING SECTOR

André Müller

The German government is aiming at a reduction of greenhouse gas emissions in the range of 80 to 95 % until 2050 compared to the base year 1990. An essential part of the overall reduction has to be achieved by reducing the emissions caused by heat demand of buildings about 80 %. This reduction is necessary, since about 93 % of the German building stock was built before the introduction of the German Energy Saving Ordinance (Energieeinsparverordnung - EnEV) in 2002. Therefore, they are inefficient according to actual building efficiency standards. In addition to this, a majority of about 80 % of these buildings is equipped with heat generators fueled with gas or oil, and thus, causing high carbon emissions today and in the next decade[1]. (1), (2)

Although the German government has the aim to increase the rate of energy-efficient refurbishments from 1 to 2 %, a significant improvement is not visible at the moment. For this reason, the overall potentials for a reduction of carbon emissions of the building stock of construction year classes before 1979 are investigated. Basis is the dynamic simulation of the heat demand of generic building models for the construction year classes from 1949 to 1979, which use data regarding the construction from example buildings of the building typology of Institute for Housing and Environment.

[1] The estimated lifetime of a new conventional heat generated is around 20 years.

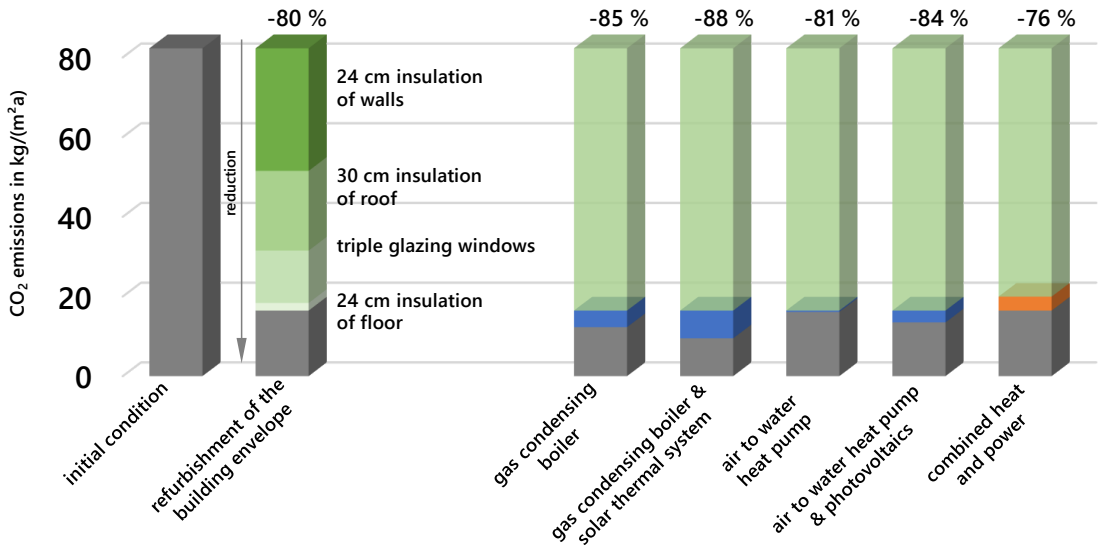

Figure 1: Potential refurbishment measures to reduce CO_2 emissions of a generic single-family house of the construction year class of 1958-68.

As an example, figure 1 shows the potentials for reduction of carbon emissions of a single-family house of construction year class 1958-1968. The results of the building simulation show that considerable potentials for a reduction of carbon emissions can be achieved when the building stock built before 1979 is refurbished with ambitious energy-efficient measures (left). Furthermore, the comparison of several types of heat generators show that today's boundary conditions of the ecologic assessment lead to contradictive results. However, the aim of carbon reduction of about 80 % – from a technological perspective – can be reached.

Acknowledgment: Dynamic building simulation and the analysis of the results were conducted by Julian Redelbach as part of his interdisciplinary master thesis.

(1) dena (2016): dena-Gebäudereport. Statistiken und Analysen zur Energieeffizienz im Gebäudebestand. Deutsche Energieagentur GmbH (dena), Berlin, 2016.

(2) Diefenbach, N.; Cischinsky, H.; Rodenfels, M.; Clausnitzer, K.-D. (2010): Datenbasis Gebäudebestand. Institut Wohnen und Umwelt, Bremer Energieinstitut, Darmstadt/Bremen, 2010.

DEVELOPMENT OF DYNAMIC EMISSIONS FACTORS FOR THE GERMAN ELECTRICITY MIX

Patrick Wörner, André Müller

In the light of the German Energiewende, electricity generation from wind power and photovoltaic systems contribute substantially to the overall power generation in Germany. Their relatively low specific greenhouse gas emissions over the life cycle are reflected by ongoing adjustments of the CO_2 and greenhouse gas factors for the German electricity mix, which are used as static input parameters for the ecological analysis and assessment of products and processes. However, the evaluation of innovative and electrified energy supply concepts is virtually impossible using the current calculation method based on the annual energy demand because it does not account for the fluctuating character of renewable energies sufficiently. With the aid of a newly developed methodology, dynamic emission factors for the German electricity mix can be generated in 15-minute temporal resolution. For this purpose, publicly accessible electricity generation time series (1) are processed, matched with results of national energy balances and finally transferred into time-variable emission factors via LCA calculations in a multi-stage process. For the year 2017, dynamic CO_2 and greenhouse gas factors are available both with and without consideration of upstream chains, e.g. from fuel supply and production of power plants, along with different reference values depending on the intended field of application.

Figure 1 illustrates the relevance of time-variable emission factors using the modified generation time series for December 2017. Due to the infeed of wind and solar energy, the electricity mix shows significant dynamics depending on day and daytime, which is also reflected in the time-variable emission factors. The actual CO_2 emissions lie above or below the static annual average factor.

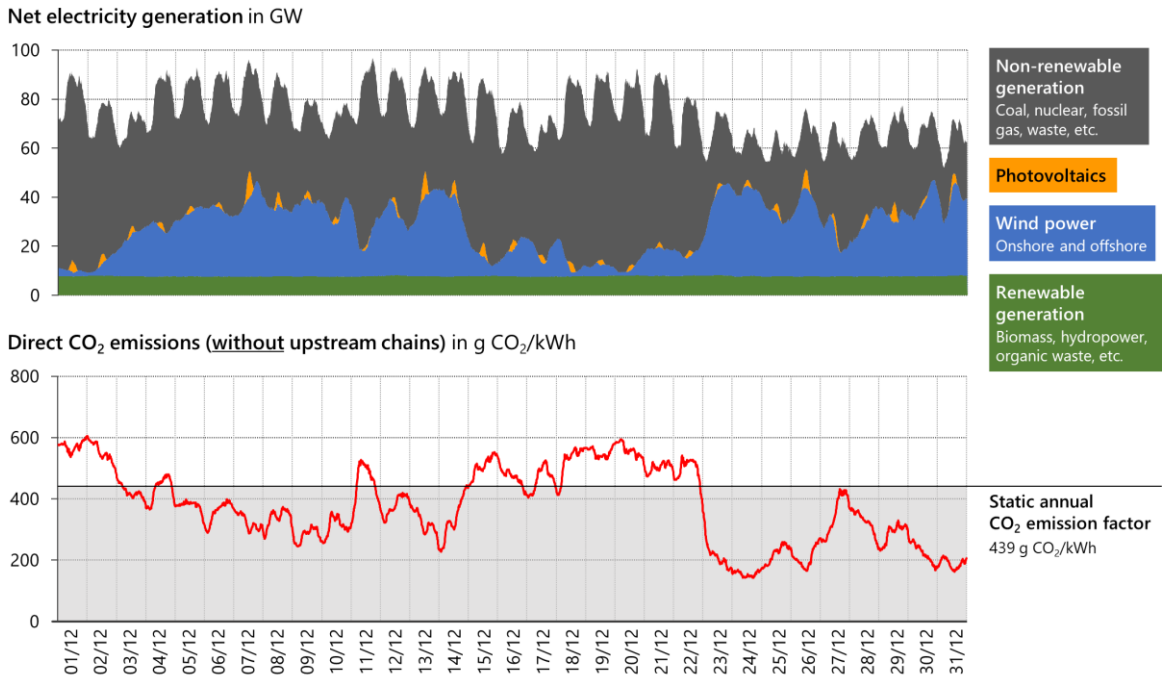

Figure 1: Electricity generation and dynamic CO_2 emission factor in December 2017

In an application example, the generated emission factors are integrated as an external signal in a heat pump control system of a fictional single-family house. Dynamic building simulations demonstrate that an optimized heat supply primarily during times of low CO_2 intensity in the electricity mix may significantly reduce emissions by 12%. (2) Therefore, the fluctuations of the emission factors described before allow to absorb potentials from the volatility of regenerative power generation during the heating period and to make a vital contribution to grid stability, too. As Figure 1 points out, the savings potential might be undetected if the standard assessment method using static emission factors was applied. That is why the implementation of dynamic CO_2 and greenhouse gas emission factors seems to be a reasonable or even necessary framework for the market penetration of innovative, electrified energy supply technologies.

(1) ENTSO-E (2019): Transparency Platform. European Network of Transmission System Operators for Electricity, Brussels, URL: https://transparency.entsoe.eu

(2) Wörner, P.; Müller, A.; Sauerwein, D. (2019): Dynamic CO2 emission factors for the German electricity mix. In: *Bauphysik, 41* (1), Berlin: Ernst & Sohn [to be published].