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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 ladies and gentlemen,

With the now 34 th edition of the "Darmstadt Concrete" we continue the good tradition of our Institute to inform you about the latest activities that have been made at the Institute of Concrete and Masonry Structures and the "Freundeverein des Instituts für Massivbau der TU Darmstadt e. V." at the turn of the year. In 2019, too, we can look back with pride on a pleasant development both in research and in lecturing. From an economic point of view, we managed to keep the third-party funds on a constantly high level and, due to the great commitment that we serve concerning our teaching, the allocations from the University turned out to be only slightly lower than in the previous year. Overall there are 16 scientific employees at out institute – including three post-docs– and four technical staff members. In order to keep our high standards in the upcoming year, we will sustain our efforts. At the same time, particular attention should be paid to teaching, as the market environment for civil engineers is currently extremely positive and the demand for well-qualified graduates cannot be met. All the more reason for us to be pleased that we have once again succeeded this year in convincing several outstanding graduates to continue their professional careers after a short period of practical work with a collaboration and doctorate at the Institute of Concrete and Masonry Structures.
The latest news concerning the University are that Mrs. Prof. Dr. phil Tanja Brühl took office her mandate term as the new president of TU Darmstadt after having served at Goethe University as Vice President for the past few years since 2012. Furthermore, it must be announced that the current Dean of our Faculty, Prof. Dr.-Ing. Jens Schneider, will be a member of the Executive Board of the TU Darmstadt as Vice President for International Affairs and Transfer from 01.01.2020. At the request of the Executive Board, our Civil and Environmental Engineering Department will undergo an external evaluation at the beginning of 2020 in which the teaching activities and research excellence of the individual departments will be put to the test in order to identify new fields of research and interdisciplinary cooperation. We believe that the Institute of Concrete and Masonry Structures is excellently positioned here due to its wide range of research topics and the depth of processing.

The national and international visibility of the Institute is also reflected in the fact that we participate in a large number of standardization committees and act as experts for the German Research Foundation (DFG), other funding bodies and reputable specialist journals.A highlight of the past year was certainly the 40th Darmstädter Massivbauseminar, which was held in April 2019 as the "Frankfurt Skyscraper Conference".

Twelve proven experts reported on current high-rise projects in Frankfurt and gave the almost 200 participants insights into the latest developments in all fields relevant to high-rise construction. Our special thanks go to Merck in Darmstadt for generously providing the rooms for this conference in the Merck Innovation Center in Darmstadt-Arheilgen.

In addition to the pleasingly high number of new research projects acquired at the Institute, the successful completion of research projects, the successful doctorates of our scientists and the successful graduations of our graduates are among the success indicators of the past year. In addition to that our graduates were able win numerous notable prices. In this context we want to mention Mr. Maximilian Groß, B. Sc. who won this year´s Dreßler Bau-Preis for his Bachelor´s thesis. Furthermore Mr. Lukas Bujotzek, M. Sc. and Mr. Dominik Hiesch, M. Sc. received the sponsorship award of the "Verband Baugewerblicher Unternehmer Hessen e. V." in the 1st and 2nd place. 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.

In the expired year, two former institute employees completed their doctorate at the Institute of Concrete and Masonry structures. Our congratulations go out to:

Dr.-Ing. **Katharina Fritz**:	*Qualifizierte Beurteilung der sektoralen Ressourceninanspruchnahme – Ein Vorschlag zur Beurteilung der Ressourceninanspruchnahme im deutschen Bauwesen im Hinblick auf einen schonenden und effizienten Ressourceneinsatz*
Dr.-Ing. **Jochen Zeier**:	*Thermisch getrennte Stützen-Decken-Anschlüsse im Stahlbetonbau – Ein Modell zum Tragverhalten bei großen Fugendicken*

At this point we would also like to congratulate Mrs. **Prof. Kati Herzog** on her professorship Real Estate Management & Leadership at the HSBA Hamburg School of Business Administration.

Of course it is a special concern to thank all the assistants for their support in the past year. Only through the team effort of all members of the institute, no matter in which position, is it possible

for us to look back on such a successful year 2019. In this connection we wish good luck to all the newcomers for their activities in research and teaching. At the same time, we wish all the employees who left the institute every success for their further tasks in career terms.
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 2019 as well as further information can be found on the homepage of the Institute under:

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

We would like to take this opportunity to express our gratitude to all our highly qualified lecturers and external speakers without whose energetic support it would not have been possible to maintain the wide range of our courses. Thank you very much for your honorary commitment!

Last but not least, we would like to take this time to thank the “Freundeverein des Institut für Massivbau der TU Darmstadt e. V.” who not only help us as organizers of the “Darmstädter Massivbauseminar”, but also advise, support and promote our employees in many ways. Once again, we were able to combine the annual general meeting with an institute summer party in unfortunately rather wet weather, where numerous friends of the institute could take the opportunity to meet former colleagues and acquaintances again. A prize was awarded for the best graduate at the course “Prefabricated Constructions” sponsored by the “Verband der Deutschen Fertigteilindustrie” at this event. At the same time there was the opportunity to inform oneself about the current status of the institute and the current research activities. In the coming year, the Annual General Meeting on June the 18th 2020 will again be linked to a summer festival of the Institute, which we are all already looking forward to. In addition, we would like to announce the next “Darmstädter Massivbauseminar”, which will take place on 29.09.2020 on the topic "Innovationen im Bauwesen durch Forschung und Entwicklung".
Full of optimism, we look forward to a hopefully successful year 2020. The Institute wishes you and your relatives a Merry Christmas and a good start for all your endeavours in the New Year.

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

Dr.-Ing. Tilo Proske

1.2 PARTICIPATION IN STANDARDISATION COMMITTEES

Prof. Graubner will continue to be scientifically active in the future as elected chairman of the standardization committee NA 005-06-01 AA "Mauerwerksbau" in the highest national committee in standardization issues, especially in the field of masonry construction. Furthermore, Prof. Graubner will act as vice chairman of NABau Fachbereich 06 "Mauerwerksbau", the highest DIN standards committee in the field of masonry construction. Prof. Graubner also represents German interests in masonry construction through his participation in the European standardization bodies Scientific Committee 6, Working Group 1 and directs Project Team 2 to revise DIN EN 1996-3. Moreover, Prof. Graubner is an elected member of the standardization committee NA 005-07-01 AA "Bemessung und Konstruktion" of the department of concrete and reinforced concrete construction. As a long-standing member of several expert committees of the German Institute for Construction Technology DIBt in Berlin and of several subcommittees of the German Committee for Reinforced Concrete DAfStb, he also contributes his expertise in the approval of construction products and in the drafting of guidelines.

Prof. Graubner has been a member of the editorial advisory board of the journal "Mauerwerk" since 2012 and since 2016 author of the chapter "Mauerwerk" in the well-known "Schneider Bautabellen" 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 Deputy Chairman of the German Masonry Committee (DAfM) and appointed Chairman of the Research Advisory Board of the DAfM.

In order to anchor research in the field of fibre-reinforced plastic reinforcement, the Institute of Concrete and Masonry Structures is represented by employees in the sub-committee "Nichtmetallische Bewehrung" of the German Committee for Reinforced Concrete.

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

Deutsches Institut für Normung e.V. (DIN)

- NA 005-51 FBR KOA 01; Mechanische Festigkeit und Standsicherheit
- NA 005-06 Fachbereich 06 – Mauerwerksbau (stellv. Vorsitzender)
- NA 005-01-31 AA Nachhaltiges Bauen (Sp ISO/TC 59/SC 17 und CEN/TC 350)
- NA 005-06-01 AA Mauerwerksbau (Sp 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 Mauerwerk (DAfM)

- Vorstandsmitglied und stellvertretender Vorsitzender
- Forschungsbeirat (Obmann)
- TA 01: Technik

Deutscher Ausschuss für Stahlbeton (DAfStb)

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

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“ (Obmann)

Weitere Mitgliedschaften

- American Concrete Institute (ACI)
- Verband Deutscher Betoningenieure e.V. (VDB)
- Deutscher Beton- und Bautechnik Verein (DBV)
- International Masonry Society (IMS)
- Joint Committee on Structural Safety (JCSS) Réunion International de Laboratoire et de Matériaux (RILEM)

1.3 SEMINARS AND EVENTS

1.3.1 TRAINING SEMINAR FOR STRUCTURAL ENGINEERS

As in previous years, the Institute of Concrete and Masonry Structures has also invited this year to the well-known training series "Weiterbildung für Tragwerksplaner - aus der Praxis für die Praxis". A total of 21 speakers at six seminars were able to present exciting practical reports to the over 600 participants throughout the year and present the current state of research and standardization. In spring, EC 2 interpretation questions were explained, special design problems discussed and the topic of planning law and planning responsibility dealt with. In autumn, the training series on cracks and restoration as well as an outlook on innovative building products covered two design topics which were rounded off by the global topic of FE calculation and modelling. The six individual events are listed 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 2019

Due to the positive feedback and high attendance in the past years, we will organise the seminar again in 2020. We are confident that the combination of interesting topics and renowned speakers will again attract many structural engineers. The topics of the seminars in 2020 are shown below:

- Non-metallic reinforcement | 11th March 2020
- Glass construction and facades | 25th March 2020
- Building in existing buildings | 26th August 2020
- Design of foundation structures | 9th September 2020
- Steel construction and timber construction | 7th October 2020

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 SEMINAR FOR CONCRETE AND MASONRY

In times of increasingly scarce space, prices for apartments and offices in Germany's metropolitan regions have been rising for years. High-rise construction is experiencing a veritable renaissance and makes it possible to create urgently needed living and working space on a scarce land space. In Frankfurt/Main in particular, the cityscape is clearly marked by the imposing buildings of the Frankfurt skyline.

On April 04, 2019, the 40th edition of the Darmstädter Massivbauseminar took place under the heading "Frankfurter Skyscraper Conference". The location of the conference was the breathtaking new building of the MERCK Innovation Center in Darmstadt, which the Verein der Freunde des Instituts für Massivbau der TU Darmstadt e. V. was the first external organiser to use.

The event, at which renowned experts from the field demonstrated the challenges and opportunities of high-rise construction, brought together all participants and interested parties and enabled personal and professional exchange as well as the establishment of new networks. The accompanying exhibition, which was attended by Merck KGaA, RIB Software, FILIGRAN and PERI, was also very well received by the participants.

The speakers of the event were Simone Zapke, Dipl.-Ing. Architekt S.M. Arch./MIT Jürgen Engel, Dr.-Ing. Sebastian Pohl, Dipl.-Ing. (FH) Tom Soreq, Dr.-Ing. Gert Riegel, Dr.-Ing. Hubert Bachmann, Dr.-Ing. Simon Meißner, Dr.-Ing. Gerd Remmel, Dr.-Ing. Guido Hausmann, Dr.-Ing. Andreas Bachmann, Prof. Dr.-Ing. Jochen Zehfuß and Prof. Michael Cesarz.

The event, attended by almost 200 participants, received very positive feedback from the participants. More than 70% of the visitors also said that they would take part in future Darmstädter Massivbauseminaren.

We thank Merck KGaA for the opportunity to host the conference in the Innovation Center. We would also like to thank the speakers and all those involved for their high level of commitment, which contributed significantly to the success of the event.

Figure 1-1: Professor Carl-Alexander Graubner (right) and Dr.-Ing. Simon Meißner (left) as part of the 40th Massivbauseminar at the MERCK Innovation Center

1.3.3 DARMSTADT DAYS OF PREFABRICATED CONCRETE ELEMENTS

Also in the year 2018 a new edition of the " Darmstadt Days for Prefabricated Concrete Elements" took place. The seminar series celebrated its 12th anniversary and once again met with great interest among over 80 participants from engineering practice and students. In cooperation with the Fachvereinigung Deutscher Betonfertigteilbau e. V. (Association of German Prefabricated Concrete Builders) and the InformationsZentrum Beton (Concrete Information Centre), numerous aspects of precast concrete construction were discussed over four days. In addition to current developments, such as construction with room modules or innovative carbon concrete structures, the focus was on the basics and special features of prefabricated elements. This covered a wide range of topics, which on the one hand enabled the participants to get connected with the construction method and on the other hand offered the opportunity to deepen existing knowledge. In addition to basic topics such as construction with prefabricated elements or typification principles, special components or construction methods such as prestressed constructions or detail points such as joints were also presented. The program was rounded by practical lectures with examples, e.g. on large and complex projects using prefabricated elements or slender prefabricated concrete facades. The seminars were accompanied by a trade exhibition of well-known building product manufacturers from the field of precast construction.

In addition to engineers from practical experience, the event is also aimed at students who will be dealing in depth with the design of precast concrete elements on a special "Student Day". Thus, the lecture "Prefabricated Concrete Constructions", which takes place within the “Darmstadt Days for Prefabricated Concrete Elements”, can be integrated into a structural engineering study. Since 2017, the Fachvereinigung Deutscher Betonfertigteilbau e. V. has also sponsored the „FDB Förderpreis“. This award honours the best examination performance and is conferred annually. Three students shared the prize this year. Olivia Schneider, Nils Wadowski and Benedikt Waldschmitt received their prizes at the summer party of “Verein der Freunde des Instituts für Massivbau”.

In the upcoming year, the seminar series with interesting lectures, practical examples and our well-attended exhibition is going to be celebrated for the 11th 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 2020:

- 05.03.2020 | Basic Principles of Planning and Trends
- 06.03.2020 | Prefabricated Concrete Structures
- 19.03.2020 | Building Material and Prestressing
- 20.03.2020 | Fire Protection Requirements and Connections

Update on the event can be found on the homepage of the department of solid construction (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.

Figure 1-2: Awarding the „FDB Förderpreis“ 2019 (from left to right: Mathias Tillmann (FDB e.V.), Nils Wadowski, Benedikt Waldschmitt, Olivia Schneider und Prof. Graubner)

1.4 EXCURSIONS

1.4.1 ANNUAL EXCURSION OF TU DARMSTADT AND TU KAISERSLAUTERN

From 11th to 14th of June, the large whit excursion together with the institutes for solid construction and steel construction of the TU Kaiserslautern took place again this year. This year's excursion took the 48 participants through the north of Germany.

The first destination was the large construction site of the FAIR accelerator centre in Darmstadt. 25 buildings are being constructed in total on an area of around 150,000 m², including an underground ring accelerator with a diameter of 1100 m, in which ions will be accelerated to up to 90 % of the speed of light. 600,000 m³ of concrete will be used for this multinational construction project. On the way to Hanover, the "Goldbachtal" viaduct was visited. Over a total length of 285 m, a composite bridge is being built here, which is part of the new construction of the Bundesautobahn A49.

After arriving in Hanover, the “Testzentrum Tragstrukturen“ was visited. The test centre is an institution of the Faculty of Civil Engineering and Geodesy at Leibniz Universität Hannover and is closely linked to the Fraunhofer Institute for Wind Energy Systems and the Wind Energy Research Network. All aspects of wind-powered energy generation are researched here, from the foundation to the turbine. Highlights included the large-scale test facility for testing large-scale bored piles and the wave channel, which is over 300 m long.

After arriving in Hamburg, the construction site of the Westfield Überseequartier could be visited in the HafenCity. On a total area of 429,000 m², a new quarter with 650 apartments, 4,000 workplaces and various entertainment and leisure facilities is being built. There also arise three hotels and a cruise terminal. Subsequently, the “Baakenhafen Baufeld 89” was visited. Here, a 6-storey solid wood building, planned by a joint building venture, is being constructed.

On the third day a trip to the 295 m long historical “Rendsburger Hochbrücke” was on the agenda. The bridge was built in the early 1910s and is part of a 4 km long "loop" to adjust the height of the railway tracks. Another special feature of the bridge is the floating ferry, with which the Kiel Canal can be crossed. Other highlights included a tour to a car park construction site using a composite construction system and a sightseeing tour in the harbour of Hamburg.

On the way back to Darmstadt and Kaiserslautern on the following day, the new construction of a canal crossing was visited along the Ems. The steel construction spans over 60 and has a steel weight of 2,000 tons. The tub cross-section has a navigable width of 26 m and is pushed into its final position over the Ems river after pre-assembly.

We would like to thank all participants, organizers and companies for the very interesting days and look forward to next year's excursion from 2nd to 6th of June 2020.

Figure 1-3: Impressios of the whit exkursion: top: construction site Westfield Überseequartier in Hamburg, canal crossing Ems; bottom: group photo of the participants, historical Rendsburger Hochbrücke

1.4.2 EXCURSION OF BSE AND SFM & SD

As part of the lectures “Technische Gebäudeausrüstung I” and “Strategically Facility Management & Sustainable Design” a study trip to construction site of the OMNITURM in Frankfurt a. M. took place on Friday, 14th December 2018. About 35 students accompanied by research assistants and Mr. Dipl.-Ing. Thomas Heß visited the project office of developer *Tishman Speyer* and *Frankfurt Construction Management* (FCM), which was located in the Taunusturm Frankfurt a. M.

First, *Tishman Speyer* introduced to the students the ideas of the 190 m high OMNITURM, which combines highest quality working and living spaces. Then, *FCM* and Mr. Heß illustrated the high complexity of the project and the necessity for integral planning and commissioning processes.

Figure 1-4: Participants of the field trip at the construction site of OMNITURM.

Figure 1-5: Mounting of a central ventilation unit at the top of OMNITURM

After this introduction, two hours of first hand impressions on the construction site followed. As a part of this, the students had the chance to see the heating, ventilation, drinking water and fire extinguishing distributions of a typical floor configuration. Furthermore, the group could visit the central ventilation systems, the heating centre with its connection to the district heating grid, as well as an uninterruptible power supply system.

On behalf of all participants, the Institute of Concrete and Masonry Structures thanks Mr. Heß as well as the companies *Tishman Speyer* and *Frankfurt Construction Management* for organizing the study trip and guiding the interesting tour onsite. This trip was possible only due to the generous support of the “Freunde des Instituts für Massivbau der TU Darmstadt e. V.”, to whom we express our sincere thanks.

1.5 PERSONAL MATTERS

Since April 1st 2019 **Mr. Dominik Hiesch, M.Sc.** is employed at the Institute of Concrete and Masonry Structures. Mr. Hiesch studied Civil Engineering at the TU Darmstadt, specialising in the fields of solid construction, steel construction and geotechnical engineering. In his master's thesis "Carbon-reinforced concrete members under long-term static loading – experimental and theoretical investigations" he dealt with the long-term behaviour of carbon-reinforced concrete members with the main focus being the development of a prediction model to calculate the deflection of said members. After completing his studies, Mr. Hiesch worked as a project engineer at „Gruber+Hartmann - Ingenieurbüro für Baustatik“ in Darmstadt. His work included the verification of static analyses as well as the planning of constructions in the field of structural engineering. As part of his activities at the Institute of Concrete and Masonry Structures, Mr. Hiesch will be in charge of the lectures "Prestressed concrete construction" and "Massive bridge construction and scaffoldings".

Since September 2019 Mr. Johannes Koert, M.Sc. is employed at the Institute of Concrete and Masonry Structures. Mr. Koert studied Civil Engineering and Business Administration at the TU Darmstadt. During his studies, he worked already as a student assistant at the Institute to support the energy research group. For his master thesis he developed a method for economic evaluation of existing districts on the basis of an actor-related perspective. As part of his doctorate at the Institute of Concrete and Masonry Structures he will be the lead for the project “E4Q”. In this project, funded by the Federal Ministry for Economic Affairs and Energy, an existing method for evaluating the energetic, ecologic and economic effects of energy supply concepts for existing and newly built city districts will be advanced in cooperation with the Institute for Housing and Environment. Furthermore, Mr. Koert will be responsible for the lectures “Building Technology I and II”.

Since October 1st 2019 **Mr. Lukas Bujotzek, M.Sc.** is employed at the Institute of Concrete and Masonry Structures. Mr. Bujotzek studied Civil Engineering at the TU Darmstadt, specialising in the fields of solid construction, steel construction, structural mechanics and geotechnical engineering. In his master's thesis "Monte Carlo Simulation of unreinforced masonry walls considering spatially variable material properties" he dealt with the influence of spatial variability on the reliability of masonry walls load capacity. After completing his studies, Mr. Bujotzek worked as a project engineer at „KHP König und Heunisch Planungsgesellschaft mbH & Co. KG" in Frankfurt am Main. His work included the verification of static analyses as well as the planning of constructions in the field of water and bridge engineering. As part of his activities at the Institute of Concrete and Masonry Structures, Mr. Bujotzek will be in charge of the lecture "Applied Structural Dynamics".

Since November 1st 2019 **Mr. Maximilian Brinkmann, M.Sc.** is employed at the Institute of Concrete and Masonry Structures. During his studies in civil engineering at Technische Universität Darmstadt, Mr. Brinkmann focused on solid and steel constructions, structural mechanics and geotechnical engineering. In the course of his master thesis "Load-bearing behavior of unreinforced unfired clay masonry in compression", he dealt with the numerical analysis of unfired clay masonry and investigated the load-bearing capacity of slender unfired clay walls. As an employee of the Institute of Concrete and Masonry Structures he is responsible for the research project "Creation of design rules for earth masonry on the basis of EN 1996 by experimental and numerical analysis", which is funded by the Deutsche Bundesstiftung Umwelt and carried out in cooperation with the Bundesanstalt für Materialforschung und –prüfung. He is also in charge of the lecture "Mauerwerksbau und Sonderfragen aus dem Betonbau".

1.6 AWARDS

1.6.1 AWARDS OF THE „FREUNDE-VEREIN“

As in previous years, the Freunde-Verein awarded a prize in 2019 for the best masterthesis at the Institute for Concrete and Masonry Structures. This year the GOLDBECK company again took over the prize foundation. This year's award winner was Mr. Dominik Hiesch, M.Sc. with his thesis on "". The work was supervised by Mr. Redouan El Ghadioui, M.Sc. We congratulate Mr. Hiesch very cordially and wish him much success in his further work on the topic within the framework of his activity as a scientific employee at the Institute for Concrete and Masonry Structures!

Figure 1-6: Awarding the prizes of the „Freunde-Verein“ on the annual summer party2019

1.6.2 DREßLER BAU AWARD

The Dreßler Construction Prize was awarded on 12 November 2019 for the seventh time for outstanding construction work in the fields of solid construction and construction operation. This year the Institut für Massivbau was represented in persona of the award winner Maximilian Groß, who wrote his bachelor thesis on "Experimental investigations on the tensile strength of fibre-reinforced plastic reinforcement". The work was supervised by Mr. Redouan El Ghadioui, M.Sc.

We congratulate at this point to this success!

Figure 1-7: Maximilian Groß (Award winner IfM), Ann-Kathrin Gorr (Award winner Insitute for Construction Management), Eva Maria Köhler (Award winner Insitute for Construction Management), Tobias Mann (Dreßler Bau) Picture: Claus Völker

1.6.3 VERBAND BAUGEWERBLICHER UNTERNEHMER AWARD

The “Verband Baugewerblicher Unternehmer Hessen e.V.” awarded prizes to students and graduates for their theses and dissertations on November the 8th 2019. In four different categories respectively the three best works were distinguished. In the range structural engineering the Institute for Concrete and Masonry Structures could occupy the first and second place. The award winners of the institute are Mr. Lukas Bujotzek (1st place) and Mr. Hiesch (2nd place) both employees of the Institute for Concrete and Masonry Structures. The award was given for the master theses with the titles " Monte Carlo Simulation of unreinforced masonry walls considering spatially variable material properties " (Bujotzek) and "Carbon-reinforced concrete members under long-term static loading – experimental and theoretical investigations " (Hiesch).

We congratulate to this success!

Figure 1-8: Lukas Bujotzek (Award Winner IfM), Marina Tillmann (Award Winner TH Mittelhessen), Dominik Hiesch (Award Winner IfM), Picture: Axel Gross

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:

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Beton Kemmler GmbH
Birco GmbH
BT3 Betontechnik GmbH
Bundesamt für Bauwesen und Raumordnung (BBSR)
Bundesanstalt für Straßenwesen
Bundesministerium für Bildung und Forschung
Bundesministerium für Verkehr und digitale Infrastruktur
Bundesministerium des Innern, für Bau und Heimat
Bundesverband der Deutschen Ziegelindustrie
Bundesverband der Kalksandsteinindustrie e.V.
Bundesverband Porenbetonindustrie e.V.
Bundesverband Deutsche Beton- und Fertigteilindustrie e.V.
Bundesverband Leichtbetonzuschlagindustrie e.V.
Deutsche Basalt Faser GmbH
Deutsche Bundesstiftung Umwelt (DBU)
Deutsche Forschungsgemeinschaft (DFG)
Deutsche Gesellschaft für Mauerwerks- und Wohnungsbau e.V. (DGfM)
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H-BAU Technik GmbH
Halfen GmbH & Co. KG
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V.FRAAS GmbH
Verein Deutscher Zementwerke e. V.
Waibel KG
Wienerberger AG
Xella Technologie und Forschungsgesellschaft mbH

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
Prof.-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
Dr.-Ing. Diethelm Bosold
Dipl.-Ing. Jörg Burkhardt
Dipl.-Ing. Heinz Eberherr
Dipl.-Ing. Thomas Haustein
Dipl. -Ing. Elisabeth Hierlein
Dipl.-Ing. Werner Hochrein
Dr.-Ing. Matthias Molter
Dipl.-Ing. Ralf Niehüser
Dr.-Ing. Christoph Schmidhuber
Dipl.-Ing. Erwin Scholz
Friedhard Ströhmann
Dipl.-Ing. Mathias Tillmann

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

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

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. Rudi Becker
Dipl.-Ing. Patrick Bös
Dipl.-Ing. Robin Engelmann
Ing. Marcel Jansen
Dr.-Ing. Leif Pallmer
Dipl.-Ing. Olaf Pielke
Verena Schön M.Sc.
Prof. Dr.-Ing. Benjamin von Wolf-Zdekauer
Dr.-Ing. Claudia Weißmann

1.8 PUBLICATIONS

Selected papers and book chapters:

Proske, T.; Rezvani, M.; Graubner, C.-A.: A new test method to characterize the pressure-dependent shear behavior of fresh concrete, In: Construction and Building Materials, Vol. 233, 2020, Elsevier, Amsterdam, S. 1-9, ISBN: https://doi.org/10.1016/j.conbuildmat.2019.117255.

El Ghadioui, R.: Carbonbewehrte Betonbauteile unter statischer und zyklischer Dauerbeanspruchung, In: Tagungsband 11. Carbon- und Textilbetontage 2019, 24.-25. September 2019, S. 86-87.

El Ghadioui, R.; Tran, N.; Proske, T.; Graubner, C.-A.: Cracking behaviour of carbon textile reinforced concrete members, In: Advances in Engineering Materials, Structures and Systems: Innovations, Mechanics and Applications, In: 7th International Conference on Structural Engineering, Mechanics and Computation, Cape Town, South Africa, 02.-04. September 2019, Taylor & Francis, London, S. 1474-1479, ISBN: 978-0-429-42650-6, DOI: https://doi.org/10.1201/9780429426506.

Wörner, P.; Müller, A.; Sauerwein, D.: Dynamische CO2-Emissionsfaktoren für den deutschen Strom-Mix. Möglichkeiten zur realistischen Bewertung zukünftiger Energieversorgungskonzepte auf Gebäudeebene, In: Bauphysik, Band 41, Heft 1, 2019, Ernst & Sohn Verlag, Berlin, S. 17-29, DOI: 10.1002/bapi.201800034.

Förster, V.; Graubner, C.-A. Erweiterung des Anwendungsbereiches von DIN EN 1996-3/NA für hohe Wände, In: Mauerwerk, Band 23, Heft 5, 2019, Berlin S.284-299, ISBN: 1432-3427, DOI: 10.1002/dama.20190001.

Förster, V.; Graubner, C.-A.; Proske, T.: Experimentelle Traglastermittlung einer teilweise bewehrten Lochfassade aus Ziegelmauerwerk In: Mauerwerk, Band 23, Heft 5, 2019, Ernst & Sohn Verlag, Berlin, S. 324-333, ISBN: 1432-3427.

Müller, A.; Wörner, P.: Impact of dynamic CO2 emission factors for the public electricity supply on the life-cycle assessment of energy efficient residential buildings, In: IOP Conference Series: Earth and Environmental Science, Vol. 323, Issue 2019 (012036), S. 1-9, DOI: 10.1088/1755-1315/323/1/012036.

Müller, D.; Graubner, C.-A.: Modification of the partial safety factor for compressive strength of existing masonry using a Bayesian method, In: Proceedings of the 17th International Probabilistic Workshop, 11.-13. September 2019, Edinburgh, UK, S. 133-138.

Graubner, C.-A.; Purkert, B.: Nachweis des Feuerwiderstands von Ziegelmauerwerk – Tipps für eine effiziente Bemessung, In: Mauerwerk, Band 23, Heft 5, 2019, Berlin S.306-315, ISBN: 1432-3427, DOI: 10.1002/dama.20190001.

Proske, T.; Rezvani, M.; Graubner, C.-A.: Ökobetone aus Kalksteinmehl – Green concretes with limestone powder, In: Innovation in Beton, Kongressunterlagen 63. Betontage, 12. 2. 2019, Neu-Ulm, S. 12-13.

Proske, T.; Rezvani, M.; Graubner, C.-A.: Pressure-Dependent Shear Behaviour of Fresh Concrete – Development of a specific Testing Device, In: Proceedings of the 2nd International Conference on Rheology and Processing of Construction Materials (RheoCon2) and the 9th International RILEM Symposium on Self-Compacting Concrete (SCC9), 08.-11. September 2019, Radebeul, S. 16.14.

El Ghadioui, R.; Graubner, C.-A.: Querkrafttragfähigkeit carbonbewehrter Betonbauteile ohne Querkraftbewehrung, In: Beton- und Stahlbetonbau, Heft 11, 2019, Ernst & Sohn Verlag, S. 827-836, DOI: https://doi.org/10.1002/best.201900052.

Rezvani, M.; Proske, T.; Graubner, C.-A.: Shrinkage of eco-friendly concretes made with limestone-rich cements, In: ZKG INTERNATIONAL Zement Kalk Gips, Issue 6, 2019, Bauverlag, Gütersloh, S. 60-67, ISBN: 2366-1313.

Graubner, C.-A.; Müller, D.: Vereinfachter Nachweis von Aussteifungswänden aus unbewehrtem Mauerwerk, In: Mauerwerk, Band 23, Heft 5, 2019, Berlin, S. 300-305, ISBN: 1432-3427, DOI: 10.1002/dama.20190001.

Selected presentations:

Hofmann, S.: Shear capacity of BFRP reinforced concrete beams without shear reinforcement, 7th International Conference on Structural Engineering, Mechanics and Computation, Kapstadt (Südafrika), 03.09.2019.

Graubner, C.-A.; El Ghadioui, R.: Technologische Grundlagen von Carbonbeton, 29. Kassel-Darmstädter Baubetriebseminar, 28.11.2019

Proske, T.; Rezvani, M.; Graubner, C.-A.: Pressure-Dependent Shear Behavior of Fresh Concrete – Development of a specific Testing Device, 2nd International Conference on Rheology and Processing of Construction Materials (RheoCon2) and the 9th International RILEM Symposium on Self-Compacting Concrete (SCC9), 09.09.2019

Herget, C.; Rezvani, M.; Proske, T.; Graubner, C.-A.: Schwindarme Konstruktionsbetone mit hohem Anteil an Gesteinsmehl? Farbe und Lack Konferenz, Kassel, 27.11.2019

Müller, D.; Proske, T.; Graubner, C.-A.: Modifizierte Teilsicherheitsbeiwerte für Mauerwerkswände im Bestand, 13. Projektetage der Bauforschung, Bonn BBSR, 05.11.2019.

Müller, D.; Graubner, C.-A.: Modification of the partial safety factor for existing masonry using a Bayesian method, 17th International Probabilistic Workshop, Edinburgh, 12.09.2019.

El Ghadioui, R.: Carbonbewehrte Betonbauteile unter statischer und zyklischer Dauerbeanspruchung, 11. Carbon- und Textilbetontage, Dresden, 25.09.2019.

El Ghadioui, R.: Cracking behaviour of carbon textile reinforced concrete members, 7th International Conference on Structural Engineering, Mechanics and Computation, Kapstadt (Südafrika), 02.09.2019.

Rezvani, M.; Proske, T.; Herget, C.; Graubner, C.-A.: Baustoffe von Übermorgen – Ressourceneffiziente Ökobetone aus Kalksteinmehl, 63. BetonTage, Neu-Ulm, 19.02.2019.

1.9 STUDENT FINAL THESES AT THE INSTITUTE IN 2019

Title of final thesis	Supervisor	Type of thesis
Modellierung des Energiebedarfs von Nichtwohngebäudebeständen(Arbeitstitel)	André Müller	Master´s thesis
Trag- und Verformungsverhalten biegebeanspruchter CFK-bewehrter Betonbauteile	Redouan El Ghadioui	Master´s thesis
Entwicklung eines Inbetriebnahmemanagements und eines Technischen Inbetriebnahmemanagements für ein Berufsschulzentrum in Darmstadt	Marleen Fischer	Master´s thesis
Nachhaltigkeitsbewertung einer Fußgängerbrücke aus Carbonbeton mittels Ökobilanz und Lebenszykluskostenberechnung	Patrick Wörner	Bachelor´s thesis
Mechanismen, Einflussparameter und Vorhersagemodelle des Schwindens von Zementstein und Beton	Christian Herget	Bachelor´s thesis
Betonfertigteile mit faserverstärkter Kunststoffbewehrung für den Hochbau – Anforderungen, Konstruktion und Bauausführung	Sebastian Hofmann	Bachelor´s thesis
Fließverhalten von Frischbeton unter Druck	Moien Rezvani	Bachelor´s thesis
Trocknungsschwinden von Beton aus kalksteinreichen Zementen	Christian Herget	Master´s thesis
Geschichtliche Entwicklung der Konstruktionsweisen im Betonfertigteilbau	Jonas Klein	Bachelor´s thesis
Schätzung der Unsicherheiten der Energiebedarfsberechnung für Wohngebäude	André Müller	Master´s thesis
Untersuchungen zum Rissabstand textilbewehrter Betonbauteile	Redouan El Ghadioui	Bachelor´s thesis
Bewertung der Standsicherheit bestehenden Mauerwerks unter Verwendung modifizierter Teilsicherheitsbeiwerte	Dominik Müller	Master´s thesis
Stochastische Modellierung und Simulation unbewehrter Mauerwerkswände mit räumlich streuenden Materialeigenschaften	Dominik Müller	Master´s thesis
Status Quo der Energiewende in Deutschland	Marleen Fischer	Bachelor´s thesis
Untersuchung zum Tragverhalten filigraner, textilbewehrter Flachstürze	René Mazur	Master´s thesis
Experimentelle Untersuchungen zur Zugfestigkeit faserverstärkter Kunststoffbewehrung	Redouan El Ghadioui	Bachelor´s thesis
Brandschutzbemessung von Stahlbetonstützen mit hohem Bewehrungsgrad	Jonas Klein	Bachelor´s thesis

Title of final thesis	Supervisor	Type of thesis
Untersuchungen zum Tragverhalten von stahl- und textilbewehrten Platten unter der Einwirkung punktueller Lasten	Larissa Krieger	Master´s thesis
Verbundverhalten in Beton von Bewehrungsstäben aus Basaltfaserverbundkunststoff (BVFK)	Sebastian Hofmann	Bachelor´s thesis
Vergleich von Sicherheitsformaten zur nichtlinearen Bemessung schlanker Stahlbetondruckglieder	Dominik Müller	Master´s thesis
Entwicklung einer Methodik zur ökonomischen Bewertung von Bestandsquartieren unter einer akteursbezogenen Betrachtungsweise	André Müller	Master´s thesis
Ganzheitliche Nachhaltigkeitsbetrachtung von Erd- und Holzhäusern nach dem Cradle-to-Cradle-Prinzip	Marleen Fischer	Master´s thesis
Carbonbewehrte Betonbauteile unter zyklischer Dauerbeanspruchung – Experimentelle und theoretische Untersuchungen	Redouan El Ghadioui	Bachelor´s thesis
Betongefüllte Großkammerziegel – Vergleich der Tragfähigkeit der Ziegelschale mit der Betonfüllung	Benjamin Purkert	Bachelor´s thesis
Entwicklung einer allgemeingültigen Methodik zur ökologischen Bewertung von Elektromobilität	Marleen Fischer	Master´s thesis
Vergleich von Verfahren zur experimentellen Bestimmung der Druckfestigkeit bestehenden Mauerwerks	Dominik Müller	Bachelor´s thesis
Vorgespannte Brückenbauwerke mit nichtmetallischer Bewehrung	Redouan El Ghadioui	Master´s thesis
Tragverhalten unbewehrten Lehmmauerwerks unter Druckbeanspruchung	Benjamin Purkert	Master´s thesis
Schwindverhalten zementbasierter Mörtel bei Verwendung inerter Betonzusatzstoffe	Christian Herget	Bachelor´s thesis
Zeitabhängiges Materialverhalten faserverstärkter Kunststoffbewehrung	Redouan El Ghadioui	Bachelor´s thesis
Experimentelle und theoretische Untersuchungen zur Querkrafttragfähigkeit carbonbewehrter Betonbauteile	Redouan El Ghadioui	Master´s thesis
Experimentelle Untersuchung zur Rissentwicklung in Betonbauteilen mit basaltfaserverstärkter Kunststoffbewehrung	Sebastian Hofmann	Bachelor´s thesis
Analyse des deutschlandweiten Ausbaupotenzials von Offshore-Windkraft	Marleen Fischer	Bachelor´s thesis
Finite-Elemente-Modellierung massiver Hochbaukonstruktionen im Bauzustand	Jonas Klein	Bachelor´s thesis
Maschinelle Oberflächenbehandlung von Schrägkabeln und Hängern im Brückenbau	Jonas Klein	Bachelor´s thesis
Historische Entwicklung des Bauens mit Mauerwerk aus künstlichen Steinen	Dominik Müller	Bachelor´s thesis

Title of final thesis	**Supervisor**	**Type of thesis**
Bemessung von Konsolen – Analyse und Vergleich verschiedener Bemessungsansätze	Jonas Klein	Bachelor´s thesis
Schnittgrößenermittlung bei FVK-bewehrten Betonbauteilen unter Berücksichtigung der Rotationskapazität	Redouan El Ghadioui	Bachelor´s thesis
Methoden zur Anpassung von Teilsicherheitsbeiwerten für Bestandsmauerwerk	Dominik Müller	Bachelor´s thesis
Biegetrag- und Verbundverhalten von Betonbauteilen mit Be-wehrung aus basaltfaserverstärktem Kunststoff	Sebastian Hofmann	Bachelor´s thesis
Vergleich von Modellen zur Bestimmung der Mauerwerks-druckfestigkeit	Dominik Müller	Bachelor´s thesis
Untersuchung des Einflusses unterschiedlichen Nutzerverhaltens auf den Energieverbrauch in Wohngebäuden	André Müller	Master´s thesis

1.10 NEW EQUIPMENT FOR THE TESTING LABORATORY

In 2019, extensive investments were made in equipment for the research and testing laboratory of the Institute in order to be able to perform our various experimentally oriented activities in research, teaching and material testing at a high level.

Especially worth mentioning is the acquisition of a photo-optical measurement system based on Digital Image Correlation (DIC), which was in a grateful manner financially supported by the association "Freunde des Instituts für Massivbau der TU Darmstadt e.V.". This innovative system allows high-resolution 3D strain and deformation measurement on large concrete and masonry components (cf. Figure 1-9).

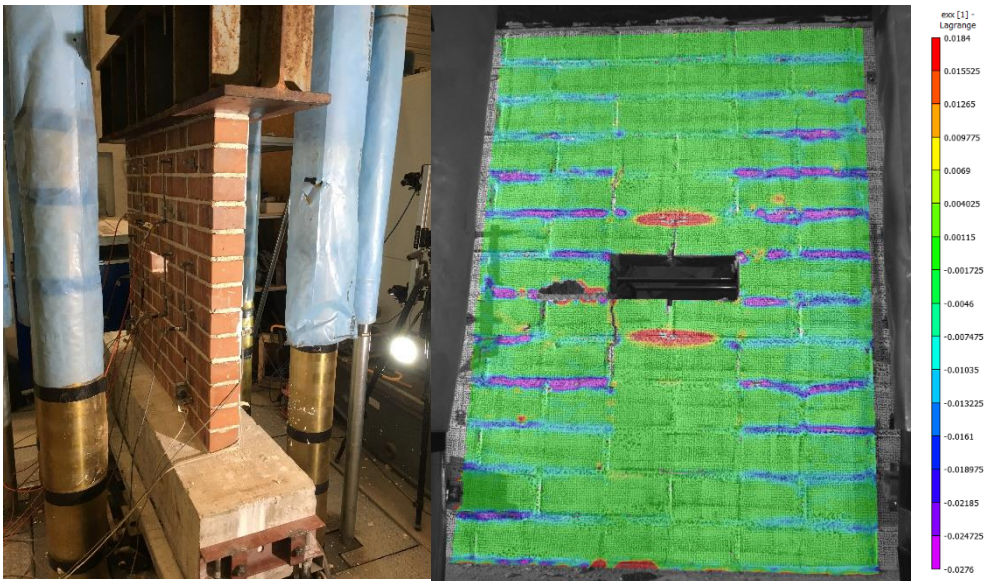

Figure 1-9: Use of the DIC measuring system when carrying out load tests on masonry (left) and as a result strain in vertical direction (right)

Two new compression testing machines with a maximum load of 200 kN (for cement and mortar tests) and 1000 kN (for concrete, drill core and masonry stone tests) were purchased to replace the aged and in some cases not repairable equipment (cf. Figure 1-10). In combination with our existing 5000 kN testing machine, our institute is now very well equipped for compression tests. In addition, a new 60-litre laboratory mixer, a new sample grinding machine, new drying ovens, an ultrasonic measuring device (Vikasonic) and a strong traverse (the latter with grateful financial support from Prof. Markus Hartmann) were purchased. Also in the new year we will continue to invest in our equipment intensively.

Figure 1-10: Compression testing machine with maximum load of 200 kN (left) and 1000 kN (centre) and specimen grinding machine (right)

2 DARMSTADT CONCRETE 2019: 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 2-1 Research Fields at the Institute of Concrete and Masonry Structures

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

- <u>Construction and Design</u>

  Construction and Design, Masonry, Risk and Safety
- <u>Mineral and ecological building materials</u>
- <u>Energy and Sustainability</u>

  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.

LOAD-BEARING CAPACITY OF SLENDER EARTH MASONRY

Maximilian Brinkmann

Due to its ecological properties, its reusability and its positive influence on the indoor climate, building with earth masonry offers valuable advantages especially for residential construction. In Germany, the design of load-bearing earth masonry is based on the Lehmbau Regeln (1). However, as these design regulations no longer correspond to the current state of the art, they will be withdrawn by the Deutsches Institut für Bautechnik in 2023. In order to enable the design of earth masonry after this date, the applicability of EN 1996-3 is investigated and new design regulations for earth masonry are developed at the Institute of Concrete and Masonry Structures as part of a research project funded by the Deutsche Bundesstiftung Umwelt.

Since tests have shown that earth masonry with $E/f_k \approx 350 - 500$ (2) has a significantly lower stiffness than conventional masonry, it has to be examined whether the design equation for slender masonry walls according to EN 1996-3 (see equation (1)) is also applicable to the design of earth masonry.

$$\Phi_s = 0,85 \cdot \frac{a}{t} - 0,0011 \cdot \left(h_{ef} / t_{ef} \right)^2 \tag{1}$$

On this occasion, the slender-dependent load-bearing capacity of earth masonry under eccentric compression load is investigated numerically by using a finite element model (3). To validate the numerical results, the load-bearing capacity of earth masonry is also approximated by using an analytical approach (4). The results are displayed in Figure 1.

As EN 1996-3 does not specify the eccentricity on which the design equation for slender masonry is based, a reverse calculation for the following comparison was done yielding $e = 0.075 \cdot t$, assuming a fully supported slab and ideal plastic material behaviour.

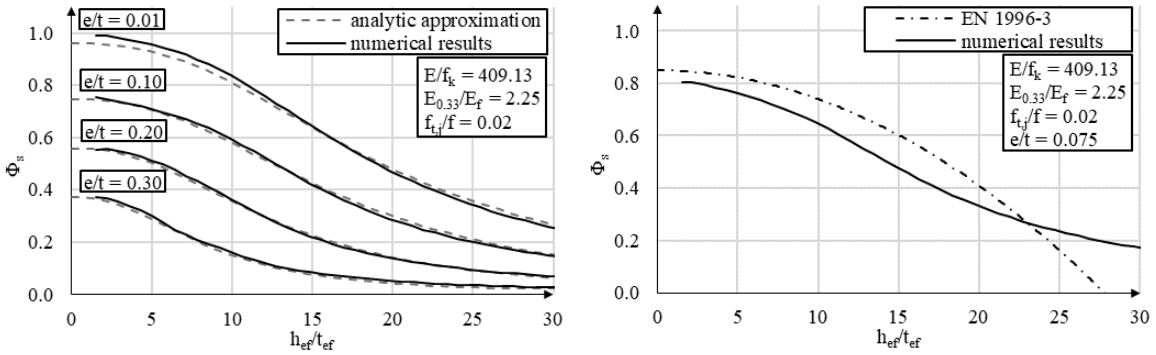

Figure 1: Numerically simulated load-bearing capacity (left)

The comparison in Figure 1 shows that EN 1996-3 for the most part provides higher load-bearing capacities than the numerical examinations, which is why the applicability of equation (1) to the design of slender earth masonry is questionable. In order to be able to conclusively assess the applicability of EN 1996-3 to the design of earth masonry, however, further investigations must be carried out, in which in particular the influence of ambient moisture and creep on the deformation behaviour of slender earth masonry is taken into account.

(1) Volhard, F.; Röhlen, U. (2009): Lehmbau Regeln – Begriffe – Baustoffe – Bauteile. 3. Auflage, Springer Vieweg Verlag.

(2) Müller, P.; Miccoli, L.; Fontana, P. & Ziegert, C. (2017): Development of partial safety factors for earth block masonry. In: Materials and Structures 50. Springer Netherlands

(3) Brinkmann, M. (2019): Tragverhalten unbewehrten Lehmmauerwerks unter Druckbeanspruchung.

(4) Glock, C. (2005): Traglast unbewehrter Beton- und Mauerwerkswände: Nichtlineares Berechnungsmodell und konsistentes Bemessungskonzept für schlanke Wände unter Druckbeanspruchung; Dissertation TU Darmstadt.

BOND BEHAVIOUR OF TEXTILE REINFORCEMENT ELEMENTS

Redouan El Ghadioui

The size of crack spacings in reinforced concrete members is mainly dependent on the bond behaviour between concrete and reinforcement. To determine the bond characteristic values, pull-out tests are carried out and the bond stress-slip relationship is evaluated. As a simplification, the mean bond stress τ_{bm} is often assumed to be proportional to the concrete tensile strength f_{ctm} in existing standards for the determination of crack widths and spacings.

To verify the normative approaches, pull-out tests with ribbed steel reinforcement bars and CFRP textile fibre strands were carried out. The resulting bond stress-slip relationships are shown in Figure 1. In the case of the CFRP fibre strands, a rupture of the strand before the pull-out failure could be observed.

As shown in Figure 1, the bond strength of CFRP fibre strands scatters more than that of ribbed steel reinforcement bars. While steel reinforcement primarily transfers shear stresses through mechanical interlock of the ribs, bond strength of CFRP fibre strands is mainly achieved through form-fit and is therefore strongly dependent on the geometric characteristics (corrugation, variable cross-sectional shape, etc.).

According to (1), for a slip of 0.25 mm or for a crack width of 0.50 mm, respectively, the mean value of the ratio of the average bond stress to the concrete tensile strength is given with $\tau_{bm} / f_{ctm} = 2.25$. By integrating the bond stress-slip relationships for ribbed steel reinforcement bars, the mean bond stress can be determined more precisely as a function of the concrete compressive strength f_{cm} and the crack width w as follows:

$$\tau_{bm} / f_{ctm} = 9.81 \cdot w^{0,4} / f_{cm}^{0,33} \qquad (1)$$

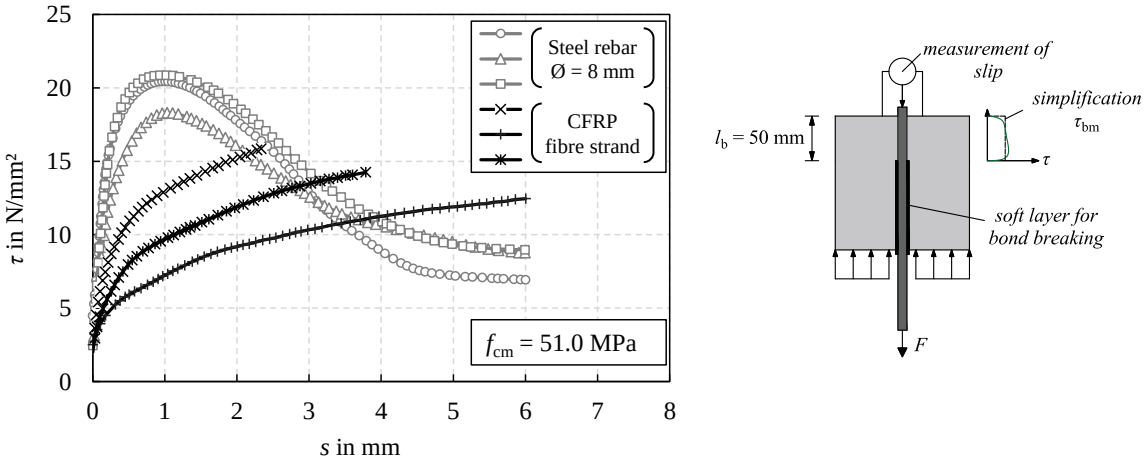

Figure 1: Experimentally determined bond stress-slip relationships

The measured values of the bond stresses evaluated for a crack width of 0.50 mm are given in Table 1. The results show that the average bond stresses of ribbed reinforcing steels are approximately twice as high as those of the tested CFRP fibre strands.

Table 1: Results of pull-out-tests

	Steel rebars **Ø = 8 mm**	**CFRP fibre strands** **$Ø_{eq}$ = 3.22 mm**
$f_{cm,exp}$	51.0 MPa	
$f_{ctm} = 0.3 \cdot (f_{cm} - 4)^{2/3}$	3.91 MPa	
$\tau_{bm,m,exp}$ **(w = 0.50 mm)**	9.82 MPa	4.92 MPa
$\tau_{bm} / f_{ctm} = 9.81 \cdot w^{0,4} / f_{cm,exp}^{0,33}$	2.00	-
$\tau_{bm,m,exp} / f_{ctm}$	2.51	1.26

Despite the lower bond strength, smaller crack spacings were found in member tests. This fact is particularly explained by the strong influence of the transverse reinforcement of the textile fabrics.

(1) International Federation for Structural Concrete: CEB-FIP Model Code 1990. London: Thomas Telford; 1993.

(2) International Federation for Structural Concrete. fib Model Code 2010 for Concrete Structures. Berlin: Ernst & Sohn; 2013.

PRESTRESSED CONCRETE REINIFORCEMENT BARS WITH FRP PRESTRESSING TENDONS

Dominik Hiesch

The research in the field of FRP (fiber-reinforced polymers) reinforced concrete members has shown that the deflection behavior is significantly influencing the design of structural components. The FRP reinforcement generally possesses a lower modulus of elasticity compared to common steel reinforcement and combined with the FRP reinforcements' increased resistance against corrosion, which leads to minimized concrete covers, the slenderness of the structural components can be increased. By using prestressed concrete reinforcement bars with FRP prestressing tendons (cf. Figure 1), the stiffness can be increased, positively influencing the structural components' deflection behavior.

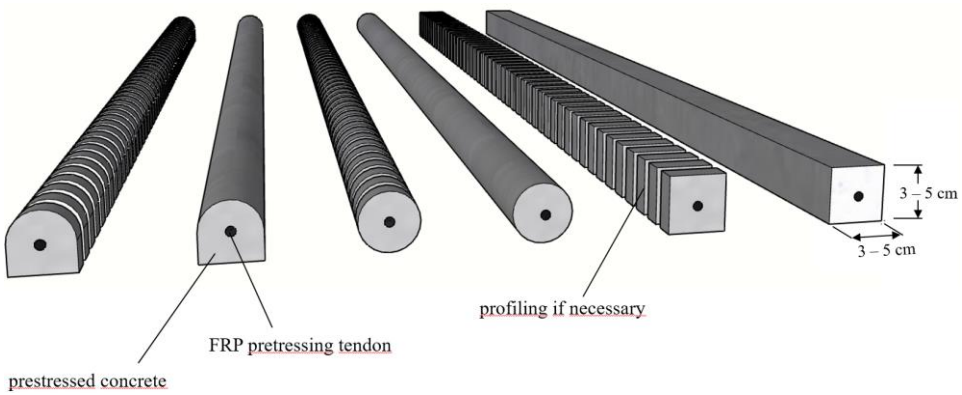

Figure 1: Possible geometric variations of the prestressed concrete reinforcement bars

The FRP tendons are prestressed in a precasting bed, resulting in residual stress states in the surrounding concrete and in the FRP tendons themselves. Due to these imposed stresses the high tensile strengths of the FRP tendons can already be utilized under service loads or rather whenever the first microcracks in the surrounding concrete appear. This leads to smaller crack widths and a reduction of the components' deflection as well.

By using this innovative type of prestressing, various manufacturing processes in the construction industry can be improved. The prestressing process is carried out in a controlled environment in a precast factory, which guarantees a constant production quality. In addition, the concrete reinforcement bars are small compared to the whole component making them easier to handle. Due to

the pre-imposed stresses in the concrete bars and the FRP tendons, prestressing equipment on the construction site isn't necessary at all. Instead, the precast prestressed concrete bars will be inserted into the formwork like regular steel rebar before adding in-situ concrete to finish the construction of the whole member. The concrete cover also makes the reinforcement elements more robust, which is particularly advantageous in terms of transport and storage. In addition to the usage on the construction site, the prestressed concrete bars can also be used in fully precast components.

Figure 2 shows the result of a first examination of the creep behavior of a CFRP tendon. It demonstrates that the given tendon doesn't show any creep tendency, when subjected to a sustained load of around 50 % of its mean tensile strength. The observable fluctuations are entirely due to the influence of temperature.

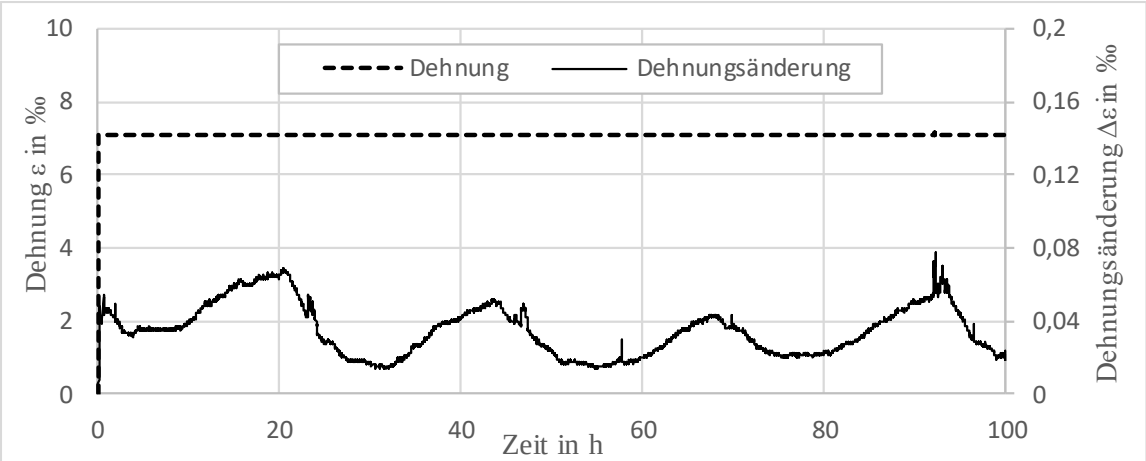

Figure 2: Strain curve of a CFRP bar under sustained load over time

CARRYING CAPACITY OF CONCRETE BETWEEN CRACKS OF BFRP RC

Sebastian Hofmann

The participation of the concrete in tension between the cracks, so called tension stiffening, leads to higher stiffness for concrete members in the post cracking stage and is significantly influenced through the bond behaviour between concrete and reinforcement. The investigated reinforcement material is a so-called basalt fibre reinforced polymer (BFRP) made from the volcanic mineral basalt and differs significantly in its material properties from conventional reinforcing steel. The BFRP reinforcement has a linear-elastic material behaviour and an approx. 2.5 times higher rupture stress and a lower modulus of elasticity (E_B / E_S ≈ ¼) than reinforcing steel. Furthermore, the investigated reinforcement has a different surface geometry with a slightly profiling and a sand coating, while steel reinforcement has a ribbed surface. As part of a tensile test on a reinforced concrete cylinder, the tension stiffening Factor β_t for the BFRP reinforcement could be determined experimentally and calculated according to Eq. (1). In the following force-strain-diagram in Figure 1, the uncracked state (a), the process of cracking (b) and the post cracking stage with the participation of the concrete in tension (c) is illustrated.

$$\varepsilon_{Bm} = \varepsilon_{B2} - \beta_t \cdot (\varepsilon_{r2} - \varepsilon_{r1}) \quad (1)$$

All required strains can be taken from Eq. (1) to calculate the tension stiffening factor $\beta_{t,B}$ = 0,5 according got Eq. (1) for the investigated BFRP reinforcement. For steel reinforcement a tension stiffening factor of $\beta_{t,S}$ = 0,4 according to DIN EN 1991-1-1/NA can be used. This comparison shows that the BFRP reinforcement allows a higher contribution of the concrete in tension due to the excellent bond properties of this reinforcement (1). Due to the low modulus of elasticity of BFRP, the bond behaviour is very important, since significantly larger deflections are to be expected compared to steel reinforced concrete components. These can be partially compensated by a larger contribution from tension stiffening.

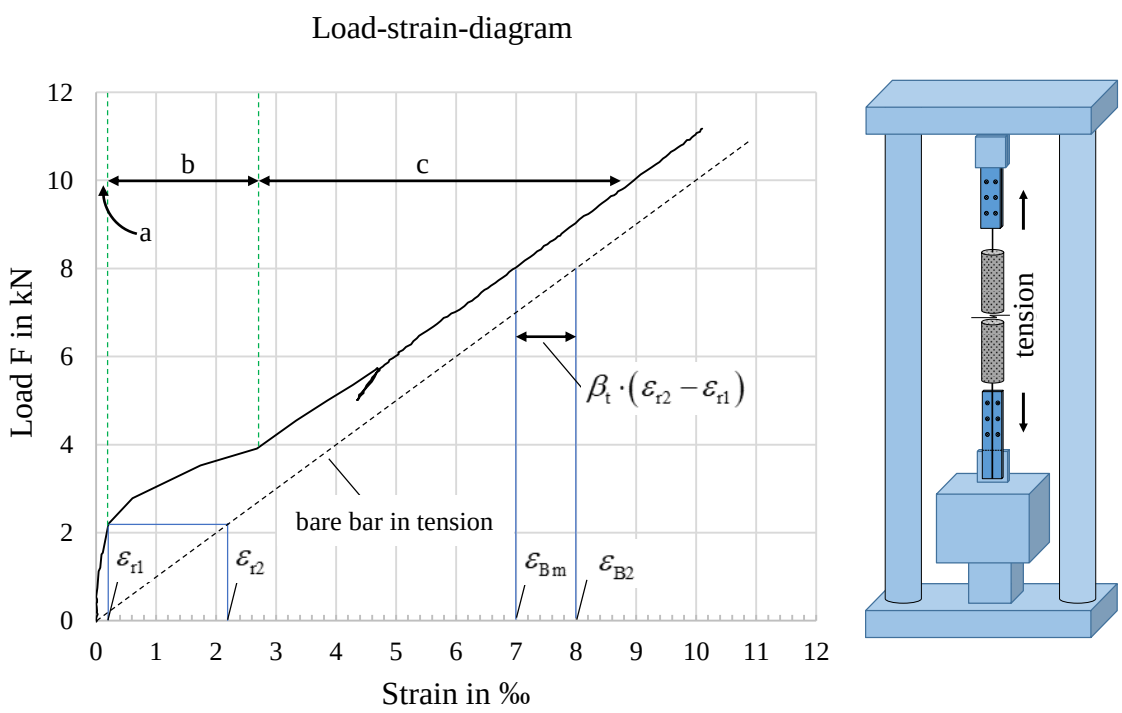

Figure 1: Load-strain-diagram of a tension test on a BFRP reinforced concrete cylinder

The obtained experimental results from this tensile test have to be verified in further experiments for example on large scale concrete slabs under bending loads. In the context of these tests, the component deformations under varying parameters such as the height of the slab, the slab span and the reinforcement ratio will be investigated in short-term as well as in long-term tests with a constant load. The goal of these experimental investigations is the derivation of a calculation model for the estimation of component deformations for BFRP reinforced concrete components.

(1) Hofmann, Sebastian (2018): Experimental investigation of the bond behaviour of BFRP reinforcement bars. In: Darmstadt Concrete, Annual Journal on Concrete and Concrete Structures, Vol. 33, 2018, Darmstadt.

CHALLENGES IN MODELLING FINITE ELEMENT BUILDING MODELS IN STRUCUTURAL ENGINEERING

Jonas Klein

Due to the increasing digitalization in civil engineering as well as the larger amount of computing power available, entire buildings are increasingly modelled as virtual three-dimensional building models in engineering practice. This development will continue in the coming years and will increase even further due to the possibility of automatically generating finite element models from existing BIM models. In addition to obvious advantages, such as the possibility of calculating complex structures - which would not be possible with a manual calculation - building models present numerous challenges and the danger of unconsciously carrying out inadequate measurements (1). One reason for this is the fact that three-dimensional models represent the load-bearing behaviour of the overall structure and thus use every element for load transfer. Similarly, a change in stiffness of structural elements or the interaction with the subsoil is often insufficiently mapped, if at all. In the following, two specific challenges, which can occur during modelling and calculation, are highlighted as examples.

Figure 1 shows different approaches to system formation in the modelling of a deep beam. In the course of a conventional design, the internal forces are determined on the basis of system a) by estimating the internal lever arm. If, on the other hand, a deep beam is modelled in a three-dimensional building model, this model also uses adjoining components such as the upper and lower ceiling slab for load transfer (2). This results in additional internal forces within the beam, which have to be considered during design. In addition, the beam is supported horizontally in the lower ceiling, which leads to an additional compressive force. If, for example, there are larger openings or bumps in the ceiling, this additional force must be taken into account in the design.

The influence of structural element or soil stiffness is illustrated in Figure 2 using a conventional framework. It can be seen that in particular a variation of the soil stiffness has significant effects on the internal forces distribution in the two columns. A consideration of different bedding stiffness - e.g. due to different foundation constructions - is therefore indispensable when considering overall models.

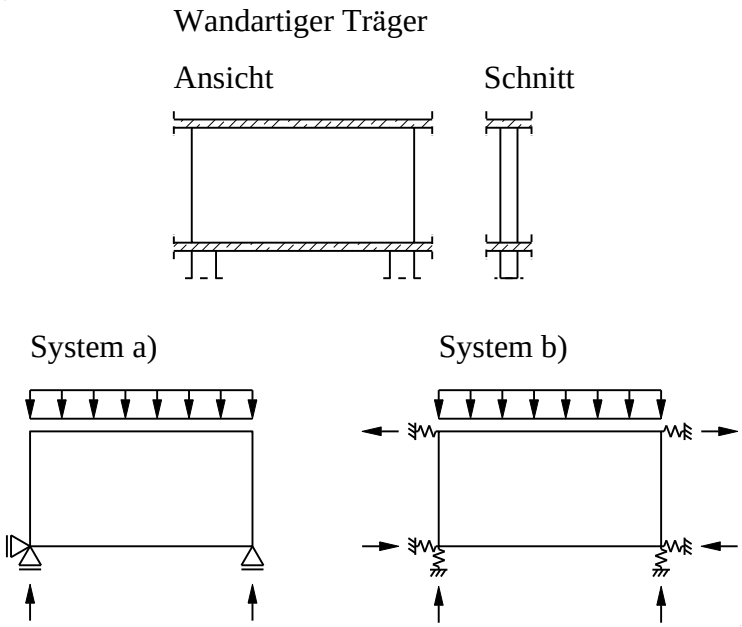

Figure 1: Modelling deep beams

k_1/k_2	EI_1/EI_2	N_{S1}	N_{S2}
1	1	40%	60%
2	1	46%	54%
2	3	48%	52%
3	3	51%	49%

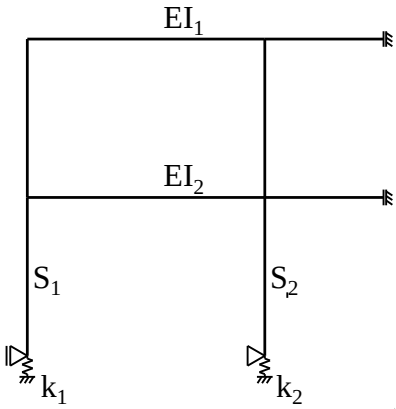

Figure 2: Variation of stiffness

(1) Rombach, Günter (2014): EDV-Unterstützte Berechnungen im Stahlbetonbau. In: Goris, A.; Hegger, J.; Mark, P. (2014): Stahlbetonbau aktuell 2014, Berlin, Beuth Verlag.

(2) Hausmann, Guido; Graubner, Carl-Alexander; Klein, Jonas (2019): Besonderheiten bei der statischen Prüfung räumlich modellierter Tragkonstruktionen von Hochhäusern. 40. Darmstädter Massivbauseminar, Darmstadt, 4t^{h} of April 2019.

DETERMINING THE PARTIAL SAFETY FACTOR FOR THE COMPRESSIVE STRENGTH OF EXISTING MASONRY

Dominik Müller

The reliable as well as economical assessment of the load-bearing capacity of existing masonry is a special challenge when dealing with existing buildings. Compared to new buildings, existing masonry often shows a greater variability of its material properties. In addition to that, in many cases the strength must be determined by material tests, which introduces statistical uncertainty due to the limited number of samples that are taken into account. A further difference is that for existing structures a reduced target reliability index can be suitable. As part of a research project funded by the programme "Zukunft Bau" of the Federal Ministry of the Interior, Building and Community, a methodology is currently being developed at the Institute of Concrete and Masonry structures, which enables to determine suitable partial safety factors for existing masonry. The aim is that the partial safety factor for an individual structure can be determined based on the number and results of conducted material tests using practice-oriented diagrams.

Figure 1 shows a preliminary result for such a diagram. The presented diagram can be used in case of indirect testing of masonry compressive strength, i.e. separate tests of unit and mortar compressive strength and subsequent calculative determination of the compressive strength of masonry. The corresponding background and input parameters are described in (1). The diagram is based on a Bayesian method with non-informative prior distributions for the stochastic parameters of unit and mortar strength as well as a target reliability index β = 3.3, i.e. a reduced target reliability compared to EN 1990.

In the presented example with 8 and 5 test results for unit and mortar compressive strength, respectively, as well as associated coefficients of variation of 15 % and 20 %, a partial safety factor γ_M = 1.42 is obtained. In order to be able to take into account prior information regarding the typical variability of the material properties of existing masonry in the future, a database with test results for unit and mortar strength of existing masonry is currently being set up, which will allow the modelling of informative prior distributions.

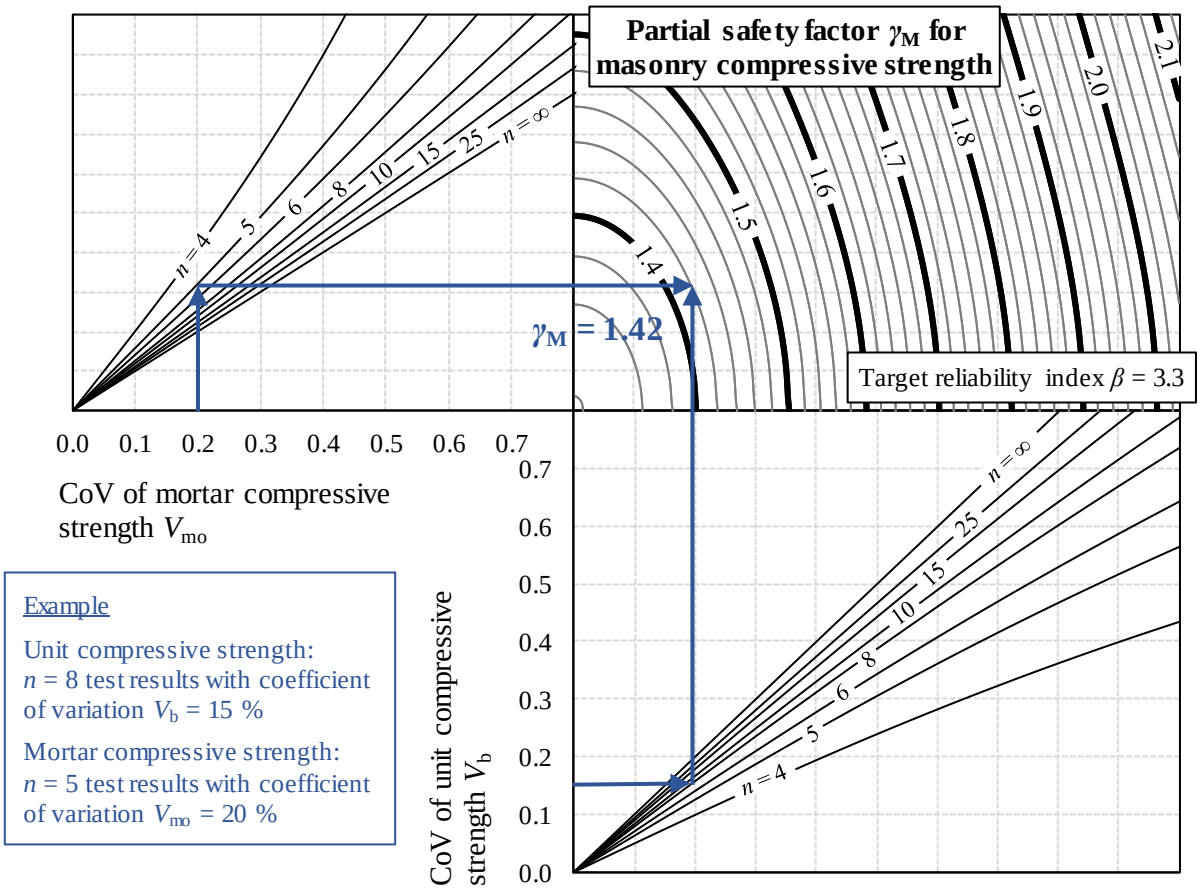

Figure 1: Diagram for determining the required partial safety factor for the compressive strength of existing masonry

(1) Müller, Dominik; Graubner, Carl-Alexander (2019): Modification of the partial safety factor for compressive strength of existing masonry using a Bayesian method. In: Proceedings of the 19th International Probabilistic Workshop, Edinburgh, UK.

STRUCTURAL FIRE DESIGN OF BRICK MASONRY ACCORDING TO NATIONAL TECHNICAL APPROVAL

Benjamin Purkert

Verification of the fire resistance of highly insulating brick masonry according to national technical approval (nta) is usually based on a loading level in fire α_{fi} according to Eq. (1), which must not exceed a limit value defined in nta. The present loading level in fire α_{fi} relates the acting normal force in fire $N_{Ed,fi}$ to the design value of the load-bearing capacity in cold design N_{Rd}, which may be determined using both DIN EN 1996-1-1/NA as well as DIN EN 1996-3/NA.

$$\alpha_{fi} = \frac{N_{Ed,fi}}{N_{Rd}} \tag{1}$$

However, since the limits defined in the nta are calibrated using the more general rules for design, the use of DIN EN 1996-3/NA automatically leads to a reduction of the permissible normal force in fire. In order to be able to exploit the load-bearing capacity of the masonry in fire even when using the simplified calculation methods in cold design, an increase factor δ_{fi} can be defined by comparing the capacity reduction factors Φ_m and Φ_2 as shown in Figure 1, since the design in mid-storey height is generally governing in case of fire. The derivation of this factor, which may be multiplied with the cold load-bearing capacity N_{Rd} according to DIN EN 1996-3/NA for use in Eq. (1), is explained in (1). A condition is that almost no bending moments due to rotation of the slab occur in the wall in mid-storey height in case of fire - apart from the system-related eccentricity in the case of a partially supported slab. Depending on the existing bearing length, the increase factors given in Table 1 can be derived.

In practice, the value of the load-bearing capacity which was determined in cold design is used for N_{Rd} in Eq. (1). In fact, however, this leads to a significant underestimation of the fire resistance, as wind effects – which often make up the essential part of the bending moment at mid-storey height – may be neglected in case of fire. Furthermore, it is also permissible to neglect the long-term factor when determining the load-bearing capacity in fire, since the limit values for α_{fi} defined in the approval also do not take this into account. Thus, even by multiplying the cold load-bearing capacity with the reciprocal of the long-term factor, an increase in the permissible normal force in case of fire can be achieved by about 15%.

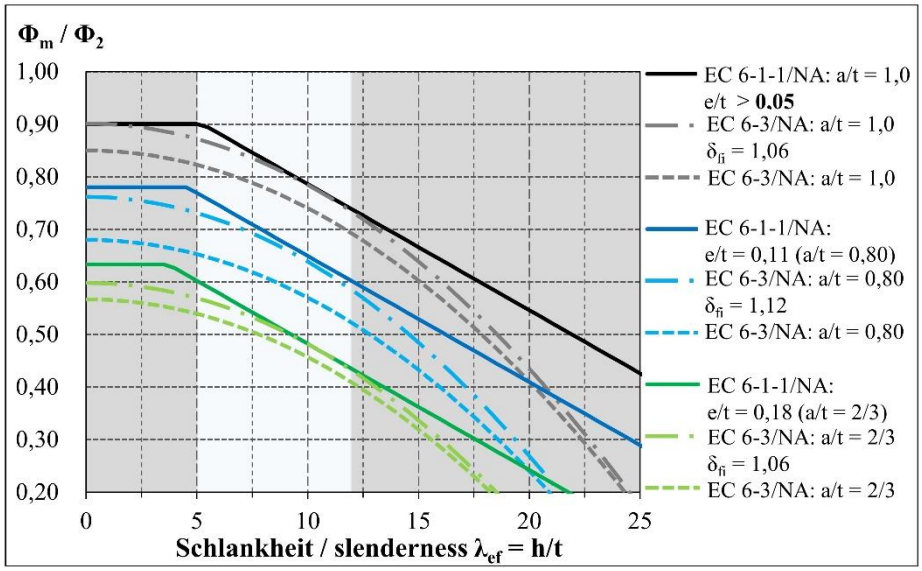

Figure 1: Comparison of the capacity reduction factor in mid-storey height according to DIN EN 1996-1-1/NA and DIN EN 1996-3/NA depending on the bearing length

Table 1: Increase factor δfi for determination of αfi using DIN EN 1996-3/NA

slenderness	a/t = 1	a/t = 0,90	a/t = 0,75	a/t = 2/3
7,5	1,07	1,18	1,11	1,07
10	1,06	1,16	1,10	1,06

(1) *Graubner, C.-A., Purkert, B.:* Nachweis des Feuerwiderstands von Ziegelmauerwerk – Tipps für eine effiziente Bemessung. Mauerwerk 23 (2019), S. 306–315.

TESTS ON CARBON FIBER REINFORCED CONCRETE SLABS SUBJECTED TO CONCENTRATED LOADS

Larissa Krieger

Multi-storey car parks seem predestined for the use of carbon reinforced concrete members due to penetration of chlorides. Component tests were conducted as part of a current research project to determine the load distribution of slabs under pointed loads (wheel loads). Finally, the test results are compared with the model approaches in DAfStb-Heft 631.

The experimental investigations include load bearing tests of uniaxial spanned (span: 2.2 m) large-sized plates (2.5 m x 4.6 m) as well as equivalent slabs with a width of 1.0 m. All slabs had a component height of 9.0 cm. Here a grid made of carbon fibres with epoxy resin impregnation was used. The influence of varying load positions will be analysed concerning the load distribution. The square load area had a width of 0.2 m.

The diagram in Figure 1 shows the load-deformation graphs of two large-sized plates and the equivalent slab with a width of 1.0 m for a centric load position (x = 1.1 m). In order to ensure comparability, the test force is related to the component width *b*.

The following issues can be highlighted:

- With increasing load, the graphs (slab 1 and 2) become even more flat. At maximum load the first fiber strand begins to crack.
- Due to a distinctive redistribution the surrounding fiber strands fail one after another. This behaviour is evidenced by the plateau and the load drops in Figure 1.

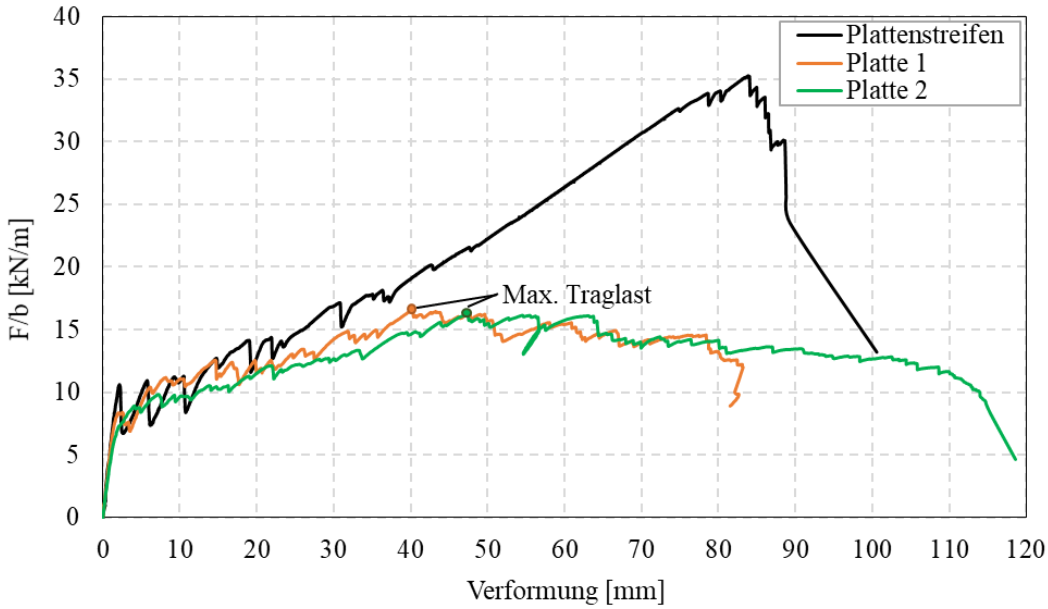

Figure 1: Load - deformation graphs of carbon-reinforced members; x/L = 0.5

By comparing the maximum capacity load of both components, the load distribution of concentrated loads can be calculated. The experimental results are greater than the model approaches in DAfStb-Heft 631 (cf. Figure 2). The effect of a smaller reinforcement ratio (black marks) can also be seen in the smaller load distribution.

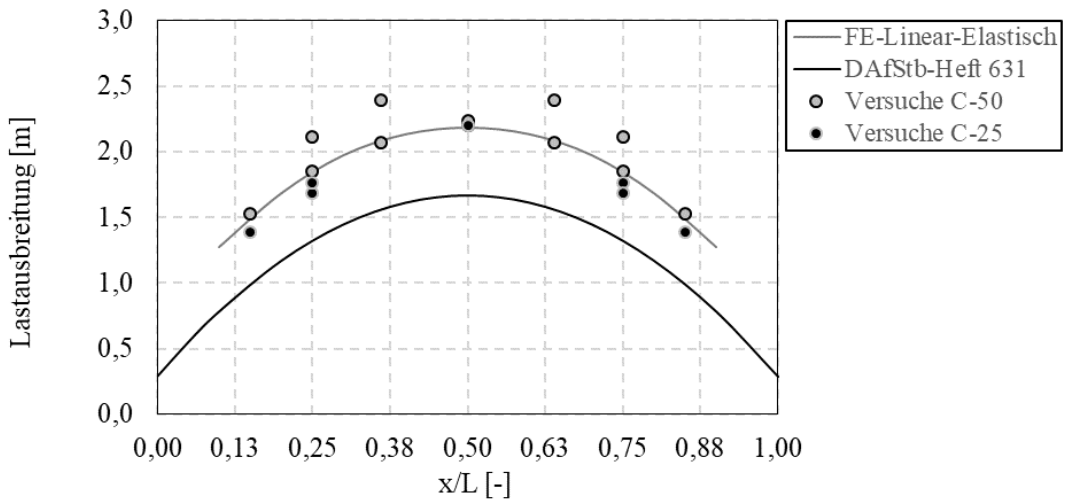

Figure 2: Load distribution at load capacity

SHEAR STRENGTH OF REINFORCED GLASS BEAMS

Ngoc Linh Tran

The shear strength is always of particular interest for members without shear reinforcement. Recently, a mechanical shear model for reinforced concrete members was developed at the institute of concrete and masonry structures, TU Darmstadt, which improves the prediction accuracy and has a great advantage in application compared to existing shear models (1). The shear strength equation according to this model is presented in simple form as follows:

$$V = \frac{1}{3} \cdot f_{ct,ef} \cdot b \cdot d \cdot k_x \cdot \left(1 + \sqrt{1 + d_0/d}\right) \quad (1)$$

with $d_0 = 2l_{ch} \cdot \frac{(3-k_x)}{(\lambda-1)\cdot(1-k_x)}$. Here, $\lambda = a/d$ is the shear slenderness, $l_{ch} = E_c G_F / f_{ct,ef}^2$ is the characteristic length of the material and $k_x = x/d$ is the relative depth of the compression zone. The effective tensile strength is calculated as $f_{ct,ef} = f_{ct}/(1+\upsilon)$, in which f_{ct} is the uniaxial tensile strength and υ is the Poisson's ratio of the material. A comparison between the predictions according to Eq. (1) and the experimental results taken from a shear test database (2) with a total of 680 reinforced concrete beams without shear reinforcement showed a mean value of the experimental-calculated ratio V_{exp}/V_{cal} of 1.03 and a corresponding variation coefficient (COV) of 15.5%.

This paper presents an application of the shear model for glass structures. A test series of reinforced glass beams reinforced by steel reinforced polymer bars and without shear reinforcement, performed by (3), was studied. The glass used has a modulus of elasticity of 70 000 N/mm^2, a Poisson's ratio of 0.2 and a flexural tensile strength of 45 N/mm^2. Since the beams were constructed with a different number of glass sheets, which can influence the effective tensile strength of glass, the tensile strength f_{gt} was determined directly from the crack moment of the studied beams, see Tab. 1. Compared to concrete, glass even shows a very brittle behaviour and its fracture energy is very low (approximately 0.005 N/mm). The results of the experiments and calculations are presented in Tab. 1. The typical crack pattern of the beams is shown in Figure 1.

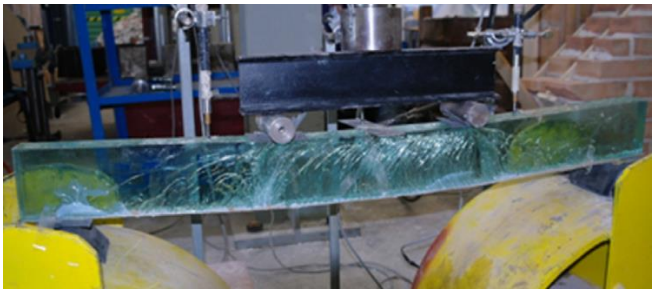

Figure 1: Crack pattern of the beam B5-a (3)

Table 1: Experimental and calculated results of shear strength of glass beams

No.	b mm	d mm	a/d -	f_{gt} N/mm²	ρ %	E_s N/mm²	V_{exp} kN	V_{cal} kN	V_{exp}/V_{cal} -
B4-a	48	120	2.92	39.9	0.317	206000	15.7	16.3	0.96
B4-b	48	120	2.92	39.9	0.475	206000	19.6	19.7	1.00
B5-a	40	100	3.00	37.6	0.190	206000	8.0	8.4	0.95
B5-b	40	100	3.00	37.6	0.380	206000	11.3	11.6	0.97
B5-c	40	100	3.00	37.6	0.570	206000	13.1	14.0	0.94
B5-d	40	100	3.00	42.1	0.480	73500	13.2	9.0	1.47
B5-e	40	100	3.00	42.1	0.720	73500	11.3	10.9	1.04

The result of the ratio V_{exp}/V_{cal} in Tab. 1 showed an average value of 1.05 and a coefficient of variation of 18.0%. If the beam B5-d is extracted from the calculation, an average value of 0.98 and a COV of 3.7% are obtained for 6 beams. This result confirms the accuracy of the new shear model and indicates that the model can also be used for glass members.

(1) Tran NL. Shear strength of slender reinforced concrete members without shear reinforcement – A mechanical model. Habilitation thesis, TU Darmstadt, 2018.

(2) Reineck KH, Kuchma DA, Fitik B. Erweiterte Datenbanken zur Überprüfung der Querkraftbemessung für Konstruktionsbetonbauteile mit und ohne Bügel. Deutscher Ausschuss für Stahlbeton, Heft 597. Berlin: Beuth Verlag GmbH Berlin-Wien-Zürich, 2012.

(3) Speranzini E, Agnetti S. Strengthening of glass beams with steel reinforced polymer (SRP). Composites: Part B 67 (2014) 280-289.

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 BEHAVIOUR OF CONCRETE MADE OF LIMESTONE RICH CEMENT

Christian Herget

As part of a project funded by the German Research Foundation (DFG), the shrinkage behaviour of concretes made with limestone rich cements is first to be determined with the aid of an extensive test programme. Based on the test results, a suitable prediction model or an adaptation to a previous prediction model for the shrinkage behaviour of concretes made with limestone rich cements will then be developed.

First, the properties of the raw materials were investigated. In particular, the chemical-mineralogical properties of the used limestone, such as the methylene blue value, alkali oxide content as well as the fineness and calcite content play a decisive role (1). Subsequently, a test program was created on hardened cement paste level, which considers the influences of the individual parameters separately from each other in order to better illustrate the correlations. On the basis of the tests on hardened cement paste, further tests were carried out on concrete specimens. Concrete-specific variables such as cement paste content, packing density and particle size distribution of the aggregates as well as specimen geometry and type of curing were varied.

The test results of the investigated hardened cement paste show clear dependencies of the shrinkage behaviour of limestone rich cements on the parameters mentioned above. By increasing methylene blue values and alkali oxide contents also the drying shrinkage of hardened cement paste increases. The reason for this can be understood as the change in surface energy caused by alkali oxides and swelling clay layer minerals. In addition, a higher calcium carbonate content leads to a reduction in shrinkage values. This can be seen very clearly in Figure 1. The test results of the concrete specimens clearly show that the shrinkage behaviour and compressive strengths are strongly dependent on the concrete-specific influencing parameters mentioned above. A higher cement paste content and a higher water-cement value lead to higher shrinkage values. Higher contents of limestone powder as well as a higher methylene blue value of the limestone used result in increasing shrinkage values. However, concretes with different proportions of limestone powder always have lower or comparable shrinkage values than the reference concretes made of ordinary Portland cement clinker with a comparable strength. Accordingly, limestone powders rich in calcium carbonate are particularly recommended for concretes to achieve a low shrinkage value.

On the basis of these test results, the applicability of existing prediction models for shrinkage behaviour in the current work package will be examined and a suitable model for shrinkage predicting of concrete made with limestone rich cements will be developed. The mechanical influences of gap pressure and capillary stresses play a decisive role in the modelling (2).

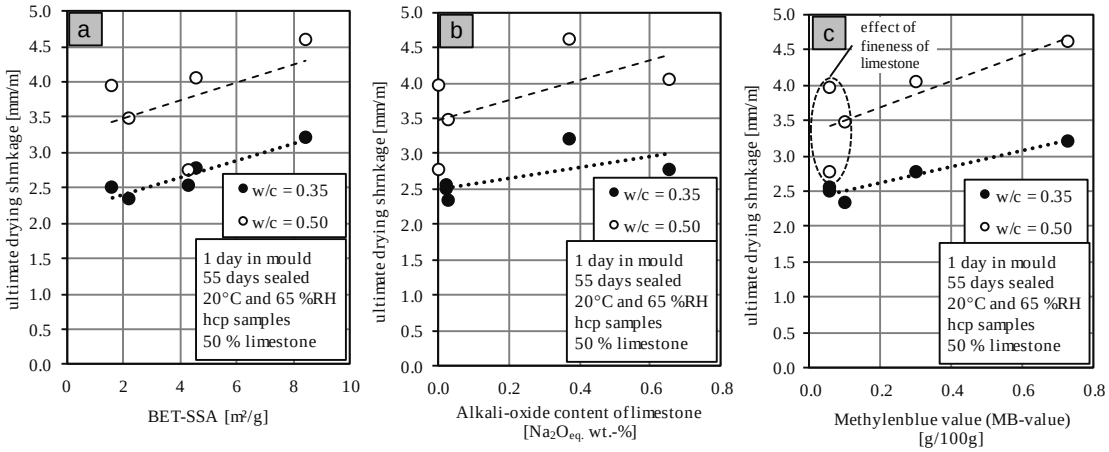

Figure 1: Influence of the chemical-mineralogical properties of the used limestone on the drying shrinkage of hardened cement paste

(1) Rezvani, M., Proske, T.: Influence of chemical-mineralogical properties of limestone on the shrinkage behaviour of cement paste and concrete made of limestone-rich cements. Construction and Building Materials 157 (2017), S. 818–828.
(2) Rezvani, M.: Shrinkage model for concrete made of limestone-rich cements - An approach from cement paste to concrete. Dissertation, Technische Universität Darmstadt (2017).

PRESSURE-DEPENDENT SHEAR BEHAVIOR OF FRESH CONCRETE

Moien Rezvani, Tilo Proske

The rheology as one of the fundamental characteristics of the fresh concrete can influence the production, processing, formwork pressure, surface quality as well as the mechanical and durability properties of concrete significantly. A detailed knowledge of the rheological behavior of fresh concrete at variable pressure levels is essential for an accurate calculation and prediction of formwork pressure and can help to improve current practice in formwork design. Further on, the high-pressure processing (e.g. pumping, extrusion and printing) of fresh concrete can be improved by a better understanding of the shear behavior of fresh concrete under pressure. In tall formwork or in concrete pipes during pumping the impact of the pressure level on the rheology can be significant. Astonishingly, systematic investigations to analyse the influence of the pressure on the concrete rheology are missing so far. Therefore, the existing model approaches to describe the flow behavior of fresh concrete are primarily applicable for atmospheric state.

Aim of the present study was to develop a new test set-up in which the concrete could be sheared directly by means of a concrete rheometer under pressurized condition. For this purpose, an ICAR vane rheometer was adapted in the pressure cell (see Figure 1). The fresh concrete sample of 20 liters was loaded vertically by a hydraulic jack as well as air pressure. The pressure levels were 0, 25, 80, 160 kPa. Fresh concrete was sheared gently with a shear rate of 0.001 rpm. At different ages of 10, 30, 60 and 90 min the static yield stress was measured. In this study, the influence of variable pressure levels on the shear behavior of fresh concrete as a function of cement paste volume and consistency class was analysed (F3, F4, F5 and F6).

Figure 1: Test set-up to measure the shear behavior of fresh concrete under pressure (left); position of vane in the pressure cell (middle top); loading of the pressure cell by hydraulic jack (middle bottom); loading of the pressure cell by air pressure (right)

Obtained results revealed the rheological behavior - especially static shear yield stress - of fresh concrete is strongly affected by the applied pressure. Independent from the concrete consistency, the yield stress growth with increasing the pressure level. However, the effect of pressure was remarkable for low flowable concretes F3 with lowest paste volume of 300 l/m³. An increase of paste volumes in concretes with higher workability (F4 and F5) reduces the pressure-dependency at early age significantly. The smallest effect of pressure on the yield stress was observed for high flowable concrete with high paste volume of 350 l/m³ and consistency class of F6. Exemplary, the vertical load was applied to a concrete of consistency class F5 using air pressure. Yield stresses comparable to those obtained using the hydraulic press were determined. Essential is the influence of pre-shearing on the magnitude of the measured yield stresses. In order to eliminate the artifact due to the pre-shearing, additional tests are planned to be conducted on intact samples at each pressure levels and ages.

EFFECT OF THE CURING MODE ON THE CO2-DIFFUSION COEFFICIENT IN CLINKER-REDUCED CONCRETE

Sarah Steiner

The development of clinker-reduced cement is a promising way to decrease the environmental impact of concrete. In doing so, sufficient durability, especially against carbonation-induced reinforcement corrosion, must be taken into account. The diffusion of CO_2 and water vapour in concrete are decisive factors for modelling the carbonation resistance. In order to optimize the mix design and accurate performance prediction of eco-friendly concretes, further research in the field of gas diffusion is necessary. The present study investigates the influence of varying curing modes and durations on the permeability of concrete.

An experimental set-up for diffusion measurements was developed, which is principally based on (1). The disc-shaped samples were carbonated before testing in order to avoid the superposition of the CO_2 diffusion by the reaction kinetics due to carbonation. The cement (c) used is composed of a portland cement clinker (cl, CEM I 52.5 R) blended with various amounts of ground limestone (LL, $CaCO_3$ > 98 wt.%). The concrete samples were prepared using a constant paste volume of 420 l/m^3 and a maximum aggregate diameter of 8 mm. The limestone content of the cement is 0, 17, 29 or 38 wt.% for the samples with a w/c ratio of 0.5 and 29 or 38 wt.% for a w/c ratio of 0.4. After mixing, the concretes were stored in covered molds at 90% RH for 24 h followed by either wet curing (20°C and 90% RH) for 3 d of hydration or water curing for 28 days. The disc-shaped samples were then cut from a drilling core and carbonated directly or cured at 65% RH for additional 5 weeks to reduce the samples' internal relative humidity before entering the accelerated carbonation chamber. Accelerated carbonation of the samples was carried out at 20°C, 20 vol.% CO_2 and 65% RH.

Figure 1 shows the CO_2 diffusion coefficient (D_{CO2}) versus the water/clinker ratio (w/cl-ratio). D_{CO2} is decreasing with decreasing w/cl-ratios. Thus, measurements indicate that if the water content of the mix design is reduced, the clinker content can be lowered (or the limestone content can be increased) and, however, increasing resistance against CO_2-diffusion can be achieved.

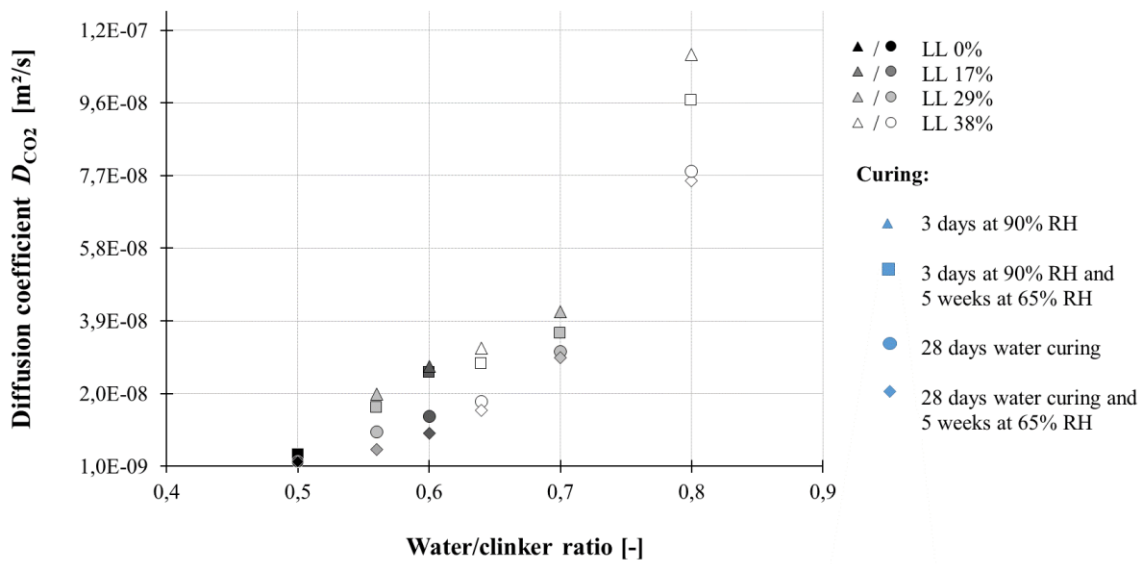

Figure 1: Comparision of the CO_2 diffusion coefficient (D_{CO2}) due to different curing modes

The comparison of CO_2 diffusion coefficients (D_{CO2}) due to various curing modes, as depicted in Figure 1, show lower D_{CO2} for water cured samples compared to wet cured (90% RH). The results thus indicate a denser concrete structure of the water cured samples, which may be a result of the longer duration of hydration and the availability of free water through the first 28 days of hydration. Furthermore, samples stored at 65% RH for additional 5 weeks prior carbonation show a slight reduction in D_{CO2} compared to those which were carbonated directly,

(1) Wierig, H. J., Hurling, H.: Untersuchungen zur Sauerstoffdiffusion durch die carbonatisierte Betondeckung der Bewehrung von Stahlbetonbauteilen. Forschungsbericht Universität Hannover (1985)

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.

MODELLING DOMESTIC OCCUPANCY BEHAVIOUR BASED ON TIME USE DATA

Patrick Wörner

With expanding generation capacities from renewable energy and the increasing electrification of the heating and transport sector, energy research focuses on the occupant as a key driver of domestic electricity demand. Not least because of the increasing, volatile electricity generation from wind power and photovoltaics, there is a high demand for reliable models to forecast time-dependent electricity consumption in the residential sector, which has not been sufficiently investigated yet. Such a model could help to plan energy supply concepts more efficiently, to dimension storage technologies and power grids according to consumption, and to integrate new electricity applications optimally into the energy system. The standard load profile (SLP) H0, which is frequently used for this purpose due to a lack of alternatives, fail to map the highly stochastic and partly arbitrary human behavior and neglects characteristic load peaks which are of main interest for planning and design.

For this reason, a methodology is being developed at the Institute Concrete and Masonry Structures which reconstructs energy-relevant occupant behavior for any number and composition of private households based on detailed time use data. The synthetically generated and temporally high-resolved user profiles are then linked with corresponding consumption data and converted into load profiles for electricity and domestic hot water demand. Social, demographic and socio-economic occupant characteristics as well as the interaction between household members are taken into account. The implementation of the methodology as a practical software allows a wide range of different applications. Moreover, the resulting time series are provided in a standardized file format that can be imported by common dynamic simulation tools for further calculations and analyses.

Figure 1 shows an exemplary simulation output for the electricity consumption of a two-person household during a winter week. On working days, the low electricity consumption during the absence of the two full-time employed occupants is quite obvious. Consequently, the use intensity increases distinctly in the evening and causes significant peak loads. The latter also occur more frequently at noon on weekends. The larger sample reflects the current demographic structure in

Germany and results in a smoothed cumulative load profile, which highly corresponds to the SLP H0 in some sections. In the course of model validation it becomes apparent that the synthetically generated load profiles and the SLP correlate with each other by 90 to 98 %, given a number of around 200 households and provided that the simulation is set up according to the demographic and consumption-related boundary conditions on which the empirically formulated SLP is based on. Remaining deviations can be explained by fundamental changes in occupant behavior.

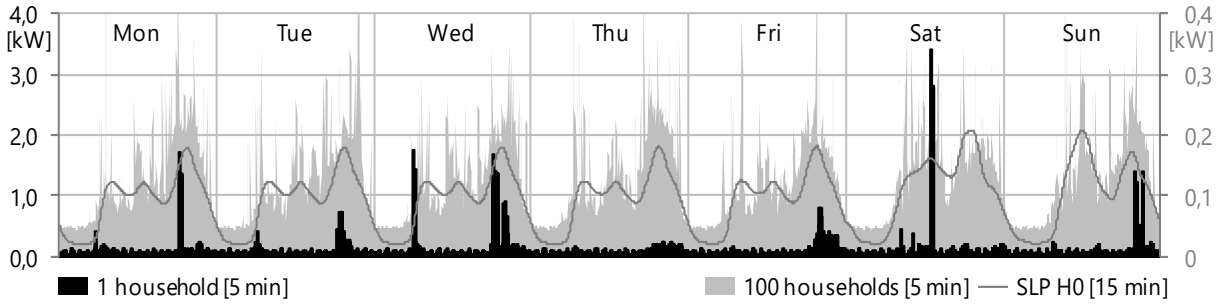

Figure 1: Exemplary simulation output for different household samples compared to the corresponding standard load profile H0

The simulation results can be displayed at person or device level and thus enables detailed analyses of domestic energy consumption. The model is also suitable for deriving household specific SLPs, which lead to a notable information gain in the course of network planning and load prognosis. Decentralized energy supply concepts can be simulated more realistically in order to derive recommendations for action targeting both private and municipal project developers. In the light of increasing energy-related requirements for new buildings, deeper knowledge about the presence of occupants and the associated internal heat gains also makes a significant contribution to the calculation of heat demand.

IMPACT OF WALL CONSTRUCTION ON THE ENERGY BALANCE OF SINGLE-FAMILY HOUSE

André Müller

The Climate Action Plan 2050 of the German federal government reaffirms the goal to reduce 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 crucial, since about 93 % of the German building stock was built before the introduction of the German Energy Saving Ordinance (Energieeinsparverordnung - EnEV) in 2002, and thus, has no standard of thermal insulation, which supports the achievement of above mentioned climate goals. In this context, the efficiency of renovation measures and the discrepancies between calculated and real energy savings are discussed. Furthermore, the uncertainties of building envelop related input parameters and their influence on the results of an energy balance have to be considered (1). For energy counseling as a part of the refurbishment of single-family houses (SFH) built in die first half of the last century and before, often there are only limited information on the construction and the building materials of the walls existent. Thus, no reliable statements on the energy-related performance of the components can be made. To analyse the impact of an unknown wall construction on the energy balance of a SFH, an exemplary building of the German building typology of Institut Wohnen und Umwelt was used and the heat transition coefficients (U-value) of the walls were varied for the energy performance calculation. Starting point is the U-value of 1.7 W/(m²K) which is documented for the exemplary building from the construction year class 1860-1918 with its solid brick masonry wall. (2) In the case of missing information regarding the walls of the building, the energy adviser could assume a different construction as well as different building materials of the walls, hence, the U-values were varied stepwise in the range of 1.4 W/(m²K) and 2.8 W/(m²K). In addition, the refurbishment level I depicted in the German building typology for this exemplary building was calculated with this range of U-values.

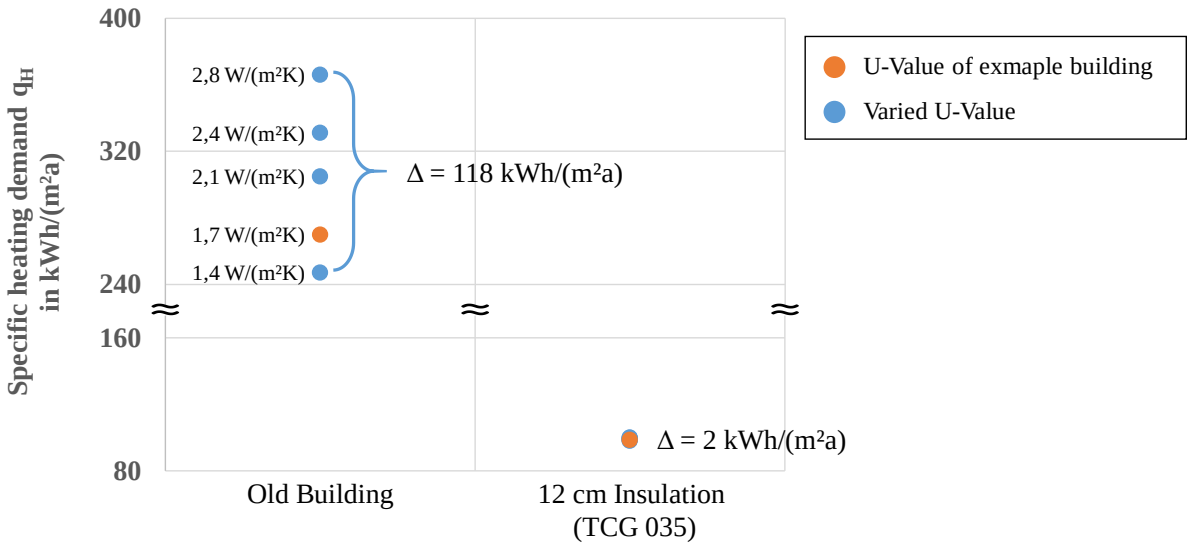

Figure 1: Impact of an unknown heat transmission coefficient on the heat demand of a single-family house of the construction year class 1860-1918

Figure 1 depicts the strong impact of the existing walls U-value on the heat demand of the building. Having a look to the refurbished building, it is obvious, that the high thermal resistance of the added layer of insulation superposes the spread of the U-values. Thus, the heat demand varies about 2 kWh/(m²a) only with a mean of 99 kWh/(m²a) for the five U-values calculated. In contrast, the interval of the heat demand for the building without any insulation lies in a range of 245 kWh/(m²a) and 366 kWh/(m²a), which is a spread of 118 kWh/(m²a). The additional thermal insulation, does not only reduce the heat demand of the building, but the uncertainties of the energy performance calculations at the same time.

(1) IWU (2019): Modellierung der Bandbreiten und systematischen Abhängigkeiten des Energieverbrauchs zur Anwendung im Verbrauchscontrolling von Wohngebäudebeständen (MOBASY). Institut Wohnen und Umwelt, Darmstadt, 2019.

(2) Loga, T; Stein, B.; Diefenbach, N.; Born, R. (2015): Deutsche Wohngebäudetypologie. Zweite erweiterte Auflage. Institut Wohnen und Umwelt, Darmstadt, 2015.

A CONTRIBUTION TO INTEGRATE SUSTAINABILITY INTO THE ASSESMENT OF ROUTES

Martina Lohmeier

Climate change, resource scarcity and population decline are major challenges that society must face and for which it must find solutions. As a result, sustainable decision-making has found its way into many areas. National and international systems for sustainability assessment in building construction have already been established for several years. Due to their regular practical application, these systems are subject to a continuous optimisation process. In the field of sustainability assessment of infrastructure facilities, comparable systems are still in the development phase. In Germany, work has been underway since 2010 to transfer an evaluation system for sustainability from building construction to road and transport infrastructure, covering the entire life cycle from concept to planning, construction, maintenance and dismantling. Research results are currently available in which partial aspects of the sustainability assessment have already been defined and tested in pilot applications. The consideration of the transport route as the sum of its individual elements - road, bridge, tunnel – are missing both within the framework of demand planning and in the planning phase (preliminary draft, draft and approval planning) when determining the route (cf. Figure 1).

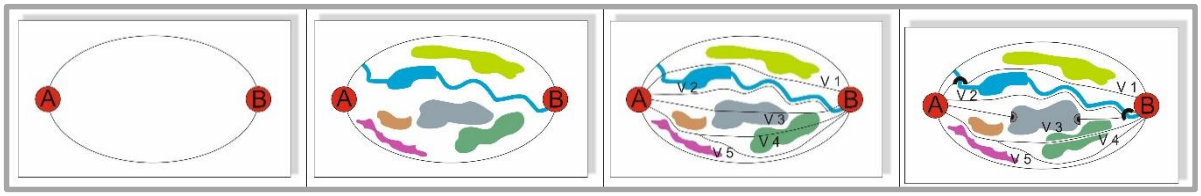

Figure 1: Different routes for connecting two locations A and B

Due to the different weighting within the assessment of the individual elements, the cross-element effect of certain criteria and the different level of detail of the input data, the results of the sustainability assessments of individual elements cannot be aggregated into an overall assessment for the train. It is therefore crucial to abstract the findings of the assessments of the three groups of individual elements and to derive a fourth assessment for the overall system. For this purpose, the

possible evaluation criteria must be defined and the availability and quality of the input data specified. The foundations for this was laid in the completed, but not yet published, research project of 2019 "Sustainability assessment of road infrastructure tracks" commissioned by the Federal Highway Research Institute. This is intended to ensure that the still missing aspects of sustainability are already considered during the planning phase and are included in the weighing process during the variant review for line determination. In order to be able to implement this additional, new instrument for variant evaluation in practice (cf. Figure 2), the results of the scientific elaboration must be validated. Within the framework of the dissertation, a tool will be created to check theoretical considerations on the evaluation system as well as the suitability of available data and input variables on the basis of real plans and to revise the system if necessary. The findings should allow conclusions to be drawn about the meaningfulness and stability of different evaluation systems and form the basis for the definition of future requirements for the input variables.

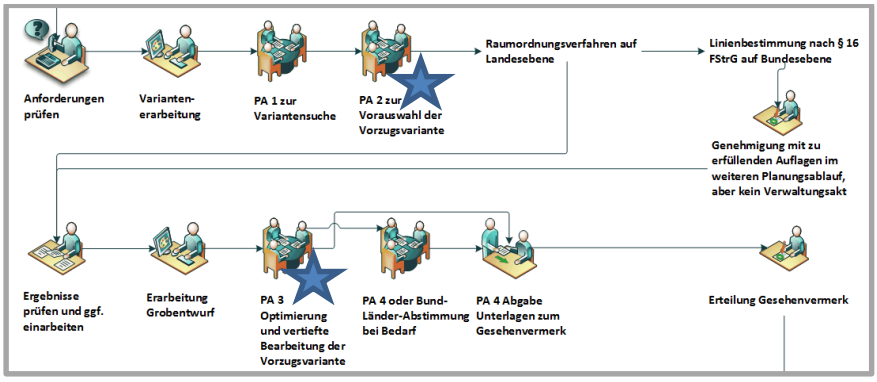

Figure 2: Possible implementation times (stars)

ACTOR-RELATED METHODOLODY TO ECONOMICALLY ASSESS EXISTING CITY DISTRICTS

Johannes Koert

A central political goal for the successful implementation of the energy system transformation is the creation of a climate-neutral building stock by 2050. Today, the building sector is responsible for 35% of Germany's final energy demand (1). In order to reduce this demand and increase the share of renewable energies, in addition to a high energetic standard in new buildings, the focus should be on the energetic refurbishment of existing buildings on a city district level. However, the renovation rates required to reach the climate-neutral building stock are still far from being achieved, with economic feasibility representing a bottleneck factor (2). In the current assessment methods for energy-related refurbishments in city districts, economic feasibility is only determined for the entirety of the actors involved in the project. For the decision to implement a measure, however, a relevant decision criterion for the respective actor is only his own economic situation.

For this reason, an evaluation methodology based on the complete financial plan was developed, which makes it possible to assess the economic effects of an energetic refurbishment measure separately for each actor in a city district. As in the other project-orientated evaluation methods, an alternative investment must be considered, to allow for making statements about the economic feasibility. In relation with an alternative investment, this allows to make statements about the economic feasibility. A complete financial plan records all incoming and outgoing payments periodically by taking into account derivative cash flows, resulting from the financing structure and interest rate effects. The links between different actors are also decisive. Figure 1 shows an exemplary case of the payment flows of the complete financial plans in the case of a city district with rented residential property. In order to also be able to represent structures at the neighbourhood level that are not owned by the building owners, an external party is introduced that can flexibly represent a large number of earnings models for modernisation and energy supply concepts.

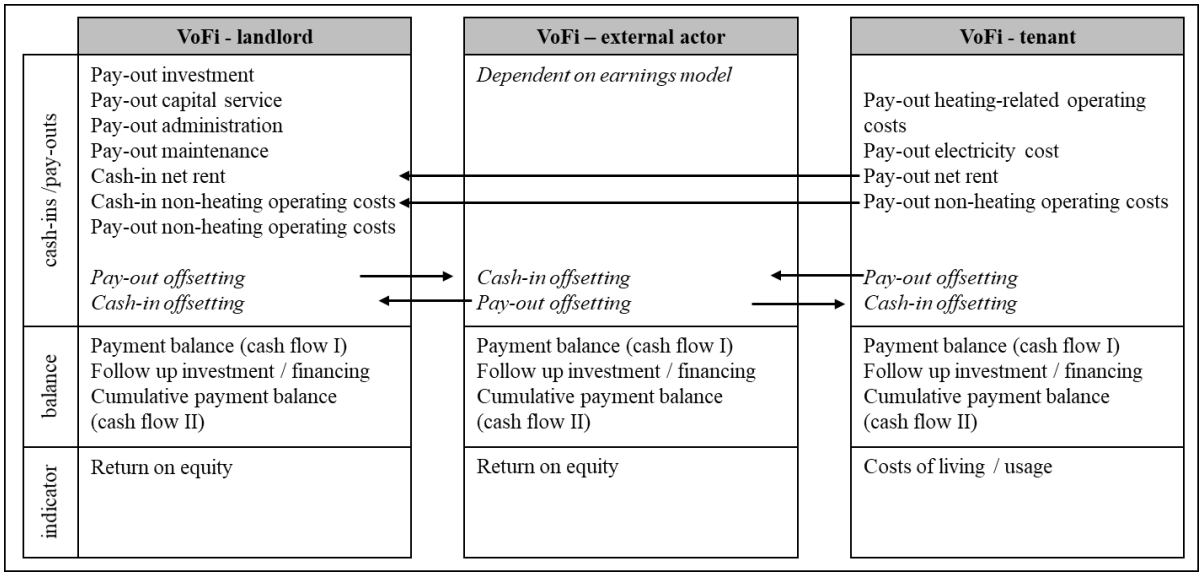

Figure 1: Schematic representation of the complete financial plans in a city district with rented residential properties, based on (3).

The developed methodology was applied to renovation measures of the building shell in a detached, owner-occupied single-family house estate with leased roof areas for PV systems and a rented multi-family block. Under the premise of the apportionability of energy-related modernisation costs in accordance with § 559 BGB, the measures lead to rising living costs for the tenants, while higher earnings result for the landlords, compared to an alternative of not performing the measures. The measures must therefore be evaluated differently for the various players with regard to their economic feasibility. A project-related evaluation without consideration of the actors would not have been able to provide this insight.

(1) BMWi; Kleber, K. (2015): Energy efficiency strategy buildings – Paths to a climate-neutral building stock, Federal Ministry for Economic Affairs and (ed.), Berlin, S.5.

(2) IWO (2013): Energy-related building renovation in Germany, Management Summary for a study conducted by the institute for heat and oil technology e.V., Hamburg, S.3.

(3) Pfnür, A.; Müller, N. (2013): Energy-related building renovation in Germany part II: Forecast of the costs of alternative renovation paths and analysis of the financial outcomes for owners and tenants up to 2050, working papers for real estate research and practice, Issue no. 28, Darmstadt, S.53.