DARMSTADT CONCRETE

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EDITORIAL AND REVIEW OF THE YEAR

Dear Friends and Partners of the Institute of Concrete and Masonry Structures,

This 30th issue of “Darmstadt Concrete” continues the tradition of reporting in good time at the turn of the year on our Institute’s activities in research, teaching and committee work in the past year. On the one hand we wish to provide, in principle and comprehensively, information on our activities and thereby offer the opportunity for rereading, reflection and questioning. On the other hand, we have to report on some fundamental decisions for the future work at and in the Institute.

Let us begin with the structural and organisational changes at the Institute of Concrete and Masonry Structures. In the course of 2015, the faculties of “Konstruktives Gestalten und Baukonstruktion” and “Werkstoffe im Bauwesen” set up independent institutes. Therefore both faculties have ceased to belong to the Institute of Concrete and Masonry Structures and both tenured professors have declined the offer to collaborate on the Executive Board of the “Freunde des Instituts für Massivbau der TU Darmstadt e.V.”.

The Research and Test Laboratory at the Institute of Concrete and Masonry Structures was also reorganised. Following the departure of Prof. Garrecht, Prof. Graubner became the Laboratory’s acting head in 2012. Since 1 January 2015, concomitant with the Institute’s reorganisation, he has been responsible solely for the Research and Test Laboratory and is effectively assisted in this task by Dr.-Ing. Proske, a long-standing member of staff.

In teaching, the Institute offered a total of 13 lecture modules in 2015; in addition, more than 45 bachelor theses and over 35 master’s theses were supervised and completed. Three field trips and the widely-known “Concrete Canoe Regatta” were held successfully. In research, some 20 projects are currently in progress.

As well as presenting what has been accomplished, this end-of-year report also affords the opportunity to offer thanks to our employees for their work and commitment. The achievements and success of our Institute in 2015 would have been inconceivable without the high quality of and untiring commitment with which our scientists as well as our secretarial, technical and laboratory staff approach their tasks and projects. We congratulate Dr.-Ing. Stefan Hainer who was able to conclude his research with the successful defence of his dissertation and welcome all “newcomers” most heartily.

To thank you, our friends and partners, for your support and allow you the usual insight into our scientific work, you will find, as in recent years, brief reports by our scientists on current research and development projects, in both German and English.

Not least, we would like to take this opportunity to thank also the “Freunde des Instituts für Massivbau der TU Darmstadt e.V.”, without whose support it would not have been possible to implement some minor but also more important measures at and for the Institute and its students. In particular, thanks are due here to the Chairman of the Executive Board Dr.-Ing. Six and the Executive Board members Dr.-Ing. Klemt-Albert and Dipl.-Ing. Hanek, who constantly advise, encourage and generously support us in diverse ways.

The past year’s achievements in research, the high rate of student attendance at our courses as well as the high approval ratings by our students and their commitment allow us to face the future with optimism.

On behalf of the entire Institute we wish you and your families peaceful and happy Christmas holidays and a good start to all your undertakings in the New Year.

Prof. Dr.-Ing. Carl-Alexander Graubner

Prof. Dr.-Ing. Gerd Simsch

SEMINARS AND EVENTS

Training seminar for structural engineers

The Institute of Concrete and Masonry construction cordially invited engineering experts to the 2015 seminar series. Speakers from practice gave presentations on newest developments in civil engineering. Throughout the year we were able to attract more than 600 structural engineers. The seminar series was almost fully booked and followed the established event concept. The seminar series in 2015 gave an overview of the latest technical developments of the civil engineering. In spring, the issues of technical building equipment, building acoustics, reinforcement and fire protection were treated. The lectures in autumn were about truss models, bridge building and timber constructions. Below you find all six individual seminars, three of which were held in spring, the other three seminars were held in autumn.

- Technical building equipment and building acoustics | 04.03.2015
- Practical reinforcements – Samples according to book 559 | 11.03.2015
- Basics of structural fire protection | 25.03.2015
- Design with concrete truss models | 16.09.2015
- Bridge Building | 30.09.2015
- Timber constructions – detailed design | 07.10.2015

Due to the positive feedback from the past years, we will organize the seminar again in 2016. We are confident that the combination of interesting topics and renowned speakers will again attract many structural engineers.

- Welding and Screw – in the past and today | 17.02.2016
- Corrosion – Steel and Concrete | 02.03.2016
- Special constructive issues | 06.04.2016
- Masonry | 14.09.2016
- Earthquakes – numerical examples for seismic design | 28.09.2016
- Updated regulations - Instandhaltungsrichtlinie, DBV-Merkblatt Parkhäuser, WU-Richtlinie | 12.10.2016

Updates on the seminars, as well as the registration can be found on the homepage of the institute (www.massivbau.tu-darmstadt.de) under the section „Veranstaltungen". In case of questions, please do not hesitate to contact Mr. René Mazur, cand. M.Sc.

Darmstadt Days for Prefabricated Concrete Elements

Due to our cooperation with the professional association “Deutscher Betonfertigteilbau e. V.” and the “Beton Marketing West GmbH”, we were able to host the renowned seminar series “Darmstadt Days for Prefabricated Concrete Elements” again in 2015. The presented topics varied from the characteristics of prefabricated constructions, which already begin with the initial sketch, to special construction elements and corresponding methods, such as job-mixed additions or prestressed constructions. Further, stability considerations define a focal point with examples, such as lateral buckling and the design and construction of the connections. In this year, about 60 structural engineers and students participated in the event. The seminars were complemented by an exhibition of renowned manufactures of construction products related to the topic of precast construction.

Generally speaking, the seminar content is tailored towards engineers from practice. However, a separate “student day” takes place in which the design of precast concrete elements will be treated. Thus, the lecture “prefabricated constructions”, which takes place in the context of the Darmstadt days of prefabricated concrete elements, can be incorporated into the students’ study design. The first day of the seminar series includes a special focus on the design possibilities with prefabricated concrete elements (e.g. photo concrete) aiming to target not only architects, but students in the field of architecture.

Despite of the comparatively little feedback in this year, the seminar series with top-notch papers, practical examples and our well-attended exhibition will still be offered to students as well as engineers from practice in 2016. 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 are going to be discussed in the upcoming seminar series in spring 2016:

- 31.03.2016 | Designing, manufacturing and art
- 01.04.2016 | Pre-dimensioning and prestressing
- 07.04.2016 | Design und concrete
- 08.04.2016 | Connections: Construction and design

Updates on the event can be found on the homepage of the department of solid construction (www.massivbau.tu-darmstadt.de) in the section “Veranstaltungen”. In case of questions, please do not hesitate to contact Mrs. Larissa Krieger, M.Sc.

Summer School „Focus on Energy“ – Darmstadt Graduate School of Excellence Energy Science and Engineering

In 2015, the Institute of Concrete and Masonry Structures supported the organization and realization of a Summer School for students about the topic „Focus on Energy“, which took place from 20th to 25th September 2015 in Annweiler am Trifels. The Summer School was hosted by Darmstadt Graduate School of Excellence Energy Science and Engineering, in which two assistants of the institute are integrated for their dissertation.

During the event the participants from all over Germany were able to learn various aspects concerning energy in lectures and talks with experts. Likewise, current research approaches concerning technology development as same as political and social issues could be explained.

The Institute of Concrete and Masonry Structures developed and supervised a workshop in which the students planned the future energy supply of the nearby city Landau i.d. Pfalz. The student teams worked on their concepts until late at night and presented their results the next day. The best concept was awarded.

The highlight of the week was a public discussion about “Transforming Energy”. Representatives from Science, economics and politics discussed various aspects of the topic while involving the audience.

Claudia Weißmann supervising the workshop (Photo: Cedric Sehrt)

Regional convention of German Society of Concrete Engineers (VDB) – Regional group Hessen at TU Darmstadt

On March 3rd, 2015 the VDB regional convention was held at the TU Darmstadt. The speakers were Prof. Dr.-Ing. C.-A. Graubner, Prof. Dr.-Ing. G. Simsch, Dr.-Ing. T. Mielecke and Dipl. Ing. F. Röser. Within the presentations the speakers outlined the latest ongoing research activities at the Institute of Concrete and Masonry Structures and the Institute of Construction and Building Materials. The main core of speeches was mainly eco-friendly building materials and sustainable construction with concrete and existing structures. The meeting was followed at the end by a visit through the research and test laboratory of the Institute of Concrete and Masonry Structures.

Announcement: German Masonry Convention 2016

In 2016, the 9th German Masonry Convention will take place in Darmstadt from January the 19th till 20th. It is arranged by the Institute of Concrete and Masonry Structures of the Technical University of Darmstadt in collaboration with the German Society of Masonry and Domestic Construction as well as the Association of Structural Engineering and Solid Construction. The participants can look forward to a diversified and interesting agenda with well-known speakers in the range of politics, economy and science.

The German Masonry Convention will be opened with the New Year's Reception of the German masonry industry at January the 19th. Apart from a lecture by Bruno Baumann concerning the "relationship between innovation, risk and security", the newly created "Walther-Mann-Prize" for outstanding dissertations in the field of masonry construction is awarded for the first time.

The second day of the congress focuses on affordable domestic construction. In several lectures the multi-story housing is regarded from different views and current developments are depicted. In addition to constructive, creative and structural-physical aspects also political and social questions are discussed. Subsequent to the speeches as well as during the breaks, there is enough time for discussing with regards to content or to communicate individually with each other.

Of course we are really looking forward to welcoming preferably many of our "friends" at the German Masonry Convention. Registration is still possible via the website of the congress www.mauerwerkskongress.de/der-kongress/anmeldung.html until the beginning of January.

Flyer for German Masonry Convention 2016

COLLABORATION IN STANDARD BODIES

Prof. Graubner is still chairman of the standardization committee NA 005-06-01AA "Masonry Structures", the leading national standards body dealing with issues of standardization in the field of masonry structure. He simultaneously acts as German delegate at European level. The current focus is to support the already started "systematic review" of EN 1996 in the Scientific Committee and to obtain an appropriate representation of the widespread German simplified calculation methods in European regulations. Furthermore, a proper determination of so called National Determined Parameters (NDP) must guarantee the usual national level of reliability. Further details can be found in the article "New approaches in masonry standardization". Moreover, Prof. Graubner is selected member of standard committee NA 005-07-01 AA "Design and Construction of Reinforced Concrete".

Due to his high interest in the topic and his ongoing research activities regarding sustainable building, Prof. Graubner is counselling the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Roundtable "Sustainable Building") and furthermore he organizes the Roundtable "Resource Efficiency in the Building Sector" of this Federal Ministry. He is also active in the working group "Sustainability Assessment of Road Infrastructure" at the Federal Highways Research Institute. As a long-standing member of different expert groups Prof. Graubner supports the national German Center of Competence in Civil Engineering.

Following the aforementioned activities in the field of masonry structures Prof. Graubner is editorial advisor for "Mauerwerk" journal and coeditor of "Mauerwerksbau aktuell", a yearbook which reflects the latest developments and advances in both research and practice of masonry structures. Finally, he is author of the chapter "Masonry" in the well-known "Schneider Bautabellen".

Prof. Graubner was recently reelected as a member of assembly of TU Darmstadt. In addition he advices the "Förderinitiative Interdisziplinäre Forschung" at Technische Universität Darmstadt, which supports inter-discipline research project activities. At the same time he is a representative expert of the „Graduate School of Energy Science and Engineering".

EXCURSIONS

Site Excursion to the Nibelungen-Bridge (Worms) and the Hochmoselquerung

On Friday, July 17th, 2015, 37 students and 2 scientific employees of the Institute of Concrete and Masonry Structures went to an excursion. First stop of the excursion was the newly built bridge over the Rhine River in Worms, where the participants could get an overview of the details of this prestressed concrete bridge by representatives of the central public transport authorities in Worms (LBM).


Interior view of the Nibelungen-Bridge (left) and view on the new bridge over the Mosel River (right)

Afterwards the attendees got extensive information in the information center of the LBM Trier about the planning and the execution of this 1.7 km long bridge over the Mosel River. During the following site visit the students and scientific employees got a comprehensive overview of the works on this steel bridge with orthotropic deck slab. This led to numerous interesting discussions and to intensive exchanges of views between students and scientific employees.

In the name of all participants the Institute would like to thank the public transport authorities in Worms and Trier, Mr. Zillien, Mr. Darmstadt and Mr. Wacht for the interesting site visits. This trip was only possible with the generous support from the “Freunde des Instituts für Massivbau der TU Darmstadt e.V.”. We would like to thank the members at this point sincerely.

Site excursion to the Lahntal-Bridge near Limburg

On Thursday, November 20th, 2014, 45 students and 4 scientific employees of the Institute of Concrete and Masonry Structures went to the Lahntal-Bridge near Limburg. After an introduction into the project the participants got detailed information about the whole planning and building process. During the following site visit the students and scientific employees got a comprehensive overview of the works on this prestressed concrete box girder bridge and the building process of the cantilever construction. On site many questions regarding the building and prestressing process have been answered.


Picture of the group at the Lahntal-Bridge (left) view of the prestressed concrete box girder bridge (right)

In the name of all participants the Institute would like to thank Mr. Vaupel, site manager of the company Max Bögl, for the interesting site visit. This trip was only possible with the generous support from the “Freunde des Instituts für Massivbau der TU Darmstadt e.V.”. We would like to thank the members at this point sincerely.

Excursion to the production facility of Viessmann at Allendorf/Eder

Accompanied by three research assistants, 21 students of the lectures Technische Gebäude-ausrüstung I and Strategisches Facility Management & Sustainable Design went on an excursion to Allendorf/Eder on Friday, December 12th, 2014. There the participants could visit the production facility of Viessmann, which is a leading manufacturer of heating systems.

At first an overview on the company´s history was given and innovative renewable energy systems were introduced. Then the guided tour continued with a presentation of the in-house production and the energy centre of Viessmann. After lunch the participants visited the Viessmann academy, where they were informed about combined heat and power systems, fuel-cell technologies and current developments in the field of heating systems.

On behalf of all participants the Institute of Concrete and Masonry Structures would like to thank Mr. Daum (employee of Viessmann) for organizing the excursion and the interesting guided tour. This trip was only possible with the generous support of the Viessmann company and the "Freunde des Instituts für Massivbau der TU Darmstadt e.V.", to whom we express our sincere thanks.

The participants of the excursion in the exhibition area of Viessmann at Allendorf/Eder

PERSONAL MATTERS

Mr. Björn Freund, M.Sc. left the Institute of Concrete and Masonry Structures at midyear 2015 and is a structural engineer at König und Heunisch Planungsgesellschaft in Frankfurt/Main from that time on. He finished his dissertation, which should be defended in spring 2016.

Dr.-Ing. Stefan Hainer obtained his Ph.D. at the Fachbereich Bau- und Umweltingenieur-wissenschaften and left the Institute of Concrete and Masonry Structures this year. He is now employed at Dyckerhoff GmbH in the department Quality and Technical Consulting. We congratulate Mr. Hainer on the achievement of the doctor's degree.

The employment of Mr. Jaroslav Kohoutek, M.Sc. was finished this year and he is now working at DB Netz AG as a project manager in the field of railway bridges. Mr. Kohoutek intends to hand his dissertation in during 2016.

Mr. Michael Schmitt, M.Sc. will leave the Institute of Concrete and Masonry Structures at the end of 2015 and will be project manager at bauart Konstruktions GmbH & Co. KG starting 2016. He aims at handing in his dissertation in spring 2016.




Björn Freund M.Sc, Dr.-Ing. Stefan Hainer, Jaroslav Kohoutek M.Sc. und Michael Schmitt M.Sc. (from left to right)

Since March 1st 2015, Mr. **Benjamin Koob, M.Sc.** is employed as a doctoral student at the Section of Concrete and Masonry Structures. He studied civil engineering at the Technical University of Darmstadt and chose “Construction Engineering” as his main research. Thereby, he focussed on Concrete and Masonry Structures and examined the “Carrying capacity of non-loadbearing masonry walls” during his master thesis. After his graduation in May 2014, Mr Koob worked at “Bernhardt Ingenieure GmbH” in Darmstadt from June 2014 until February 2015. During this time he was concerned with the inspection of the design and construction of industrial buildings like warehouses and factory buildings. During his occupation at the Institute of Concrete and Masonry Structures Mr Koob will be in charge for the basic lectures and the lecture “Mauerwerksbau und Sonderfragen aus dem Betonbau“.

Mr. **René Mazur, cand. M.Sc.** will be a doctoral student at the Institute of Concrete and Masonry Structures starting in February 1st, 2016. Mr. Mazur studies civil engineering at the Technical University of Darmstadt. During his studies, he already focused on “Construction Engineering”. Mr. Mazur will graduate with his Master thesis “Transverse direction analysis of constituent road bridges” in January 2016. He worked as a student trainee in the department for bridge building in the engineering office “König und Heunisch Planungsgesellschaft” in Frankfurt (Main) up to December 2015. During his graduation Mr. Mazur will take care of the lectures “Stahlbetonbau I“ and “Stahlbetonbau II“.

Mr. **Fabian Staab, M.Sc.** will be a doctoral student at the Institute of Concrete and Masonry Structures starting in January 1st, 2016. His Ph.D. position will be connected to the "Building Integration and Energy Self-Sustaining Settlement Areas" research platform at the Darmstadt Graduate School of Excellence Energy Science and Engineering. Mr. Staab studied Civil Engineering and Business Administration at the Technische Universität Darmstadt and received his master's degree in October 2015. During the course of studies he set his focus in civil engineering on Facility Management and Building Technology. Topic of his master thesis was a pilot phase for a draft of a sustainability rating system for construction processes. The research for his Ph.D. will be concentrated on matters of sustainability during the German energy transition process. Mr. Staab will be responsible for the lectures "Building Technology I & II".

Mrs. **Sarah Steiner, M.Sc.** is a doctoral student at the department of Concrete and Masonry Structures since June 1st, 2015. Her Ph.D. position is also included in the "Building Integration and Energy Self-Sustaining Settlement Areas" research platform which is part of the Darmstadt Graduate School of Excellence Energy Science and Engineering. Mrs. Steiner has gained her bachelor´s degree of geosciences (specialisation: engineering geology and hydrogeology) at the Technical University of Munich and the Ludwig Maximilian University of Munich in September 2012. Afterwards, she finished her studies of applied geosciences (specialization: geothermal energy) at the Technical University of Darmstadt in March 2015. The focus of research of Mrs. Steiner will be on the ecological optimization of mineral construction materials. During her graduation Mrs. Steiner will be in charge for the lecture "Facility Management & Sustainable Design".

AWARDS

Dreßler Bau award 2015

The “Dreßler Bau”-Prize has been awarded for the third time at the TU Darmstadt at November 18th, 2015. The award is handed over for outstanding bachelor theses in the technical disciplines Concrete Structures and Construction Management. In fact, this year two students of the Institute of Concrete and Masonry Structures have received this award. Mr. Max Fritsche submitted his bachelor thesis in the field of construction and design about the “Investigation of imposed loads in Laboratories”. Mr. Alexander Weiß wrote about the “Analysis of CHP electricity contribution to the total building electricity demand” in the field of energy efficient building design. We congratulate Mr. Fritzsche and Mr. Weiß on this success.

The laureates Max Fritzsche (third from left) and Alexander Weiß (third from right) with Tobias Mann, managing director of Dreßler Bau GmbH (second from left) and the supervisors from the Institut Wohnen und Umwelt GmbH (first from right) and the Institute of Concrete and Masonry Structures

Freunde des Instituts für Massivbau der TU Darmstadt e.V. award 2015

The „Freunde des Instituts für Massivbau der TU Darmstadt e.V.“ award outstanding dissertations at the institute with a special prize. In 2015 this prize was awarded to Mr. Dr.-Ing. Sebastian Pohl for his dissertation “Sustainability in building operation – Proposal for diversifying the real estate certification regime in Germany”. We congratulate Mr. Dr.-Ing. Pohl on this success.

Award of the Hessian Building Sector 2015

In 2015 the Award of the Hessian Building Sector has been awarded for the 32nd time in the categories architecture, civil engineering and civil engineering management. At November 13th, 2015 the master thesis of Ms. Katharina Beers has been honored with the 2nd prize in the category civil engineering. Her thesis with the title “Development of a model for assessing the energy efficiency and the economic quality of energy-related refurbishment measures” has been written in the field of sustainable construction in existing buildings. We congratulate Ms. Beers on this success.

GEFMA award 2015

The GEFMA award is a well-respected prize in the German real estate sector. At March 26th, 2015 the 18. GEFMA prize for academic theses was awarded during the Facility Management fair in Frankfurt/Main. Thereby, the special award in the category Sustainability was given to Dr.-Ing. Sebastian Pohl for his dissertation “Sustainability in building operation – Proposal for diversifying the real estate certification regime in Germany”. We congratulate Mr. Dr.-Ing. Pohl on this success.

DGEB award 2014

The German Association for Seismic Engineering and Structural Dynamics (DGEB) awards a prize for theses that make significant contributions to the research in earthquake engineering, engineering seismology and structural dynamics. At August 20th, 2015 the price was given to Mr. Seifeddine Jmiai for his master thesis “Dynamic analysis of machine foundations – Development of a design tool and validation with FEM-software-calculations”. We congratulate Mr. Jmiai on this success.

ACKNOWLEDGEMENTS

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

Adam Hörnig Baugesellschaft GmbH, AMIG Rudi Becker, Arbeitsgemeinschaft für industrielle Forschung, Arbeitsgemeinschaft industrieller Forschungsvereinigungen „Otto von Guericke“ e.V., BASF AG, bauart Konstruktions GmbH & Co. KG, bauserve GmbH, BERNHARDT Ingenieure GmbH, Beton Kemmler GmbH, BetonMarketing West GmbH, Bilfinger Bauperformance GmbH, Bilfinger Hochbau GmbH, Bilfinger SE, Bilfinger HSG Facility Management GmbH, BT3 Betontechnik GmbH, Bundesanstalt für Straßenwesen, Bundesministerium für Bildung und Forschung, Bundesministerium für Verkehr und digitale Infrastruktur, Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit, Bundesverband der Deutschen Ziegelindustrie, Bundesverband der Kalksandsteinindustrie e.V., Bundesverband Porenbetonindustrie e.V., Bundesverband Deutsche Beton- und Fertigteilindustrie e.V., Bundesverband Leichtbetonzuschlagindustrie e.V., Daimler AG, Deutsche Bahn AG, Deutsche Bundesstiftung Umwelt, Deutsche Poroton GmbH, Deutscher Beton- und Bautechnik-Verein E.V., Deutsche Forschungsgemeinschaft e.V., Deutsche Gesellschaft für Mauerwerks- und Wohnungsbau e.V. (DGfM), Deutscher Ausschuss für Stahlbeton, Deutsches Institut für Bautechnik, Dreßler Bau GmbH, Durth Roos Consulting GmbH, Dyckerhoff AG, Evonik Degussa GmbH, Fachvereinigung Deutscher Betonfertigteilbau e. V., fischerwerke GmbH & Co. KG, Forschungsinstitut der Zementindustrie (FiZ), Forschungsvereinigung Kalk-Sand e.V., Freunde des Instituts für Massivbau der TU Darmstadt e.V., Freunde der Technischen Universität Darmstadt, GOLDBECK GmbH, Güteschutzverband Betonschalungen e. V., H-BAU Technik GmbH, Halfen GmbH & Co. KG, H-Bau Technik GmbH, HeidelbergCement AG, Hilti Deutschland AG, Hochtief AG, Hoechst AG, HSE Technik GmbH, Ingenieurbüro Krebs und Kiefer, Ingenieurconsult Cornelius Schwarz Zeitler GmbH, Julius Berger International GmbH, Institut für Baustoffe TU Dresden, Klimaleichtblock GmbH, König und Heunisch Planungsgesellschaft mbH & Co. KG, LCEE Life Cycle Engineering Experts GmbH, Liapor GmbH & Co., Longlife-Treppen GmbH, LohrElement GmbH, MAPEI Betontechnik GmbH, Max Bögl Bauunternehmen GmbH, MC-Bauchemie Müller GmbH & Co. KG, MEVA Schalungssysteme GmbH, OPTERRA Karsdorf GmbH, pakon AG, PreConTech e.K., Ruffert & Partner, Schöck Bauteile GmbH, Sika Deutschland GmbH, sh minerals GmbH, Spenner Zement GmbH & Co. KG, Steag GmbH, Strabag AG, Syspro-Gruppe Betonbauteile e. V., TOGE-Dübel A. Gerhard KG, VdS Schadenverhütung GmbH, Verein Deutscher Zementwerke, 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 organizations is necessary and highly appreciated, especially in order to include all practical aspects of civil engineering. For their personal commitment as visiting lecturers in our institute we would like to thank the following persons:

Dr.-Ing. Herbert Duda	Baudynamik
Dipl.-Ing. Rudolf Herz	Mauerwerksbau und Sonderfragen aus dem Betonbau
Dipl.-Ing. Thomas Heß	Gebäudetechnik
Dipl.-Ing. Liane Prediger	Mauerwerksbau und Sonderfragen aus dem Betonbau
Dipl.-Ing. (FH) Michael Pröll	Mauerwerksbau und Sonderfragen aus dem Betonbau
Dr.-Ing. Gert Riegel	Strategisches Facility Management & Sustainable Design
Dr.-Ing. Holger Schmidt	Risiko und Sicherheit im konstruktiven Ingenieurbau
Dipl.-Ing. Heinz Steiger	Massivbrückenbau und Traggerüste

Mr. Dipl.-Ing. Heinz Steiger held the lectures concerning the topic of falseworks as a visiting lecturer for the last time this year. In this way, he supported our institute for over 20 years and showed exemplary commitment in integrating practical matters into academic courses. Therefore, we would like to thank Mr. Steiger very much.

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

Dr.-Ing. Markus Spengler (Baudynamik); Dipl.-Ing. Mathias Tillmann, Dipl.-Ing. Heinz Eberherr, Dipl.-Ing. Alice Becke, Dipl.-Ing. Ralf Niehüser, Dr.-Ing. Georg Hellinger, Dipl.-Ing. Erwin Scholz, Dipl.-Ing. Stefan Zwolinski, Dr.-Ing. Diethelm Bosold, Dipl.-Ing. Werner Hochrein, Dr.-Ing. Christoph Schmidhuber, Dipl.-Ing. Dipl.-Wirt. Ing. Elisabeth Hierlein, Dipl.-Ing. Dipl.-Wirtsch.-Ing. Mike Richter und Dipl.-Wirt.-Ing. (FH) Peter Schermuly (Fertigteilkonstruktionen); Dr.-Ing. Gerhard Zehetmaier und Dr.-Ing. Stefan Kempf (Massivbrückenbau und Traggerüste); Dr.-Ing. Stefan Daus (Mauerwerksbau und Sonderfragen aus dem Betonbau); Dr.-Ing. Eric Brehm (Risiko und Sicherheit im konstruktiven Ingenieurbau); Dr.-Ing. Sebastian Pohl (Strategisches Facility Management & Sustainable Design); Dipl.-Ing. Herbert Schäfer, Dipl.-Ing. Rudi Becker, Dipl.-Ing. Michael Sauerwein, Dr.-Ing. Benjamin von Wolf-Zdekauer, Dipl.-Ing. Olaf Pielke, Dipl.-Ing. Frank Bieber, Dipl.-Ing. Robin Engelmann und Dipl.-Ing. Patrik Bös (Technische Gebäudeausrüstung).

PUBLICATIONS

Selected Papers:

- Graubner, C.-A.; Pelzeter, A.; Pohl, S.: A new approach to measure sustainability in German Facility Management. In: Facilities, Vol. 33, No. 1/2, Emerald Group Publishing, Bingley, 2015
- Graubner, C.-A.; Pohl, S.: Ist vereinfacht vollständig genug? - Spannungsfeld der Ökobilanzverfahren im Deutschen Gütesiegel Nachhaltiges Bauen. In: Bauingenieur, Band 90, Januar 2015, Springer VDI Verlag, Düsseldorf, 2015
- Graubner, C.-A.; Pohl, S.: Nachhaltigkeit von Mauerwerksbauten. In: Mauerwerksbau aktuell 2015 - Praxishandbuch für Architekten und Ingenieure. Graubner, C.-A.; Rast, R.; Schneider, K.-J. [Hrsg.], Bauwerk Beuth Verlag, Berlin, 2015. ISBN 978-3-410-245223
- Graubner, C.-A.; Proske, T.; Hainer, S.: Moderne Betone aus klinkerreduzierten Zementen – Herstellung, Nachbehandlung, Umweltbilanz. In: Tagungsband, 59. Betontage Ulm, BFT-International, 02/2015, 11-13.
- Graubner, C.-A.; Schmitt, M.; Förster, V.: Praxisbeispiel: Nachweis einer Aussteifungsscheibe aus unbewehrtem Mauerwerk nach DIN EN 1996-1-1/NA. In: Mauerwerksbau aktuell 2015 - Praxishandbuch für Architekten und Ingenieure. Graubner, C.-A.; Rast, R.; Schneider, K.-J. [Hrsg.], Bauwerk Beuth Verlag, Berlin, 2015. ISBN 978-3-410-245223
- Graubner, C.-A.; Schmitt, M.; Förster, V.: Tragfähigkeitstafeln für unbewehrtes Mauerwerk nach Eurocode 6 - Teil 3. In: Mauerwerksbau aktuell 2015 - Praxishandbuch für Architekten und Ingenieure. Graubner, C.-A.; Rast, R.; Schneider, K.-J. [Hrsg.], Bauwerk Beuth Verlag, Berlin, 2015. ISBN 978-3-410-245223
- Graubner, C.-A.; Six, M.; Zeier, J.: Spannbetonbau. In: Stahlbetonbau aktuell 2015 - Praxishandbuch. Hegger, J.; Mark, P. [Hrsg.], Bauwerk Beuth Verlag, Berlin, 2015. ISBN 978-3-410-24519-3
- Graubner, C.-A.; Kohoutek, J.: Integrale Brücken im Wandel der Zeit. In: Tagungsband, 25. Dresdner Brückenbau Symposium. Curbach, M. [Hrsg.], Technische Universität Dresden, Institut für Massivbau, Dresden, 2015. ISBN 978-3-86780-421-9
- Frank, M.; Loga, T.; Schaede, C.; Weißmann, C.: Eigendeckung des Strombedarfs von Niedrigstenergiehäusern durch Photovoltaik-Anlagen - Verrechnung mit unterschiedlichen Zeitschrittweiten ergänzend zur EnEV. In: Bauphysik 2/2015. Ernst & Sohn Verlag, Berlin.

- Hainer, S.; Proske, T.; Graubner, C.-A.: Einfluss der Nachbehandlung auf das Karbonatisierungsverhalten von Beton aus klinkerarmen Zementen. In: Beton- und Stahlbetonbau 101 (2015), Heft 1, Verlag Ernst & Sohn, Berlin, 2015, 41-49.
- Hainer, S.; Proske, T.; Graubner, C.-A.: Modell zur Vorhersage der Karbonatisierungstiefe von klinkerreduzierten Betonen. In: Proceedings of the 19. Internationale Baustofftagung (ibausil), Weimar, 2015, 1-1129-1138.
- Mittermayr, F.; Rezvani, M.; Baldermann, A.; Hainer, S.; Breitenbücher, P.; Juhart, J.; Graubner, C.-A.; Proske, T.: Sulfate resistance of cement-reduced eco-friendly concretes. In: Cement and Concrete Composites, Volume 55, January 2015, 364–373.
- Rezvani, M.; Proske, T.; Graubner, C.-A.: Shrinkage of mortar samples made of limestone-rich cements. In: Proceedings of Mechanics and physics of creep, shrinkage, and durability of concrete and concrete structures, CONCREEP-10, Wien, 2015.
- Schmitt, M.; Graubner, C.-A.; Förster, V.: Mindestauflast auf Mauerwerkwänden - Eine realitätsnahe Betrachtung, In: Mauerwerk Heft 19 (2015) Heft 4, Verlag Ernst & Sohn, Berlin, 2015. ISSN: 1432-3427.
- Tran, N.L; Grziwa, U.; Graubner, C.-A.: Spatial variability of material properties and ist influence on structural reliability of UHPFC columns. Fib Symposium Proceedings, Concrete - Innovation and Design, 18-20 May 2015, Copenhagen, 2015.
- Tran, N.L; Kohoutek, J.; Graubner, C.-A.: Querkrafttragfähigkeit von Stahlbetonbauteilen ohne Querkraftbewehrung. Beton- und Stahlbetonbau 110, 2015, Heft 4, 244-253
- Weißmann, C.; Graubner, C.-A.: Ökonomische und ökologische Lebenszyklusanalyse eines Plus-Energie-Gebäudes mit elektrischem Beheizungssystem. In: Tagungsband, 7. Norddeutsche Passivhauskonferenz, Hamburg, 08.10.2015
- Weißmann, C.; Weber, T.: Development of an approach to assess the investment decision in high-capacity batteries installed in plus-energy buildings, In: Abstract Book, IYCE - International Youth Conference on Energy, 27.-30. May 2015, Pisa, 2015

Selected Presentations:

- Graubner, C.-A.: Vom Material zum Bauwerk - Forschungsschwerpunkte des Instituts für Massivbau. VDB Regionaltagung, Darmstadt, 03.03.2015
- Graubner, C.-A.; Fritz, K.: Beurteilung der Ressourceneffizienz im Bauwesen. 5. Runder Tisch Ressourceneffizienz im Bauwesen, Berlin, 17.06.2015
- Graubner, C.-A.; Proske, T.; Hainer, S.; Rezvani, M.: Moderne Betone aus klinkerreduzierten Zementen. Betontage 2015, Neu-Ulm, 24.02.2015
- Fritz, K.; Graubner, C.-A.: Beurteilungssystematik für Ressourceneffizienz im Bauwesen. Workshop Ressourceneffizienz im Bauwesen, Berlin, 16.10.2015
- Hainer, S.; Proske, T.; Graubner, C.-A.: Modell zur Vorhersage der Karbonatisierungstiefe von klinkerreduzierten Betonen. 19. Internationale Baustofftagung (ibausil), Weimar, 17.09.2015
- Proske, T.; Graubner, C.-A.; Hainer, S.; Rezvani, M.: Aktuelle Entwicklungen im Bereich umweltfreundlicher Zemente und Betone. 5. Darmstädter Beton- und Schalungstag, Darmstadt, 30.06.2015
- Ramge, P.; Fritz, K.; Graubner, C.-A.: Nachhaltigkeitsbewertung von Verkehrsinfrastrukturbauwerken - Ein Einblick in die aktuelle Forschung. IZBE-Symposium "Verkehrsinfrastruktur für unsere Zukunft - Nachhaltig investieren und betreiben", Dresden, 23.04.2015
- Rezvani, M.; Proske, T.; Graubner, C.-A.: Shrinkage of hardened cement pastes and concretes made of limestone-rich cements, Mechanics and physics of creep, shrinkage, and durability of concrete and concrete structures, CONCREEP-10, Wien, 22.09.2015
- Weißmann, C.: Development of an approach to assess the investment decision in high-capacity batteries installed in plus-energy buildings, IYCE - International Youth Conference on Energy, Pisa, 28.05.2015
- Weißmann, C.; Graubner, C.-A.: Ökonomische und ökologische Lebenszyklusanalyse eines Plus-Energie-Gebäudes mit elektrischem Beheizungssystem. 7. Norddeutsche Passivhauskonferenz, Hamburg, 08.10.2015

STABILITY FAILURE OF MASONARY WALLS WITH SMALL MODULS OF ELASTICITY

Valentin Förster, Carl-Alexander Graubner

The verification of safety against buckling of unreinforced masonry walls according to the accurate design procedure of EN 1996-1-1 Appendix G is based on semi-empirical approaches, which do not always realistically describe the load-bearing behaviour. This statement is also supported by an objection of the country Denmark concerning the load capacity function which is regulated in Appendix G. Within a research project (please refer to (1) and (2)) the stability failure of slender masonry walls and their modelling under consideration of realistic material parameters were investigated.

If we consider the currently valid European regulation (blue curves), then it can be recognized that with high slenderness ($h_{ef}/t > 20$) from a certain K_E ratio with increasing characteristic compression strength and a simultaneous decrease of K_E, the load-bearing capacity is indeed calculative reduced. This can be said to be a "defect" of EN 1996-1-1, because an increase of the compression strength must always lead to an increase of load-bearing capacity up to a certain limit. With realistic modelling of the stress-strain relationship, no reduction of load-bearing capacity with an increase of strength can be seen, as is demonstrated by the results of a calculation with the according procedure. It is also obvious that the stated effect only occurs with large slenderness, so that this only affects a very small and specific range of application in building practice. It should also be noted that in the German national annex, the load capacities for stability failure of slender walls is partially regulated way more conservatively than the regulations of EN 1996-1-1/NA and thus from the German point of view, there is no need for action, even for very low K_E values.

It can also be stated that the national rules of Germany according to DIN EN 1996-1-1/NA not only lead to very conservative results in some areas but also are very time-consuming and error-prone due to the numerous input parameters. Particularly, the rule to consider the influence of creep on the load-bearing behaviour according to 2nd order effect offers potential for simplification. In this context, a new design concept concerning stability failure of slender masonry walls has been developed and verified with the aid of numerous comparative calculations. This proposal is - compared to the current regulation - not only easier to use, but also integrates creep-effect and the shape of the relevant stress-strain relationship of the masonry directly into the load capacity function. In case of $K_E = E_0/f_k \geq 500$, it is possible to perform the design without regarding specific material behaviour. Furthermore, the determination of a number of input parameters is avoided which makes the new design proposal more practical for manual calculations.

The authors wish to explicitly thank the “Initiative Praxisgerechte Regelwerke im Bauwesen e. V. (PRB)” and the “Forschungsinitiative Zukunft Bau des Bundesinstitutes für Bau-, Stadt- und Raumforschung” for funding the research project from which the results were presented.

(1) Graubner, C.-A.; Brameshuber, W.; Jäger, W.; Seim, W.: Abschlussbericht zum Forschungsvorhaben: Verbesserung der Praxistauglichkeit der Baunormen durch pränormative Arbeit – Teilantrag 5: Mauerwerksbau. Deutsche Gesellschaft für Mauerwerks- und Wohnungsbau e.V., Berlin 2015.

(2) Graubner, C-A; Förster, V.: Simplified design concept for slender masonry walls - Vereinfachter Stabilitätsnachweis knickgefährdeter Mauerwerkswände. Mauerwerk 20 (2015) H. 6.

PRESSURE OF FRESH CONRETE OF FREE FORMED CONCRETE STRUCTURES

Björn Freund

Curved concrete components are state of the art in engineering structures. In modern architecture, inclined and curved concrete elements are becoming increasingly popularity. The production of such concrete components or structures makes high demands on the formwork technology and construction. The selection and sizing of the formwork systems is determined to a large extent from the resulting pressure of the fresh concrete. The fresh concrete pressure is the dominant influence on the dimensioning and design of formwork systems. Previous models for determining the fresh concrete pressure have made possible only calculations for vertical formwork. Until now for inclined or curved formwork system the hydrostatic concrete pressure has been applied. These has led in many cases to oversized formwork constructions or unnecessarily slow concreting.

Over the past three years, the fresh concrete pressure of inclined and curved concrete structures has been extensively studied at the Institute of Concrete and Masonry Structures and was funded by the Deutsche Forschungsgemeinschaft (DFG). Extensive material and component tests were carried out. The experimental results showed that the fresh concrete pressure of inclined concrete components in comparison to the fresh concrete pressure of perpendicular concrete components is significantly lower than in many cases (1). A simulation model developed to determine the fresh concrete pressure of vertical, inclined and curved concrete structures showed very good agreement with measurements from experiments and site measurements (1).

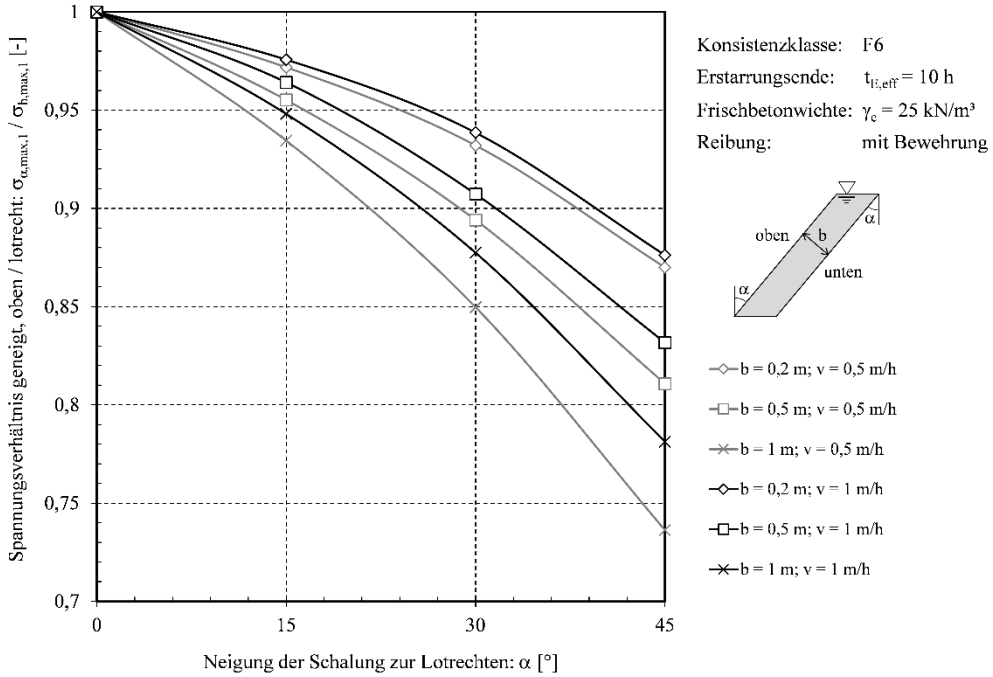


Figure 1: Pressure ratio of fresh concrete pressure of a upper inclined formwork and a vertical formwork (comp. (2))

Based on the results of extensive parameter studies (comp. Figure 1), a design model was derived and calibrated to a defined security level (2). The assessment model allows using diagrams and equations to determine the fresh concrete pressure in vertical, inclined and curved concrete elements when using flowable, highly flowable and self-compacting concrete. With the determined fresh concrete pressure can then the respective formwork system are practical enough dimensioned and sized in conjunction with the current design codes.

(1) Freund, B.; Proske, T.; Graubner, C.-A. (2014): Experimentelle Untersuchungen und numerische Verifizierung zum Frischbetondruck bei geneigten Schalungssystemen. Beton- und Stahlbetonbau, Heft 11, S.803-811, Ernst & Sohn, Berlin, 2014.

(2) Freund, B. (2015): Dissertation in Vorbereitung. TU Darmstadt - Institut für Massivbau, Darmstadt.

NEW APPROACHES IN MASONRY STANDARDIZATION

Carl-Alexander Graubner

As Germany's former national soccer coach Sepp Herberger used to say: ***"After the game is before the game!"*** Following this motto, codes are always developing.

Just barely after the building authorities introduced the European Codes for Dimensioning (DIN EN 1996 Parts 1-1 and 3) and Execution (DIN EN 1996 Part 2) of Masonry and their national annexes on the 01.01.2015, these regulations have to be reviewed for a new European version that is scheduled to be released in 2020. In the course of a systematic review all parts of the Eurocode 6 (EN 1996) are to be analysed regarding possible simplifications ("easy of use"). Furthermore the current potential for harmonization, which exists between the different national annexes, is to be identified, in order to reduce the Nationally Determinable Parameters (NDP) in quantity and regulatory depth as much as possible (see also the contribution of Koob/Graubner).

The development of a new proposal for the code takes place on European level in the "Scientific Committee No. 6" (SC6), while for the individual parts of the EN 1996 internationally staffed working groups (WG) and project teams (PT) are formed. The issues identified for revision by the countries in the course of the last years are discussed in the WG and then concretised for a final text proposal in the PT. This procedure currently takes place for the Part 1-1 of the EN 1996, which means that a first draft for the new European code regarding the more accurate design method should be presented in the spring of 2016. This draft is then to be discussed in the SC6, in order to be available for amendment in the national standardization bodies. The corresponding activities concerning the simplified calculations methods (Part 3 of EN 1996) start in the beginning of 2016.

In order to competently accompany the revision of the Eurocodes while keeping the German interests in mind, a pre-normative review of the regulations is indispensable. In this context the initiative “Praxisregeln Bau”(PRB), supported by different lobbies, was founded in 2013 already. This initiative has the goal of downsizing the design standards relevant for construction regarding the regulation density and revising them with a practical orientation. In the past two years different project groups developed proposals for simplification of the various parts of the Eurocodes (safety concept, impacts, concrete, steel, wood, masonry, soil engineering) that can now be used as a basis for the new German proposal for the systematic review.

Regarding this, especially project group 5 of the PRB, which is responsible for masonry constructions, was very active in the recent past. The representatives coming from engineering offices and associations of the masonry industry went on honorary basis through the parts 1-1, 2 and 3 of the EN 1996 and connected the European regulations with the associated national parameters (NDP). The text of the code was revised editorially, inconsistencies were eliminated and, from the German point of view, dispensable regulations were deleted. But also some German issues regarding national specialities had to be added. With this proposal the extent of the regulations can be reduced by one third in total. The national PRB proposal for the EN 1996 was already reviewed by the responsible national body DIN NA 005-06-01 under the chairmanship of Prof. Graubner and recommended for implementation in the European standardization process. In order to make the procedure more efficient, a translation into the English language is already available.

With this intensive preliminary work it can be hoped, that the revision of the EN 1996 can be accompanied appropriately in the European standardization body as well as to enable dimensioning of masonry in practice without greater effort.

MODELING OF REINFORCED CONCRETE COMPRESSION MEMBERS CONSIDERING SPATIAL VARIABILITY OF MATERIAL PROPERTIES

Ulf Grziwa, Carl-Alexander Graubner

The load capacity of slender compression members made of fiber reinforced ultra-high performance concrete (UHPC) with small load eccentricity, is decided mainly by the scattering of the young's modulus. In case of large load eccentricity it depends significantly on the scatter of the concrete tensile strength. In particular, for concrete with high fiber content it can be hypothesised, that the material-related variations due to the increasing inhomogeneity of the building material are larger than using conventional reinforced concrete.

The numerical modeling of concrete compression members is usually based on the assumption of homogeneous materials properties all over the member length. In case of pin-ended columns under eccentric normal force the point of failure is always at the middle of the member length (point of the maximum bending moment). Experimental test series carried out at the Institute of Concrete and Masonry Structures, show in contrast that there is a large spatial variability of the point of failure.

In order to reproduce the realistic behaviour of the compression member it is necessary to take into account the inhomogeneity of the building materials. At the Institute of Concrete and Masonry Structures an experimental test program was carried out to identify the statistical parameters of UHPC samples with different fiber contents as well as the spatial variability of the material properties within the compression members. In the experimental test program small test samples (cylinder, cubes, prisms) and slender columns (cross section w/h 12/12 cm and Ø 15 cm) were produced. They were cut into small samples for

identifying the compressive strength, tensile strength and young's modulus. Additionally the fiber quantity and the fiber orientation as well as the geometric parameters were determined at every cut surface. Based on the results of the experimental tests it is possible to describe the correlations between the different material properties and the functions of the distribution of the materials properties along the concrete component. These input values were used in the numerical modeling of the compressive members. Besides a number of load bearing tests were carried out for calibrating the Finite-Element-Modell (Fig.1).

Further investigations on the influence of the spatial variability of the material parameters on structural reliability will be carried out soon.

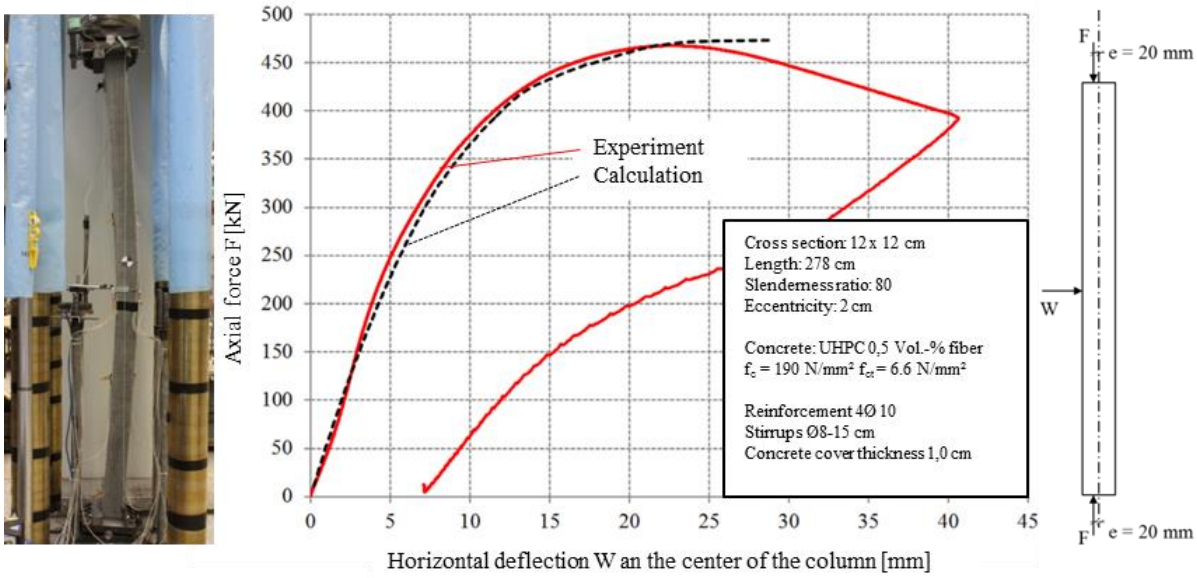


Figure 1: Experimental load bearing test (left); Stress-deformation-curve of the experimental test and the Finite-Element-Modell (right)

The authors thank the DFG for financial supporting the research project.

RELIABILITY ANALYSIS OF A FRAME BRIDGE IN ULTIMATE LIMIT STATE

Jaroslav Kohoutek

In Berching the Südbrücke crosses the Main-Donau-Channel with a width of 100 m. The load-bearing capacity of this jointless resp. integral frame bridge is influenced by the soil-structure interaction, because the frame legs are mostly located in soil. Based on the particular load bearing effect the bridge was used for reliability analyses, which determined the probability of failure of single cross sections. These reliability analyses were used to prove sufficient bridge reliabilities by utilizing realistic soil properties.

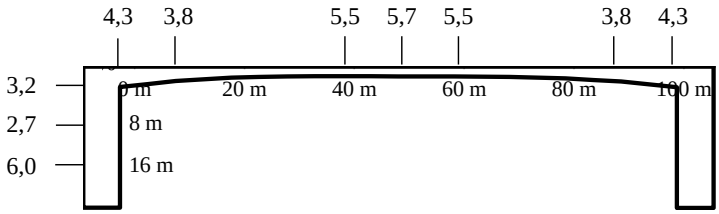


Figure 1: Reliability indexes β of the static proof bending under normal forces in ultimate limit state regarding a period of 50 years

In Fig. 1 the determined reliability indexes β in ultimate limit state (ULS) are shown. It is clear that the normative target reliability $\beta = 3{,}8$ in 50 years – which represents a probability of failure $p_f \sim 1 \cdot 10^{-6}$ – is reached or exceeded in every part of the superstructure, but not yet reached in the frame legs. The shortfall is mainly due to the use of higher traffic loads according to DIN EN 1991-2 compared to the original calculations, which lead to higher utilization factors.

Out of Fig. 2 it can be seen, that the influence of single basic variables on the reliability of the structure interdepends from the location of the cross section. While the influence of varying concrete properties is 11 % in the left corner, it increases to 33 % in 10 m distance and decreases to 3 % in midspan. On the contrary, the influence of varying self-weights increases from 8 % in the left corner towards 25 % in midspan.

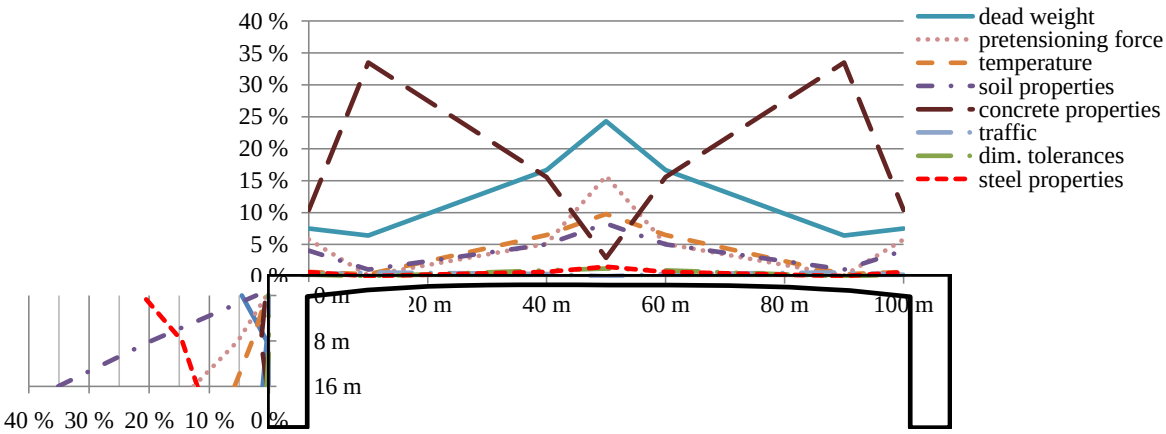


Figure 2: Basic variables of the static proof bending under normal forces in ultimate limit state without model uncertainties

Low concrete compressive strengths increase the height of the compression zone x compared to the planned compression zone x_{plan}. As a result the lever arms decrease and the utilization factors of the cross sections increase. High compression zones x_{plan} influence the lever arms more, whereby the impact of scattered soil properties on the reliability of the regarded cross section of the bridge increases (comp. Fig. 2).

Generally it can be said, that even under higher traffic loads the Südbrücke Berching meets mostly todays normative requirements on the reliability of the structure in ULS using today's traffic loads. Since it is an existing structure, the lowering of the bridge reliability in single cross-sections can be accepted.

ANALYSIS AND COMPARISON OF THE NDPS OF VARIOUS NATIONAL ANNEXES OF EUROCODE 6

Benjamin Koob, Carl-Alexander Graubner

In the national annexes of Eurocode 6, the individual European Member States are able to determine a predefined number of parameters nationally (NDPs) and to complement some rules, which do not disagree with the existing European regulations (NCI). Therefore, the normative statements in the different countries vary more or less. In terms of aspiring to an easy handling of the Eurocode, it should be the aim to get an uniform European code, which is not used significant differently because of national determinations.

For a better understanding und comprehending of the interests and concerns of other states regarding future generations of engineer standards, the individual NDPs of EN 1996 part 1-1, part 2 and part 3 of the neighboring states of Germany as well as Great Britain and Italy as important countries in masonry were compared to each other to detect the potential capacities of harmonization. In part 1-1, there are 20 parameters which have to be defined whereas in part 2, there are only five and in part 3, there are seven NDPs.

The analysis showed, that only three of the 20 NDPs of part 1-1 can be characterized with a high potential of harmonization. Most of the NDPs have just a low potential in contrast. In table 1 the NDPs of EN 1996-3 as well as the associated potential of harmonization is shown exemplary.

Table 1: Survey and potential of harmonization of the NDPs of EN 1996-3

EN 1996-3 section	description	DE	AT	BE	CZ	DK	GB	FR	IT	NL	PL	CH	potential of harmoni-zation
2.3(2)P	Partial safety factor for ultimate limit state	x	x	x	x	no NA available	x	x	E	x	x	no NA available	x
4.1(1)P	Verification of the overall stability of a building	x	x	E	-		x	E	E	x	E		
4.2.1.1(1)P	General conditions	E	E	E	E		E	E	E	E	E		
4.2.2.3(1)	Capacity reduction factor	x	E	E	x		x	E	x	E	x		
D.1(1)	Characteristic compressive strength	x	x	x	x		x	x	E	x	x		
D.2(1)	Characteristic flexural strength	x	E	x	E		x	x	E	x	x		
D.3(1)	Characteristic initial shear strength	x	E	x	-		x	x	E	x	x		

Legende:

x: specific national determination valid

E: European determination valid

-: no determination available

High potential of harmonization

Middle potential of harmonization

Low potential of harmonization

All over all you can see that Germany is the state, which has the most country-specific regulations within the NDPs and therefore differs most from the recommended European regulations. But it is completely wrong to draw negative conclusions from this, because the German rules consider some important circumstances – like the differentiation between in-plane shear stress and out-of-plane shear stress – even more correctly than the European recommendations.

Furthermore it is obvious, that there is only a low number of NDPs with a high potential of harmonization. For about one third of all NDPs a moderate chance of success for harmonization can be seen. However, there are further discussions and comparative calculations required. According to this examination, the predominant number of NDPs has currently only low chances of harmonization. In particular, the regulations of the characteristic strength values have to be mentioned in this context, because these parameters differ very much in the regarded individual countries.

CARRYING CAPACITY OF MASONRY WALLS UNDER BENDING STRESS IN CONSIDERATION OF MEMBRANE EFFECTS

Michael Schmitt

Today, non-load-bearing-walls are often used in reinforced concrete frame constructions of buildings, industry and power stations. The design is carried out with standardized methods, which use the flexural strengths normal and parallel to the bed joint as the significant material property. In this case the walls have to be designed with free or horizontal undisplaceable edges (see Fig. 1 – left and middle figure). In consideration of the normative wind loads, the maximum realizable wall areas do not sufficiently fulfill the praxis requirements. Using a friction-type connection for the joints between the non-load-bearing masonry wall and the adjacent reinforced concrete structural elements (see Fig. 1 – right figured) membrane compressive stresses can be activated in an appreciable size, so that the horizontal bearing load increases significantly.

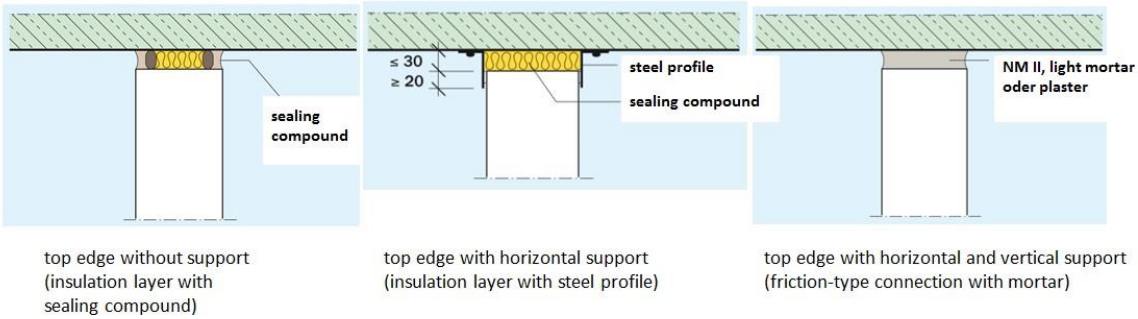


Figure 1: Supports for non-load-bearing masonry walls according to (1)

In recent years, the influence of membrane effects of the load-bearing capacity of non-load-bearing masonry walls has been extensively studied at the Institute of Concrete and Masonry Structures. In addition to numerous numerical analyses based on the finite element method an analytical design-method was developed, so that the maximum horizontal load can be determined. Additional to the vertical one-way load-bearing capacity it is also possible to design four-sided supported non-load-bearing masonry walls. Furthermore effects of shrinkage in the bed joints can be taken into account. The flexural stiffness of the adjacent reinforced concrete slabs influences the carrying capacity essentially. These compression stress-strain characteristics of the slab were determined with numerical analysis. The analytical design-method has been verified with results of full scale tests from literature. Furthermore a good correlation between the results of the analytical model and the results of the finite element analysis was found.

The results show, that in opposition to the bending capacity of masonry walls the consideration of the stiffness from adjacent reinforced concrete slabs leads to a significant higher load-bearing capacity of the non-load-bearing masonry walls (cf. (2)). It is noted that the flexural strength does not longer represent the decisive material property. The most important material and geometry property, which decide the carrying capacity, are the Young's modulus of masonry, the compression strength and the spring stiffness of the reinforced concrete slab. A simplified design model is included in (2).

(1) Schmitt, M.; Graubner, C.-A. (2014): Nichttragende Wände. In: Kalksandstein: Planungshandbuch. Planung, Konstruktion, Ausführung (PKA) – 6. Auflage. Bundesverband Kalksandsteinindustrie e.V., Hannover [Hrsg], Verlag Bau + Technik GmbH, Hannover 2014, ISBN: 978-3-7640-0591-7

(2) Schmitt, M. (2016): Dissertation in Vorbereitung. TU Darmstadt – Institut für Massivbau, Darmstadt

STOCHASTISTIC MODELLING OF LIVE LOAD FOR OFFICE BUILDINGS

Ngoc Linh Tran, Larissa Krieger

The design load for office buildings according to the technical code DIN EN 1991-1-1/NA can be taken with a value $q_k = 2{,}0$ kN/m². This assumption is valued for general office areas, as well as for corridor without heavy facilities. A classification related to the type of office-usages is not given. However, with different furniture and facilities as well as personal load the large difference of loadings can occur, which should be covered by the norminative loads. This paper presents the results of a simulation of live loads with the use of load survey for the office rooms of the Institute of Concrete and Masonry Structures, Technische Universität Darmstadt and also a comparison to the normative loads.

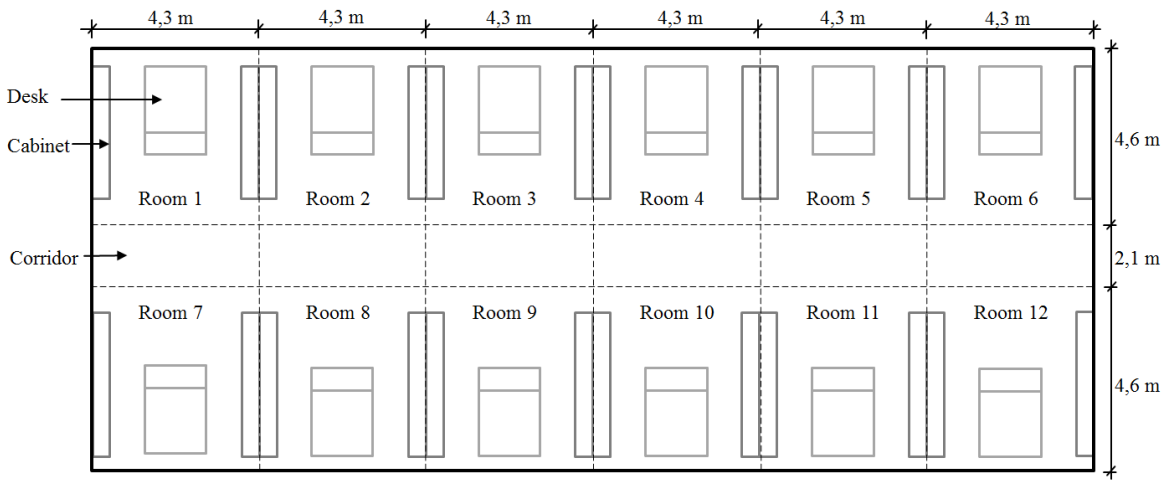


Figure 1: Schema of 12 office rooms and load areas

The Fig. 1 presents the studied office rooms with corresponding load areas (inner are desks and outside are cabinets). Beside the long-time loads from furnishings the short-term loads, which occur by change round the facilities, are taken into account with a mean value of

μ = 0,41 kN/m² and standard deviation of σ = 0,48 kN/m² taken from (1). In Addition to the characteristic value of load, the load combination factor Ψ_2 for the quasi-permanent action combination is also determined. Through simulations a random load distribution analysis was carried out and the results were statistically evaluated. The Fig. 2 presents the characteristic load q_k and the load combination factor Ψ_2 depending on the considered area A_B.

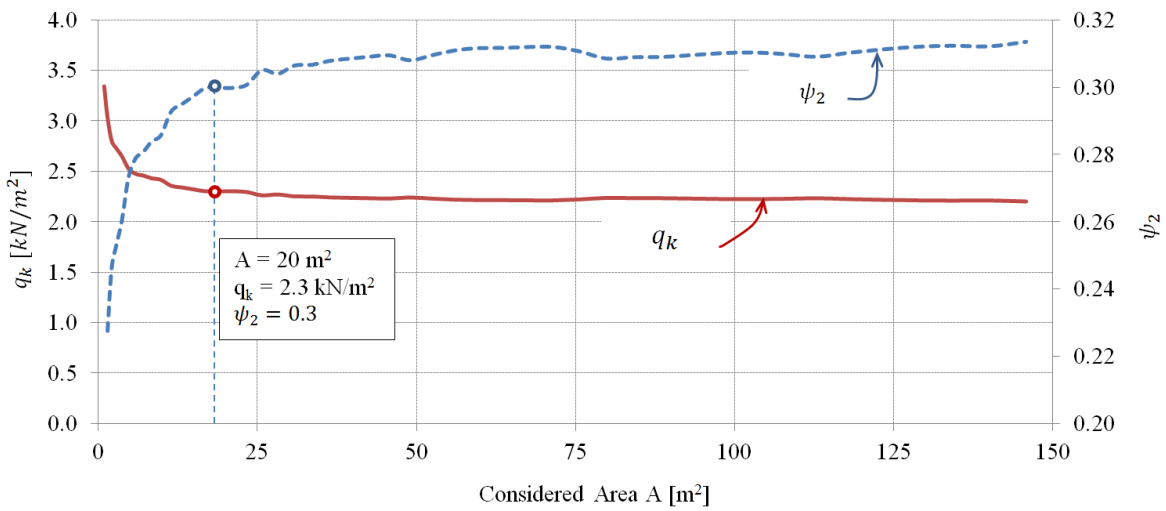


Figure 2: Characteristic distributed load q_k and load combination factor Ψ_2

The simulation results show that by a design area about 20 m² (1) the 98%- fractile value of load is q_k = 2,3 kN/m². In comparison to normative live load with the value of 2,0 kN/m² the simulated load is higher by a factor of 1,15. The increased office loads are due to the predominant use in research and teaching. Decisive for this are mainly heavy books, large amounts of files as well as high frequent and large gatherings of personal groups such as students. The normative combination factor Ψ_2 = 0,3 according to DIN EN 1990/NA for offices is confirmed by the simulation. In summary, it should be noted that the type of office uses significantly affects the live load. The results of load simulations for e.g. a university office lead to exceeding the normative load.

(1) Spaethe, G. (1992): Die Sicherheit tragender Baukonstruktionen, Springer-Verlag.

SHEAR STRENGTH OF REINFORCED CONCRETE CIRCULAR CROSS-SECTION ELEMENTS WITHOUT STIRRUPS

Ngoc Linh Tran

This paper presents an enhancement of the shear model, which was first introduced in (1) and (2), for reinforced concrete elements with circular section. In this developed calculation model the shear force is considered in compression zone and tensile zone of the section (see Fig. 1). To calculate the shear strength the neutral line of the section and the curvature of the member at the critical position $a_{crit.}$ are iteratively determined. This can be described through axial force and moment. It considered also the geometry, load position, elastic modulus of concrete E_c and steel E_s, reinforcement ratio $\rho = A_s/A_c$ and the tensile strength of concrete f_{ct}. For simplification, the reinforcement rods are here modelled as a steel ring with equivalent area, which can be described through parameters r_1 and r_2.

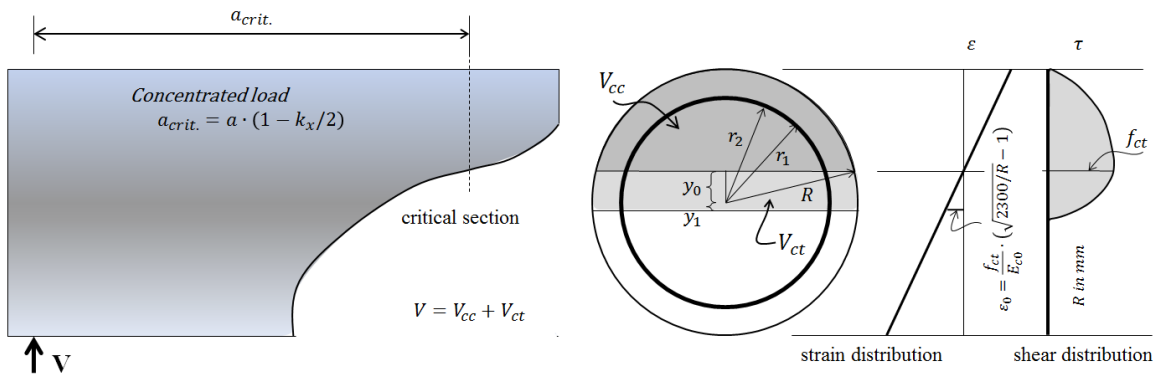


Figure 1: Shear model

The position of the neutral line, which is described through parameter $\gamma_0 = y_0/R$, is determined by solving the following equation. Here $n_e = E_s/E_c$ and $\sigma_N = N/A_c$.

$$\rho n_e \pi \gamma_0 = -\frac{\pi}{2}\gamma_0 + \gamma_0 arcsin(\gamma_0) + \frac{\sqrt{1-\gamma_0^2}}{3}(2+\gamma_0^2) + \frac{\sigma_N}{\kappa E_c}\pi \qquad \text{(a)}$$

Through moment $M = V \cdot a_{crit.} + N \cdot e$ the curvature κ at the critical position is calculated as following:

$$\kappa = \frac{12M}{E_c\left\{R^4\left(\frac{3\pi}{2} - 3\arcsin(\gamma_0) + \gamma_0\sqrt{1-\gamma_0^2}(2\gamma_0^2 - 5)\right) + 3\pi n_e(r_1^4 - r_2^4)\right\}} \tag{b}$$

The shear strength parts in the compression zone and the tensile zone are calculated according to equation (c) and equation (d). In the equation $\gamma_1 = y_1/R = (y_0 - \varepsilon_0/\kappa)/R$ describes the foot of the effective shear stress distribution in the tensile zone (see Fig. 1).

$$V_{cc} = \frac{R^4 f_{ct}}{12(R-y_0)^2}\left(\frac{15\pi}{2} - 15arcsin(\gamma_0) - \sqrt{1-\gamma_0^2}(6\gamma_0^3 - 16\gamma_0^2 + 9\gamma_0 + 16)\right) \tag{c}$$

$$V_{ct} = \frac{3R^2 f_{ct}}{4}\left(\arcsin(2\gamma_0 - 1) - \arcsin(2\gamma_1 - 1) + (4\gamma_0 - 2)\sqrt{\gamma_0 - \gamma_0^2} - (4\gamma_1 - 2)\sqrt{\gamma_1 - \gamma_1^2}\right) \tag{d}$$

To validate the new shear model 44 shear tests taken from literature (3) with a/D from 2,3 to 4,2 and D from 200 mm to 500 mm as well as ρ from 2% to 7% are recalculated. By 31 elements without axial force the mean value of the model uncertainty is $\theta_m = V_{exp.}/V_{cal.} = 1{,}13$ with the variance coefficient is $v_m = 0{,}12$. By 13 elements with normal force these values are $\theta_m = 1{,}04$ and $v_m = 0{,}09$. The evaluation with all of the tests shows a mean value of the model uncertainty $\theta_m = 1{,}10$ and a variance coefficient $v_m = 0{,}12$. These results show that the developed shear model is appropriate not only for the elements with rectangular sections but also for the elements with circular sections.

(1) Tran, N.L. ; Kohoutek, J.; Graubner, C.A.: Querkrafttragfähigkeit von Stahlbetonbauteilen ohne Querkraftbewehrung, Beton- und Stahlbetonbau 110 (2015), Heft 4.

(2) Tran, N.L. ; Graubner, C.A.: Shear model for reinforced concrete members without stirrups, fib Symposium, Kopenhagen, Mai 2015.

(3) Bender, M.: Zum Querkrafttragverhalten von Stahlbetonbauteilen mit Kreisquerschnitt, Dissertation, Ruhr-Universität Bochum, 2009.

C^3 – CARBON CONCRETE COMPOSITE

Peter Ramge, Carl-Alexander Graubner

The current research project "C^3 – Carbon Concrete Composite" which is coordinated by the TU Dresden is a long-term project funded by the German Federal Ministry of Education and Research. The major task aimed by the initiators is to develop the technique of carbon textile reinforced concrete to such an extent, that 20% of steel reinforced concrete can be substituted by carbon fiber reinforced concrete in the future. Besides the technical challenge to make the niche product carbon concrete fit for mass usage, one of the main obstacles that have to be mastered is to gain the acceptance of this new building material amongst the users in construction practice.

The main advantage of carbon concrete is seen in a drastic mass reduction. The tensile strength of carbon fibres is up to six times higher than of usual reinforcement steel and the material itself weighs about four times less than steel. Thus the required mass of reinforcement material for a specified task can be reduced significantly compared to usual reinforcement steel. Furthermore the carbon fiber is not in need of a protective alkaline milieu. Likewise the necessary concrete cover is solely determined by the needs of the force transmission and the mechanical bond conditions. Compared to ordinary reinforced concrete much finer and thinner walled construction elements can be produced by using carbon concrete. For an optimized utilization of the advantages of the carbon fiber, the concrete matrix has to be optimized as well for such thinly walled construction elements with rather close-meshed reinforcement. In this respect the adaption of the workability and the fresh concrete properties have to be considered as well as the adjustment of the hardened concrete properties to the properties of the carbon fiber.

For this purpose the Institute of Concrete and Masonry Structures (IfM) of the TU Darmstadt is involved in the project. The subproject of the IfM is split into two parts. In one part the shrinkage behavior is investigated while in the other part the focus lies on the life cycle assessment. About 5 % of the carbon dioxide emission worldwide is caused by the cement production. The life cycle assessment of ordinary concrete reveals that 95 % of the related global worming potential (GWP) is caused by the cement contained in the concrete mixture. One quite effective way to reduce the negative ecological impact of concrete construction in general is therefore to maximise the efficiency of the used cement clinker. By increasing the efficiency of the cement in a given mixture, the amount of cement needed per volume unit to achieve the aimed properties can be reduced. This strategy of eco-friendly concrete is successfully promoted by the IfM since many years. The know-how gathered on this subject can now be ideally applied in the development of the concrete matrices for the C^3-research project. Compared to steel reinforced eco-friendly, additional savings regarding the ecological impacts, especially in GWP can be achieved. In carbon concrete no alkaline milieu has to be maintained to protect the reinforcement, therefore no minimal cement content to ensure the carbonation resistance is needed. Due to the possibility of producing thinly walled filigree elements further possible savings exist regarding the mass reduction of the used materials. However, because of the following reasons a minimum cement content will still be required: To utilize the high strength of the carbon fibres the strength values of the concrete matrices tend to higher values than used in average civil engineering and there are other durability requirements that, unlike the carbonation resistance, still have to be considered also for carbon concrete, for example requirements regarding the frost resistance. To consider all these partly contradictive aspects regarding the ecological impacts during the process of a mixture optimisation, the method of life cycle assessment is a useful tool. However, the accounting must not be done solely per cubic meter of concrete or by mass. The assessment has rather to be done by evaluating complete construction elements of equal functionality.

PREDICTION MODEL FOR THE CARBONATION DEPTH OF CLINKER-REDUCED CONCRETE

Stefan Hainer, Tilo Proske

Concrete is the most important mass building material of our time, about 12 billion cubic meters of concrete are produced worldwide annually. The production of the cement contained in the concrete is responsible for approximately 5-8% of global greenhouse gas emissions. For the production of one ton Portland cement clinker approximately 700 kg of CO_2 are released. Decreasing the clinker content in cement usually leads to a reduced carbonation resistance of concrete. The development of clinker reduced and therefore environmentally friendly concrete can be promoted by prediction models for durability relevant concrete properties. Existing prediction models for the carbonation depth are not suitable for concretes containing ecologically beneficial main constituents such as limestone and granulated blast furnace slag or concretes with low water-cement ratios. To respond this, an easy applicable model for the prediction of the carbonation depth of clinker reduced concrete was developed (1). The new developed model takes into account two integral input parameters that influence the carbonation depth: the amount of carbonatable components and the density of the concrete structure. As a characteristic value for the carbonatable components the buffer of calcium hydroxide ($Ca(OH)_2$) was calculated using the molecular weight ratios of the hydration equations minus the quantity of calcium hydroxide that is consumed by pozzolanic reactions. The structural density of the concrete is simplified estimated by the water vapor diffusion resistance μ_n which can be determined as a function of the cement composition and the water-cement ratio. Equation (a) can be applied for the prediction of the carbonation depth. The exponents (b_1, b_2) and coefficients (c_1, c_2) were calibrated using the results of extensive experimental investigations. The correlation between the predicted and measured carbonation depth after

one year storage under standard conditions (20°C, 65% r. F., 0.04 Vol.-% CO_2) is shown in Figure 1. The developed model is able to predict the carbonation depths of the investigated concretes quite good, independent of the cement composition and the w/c-ratio.

$$x_{c,NAC365d} = \frac{1}{\left(Ca\left(OH\right)_2\right)^{b_1} \cdot \mu_n^{\,b_2}} \cdot c_1 - c_2 \qquad \text{(a)}$$

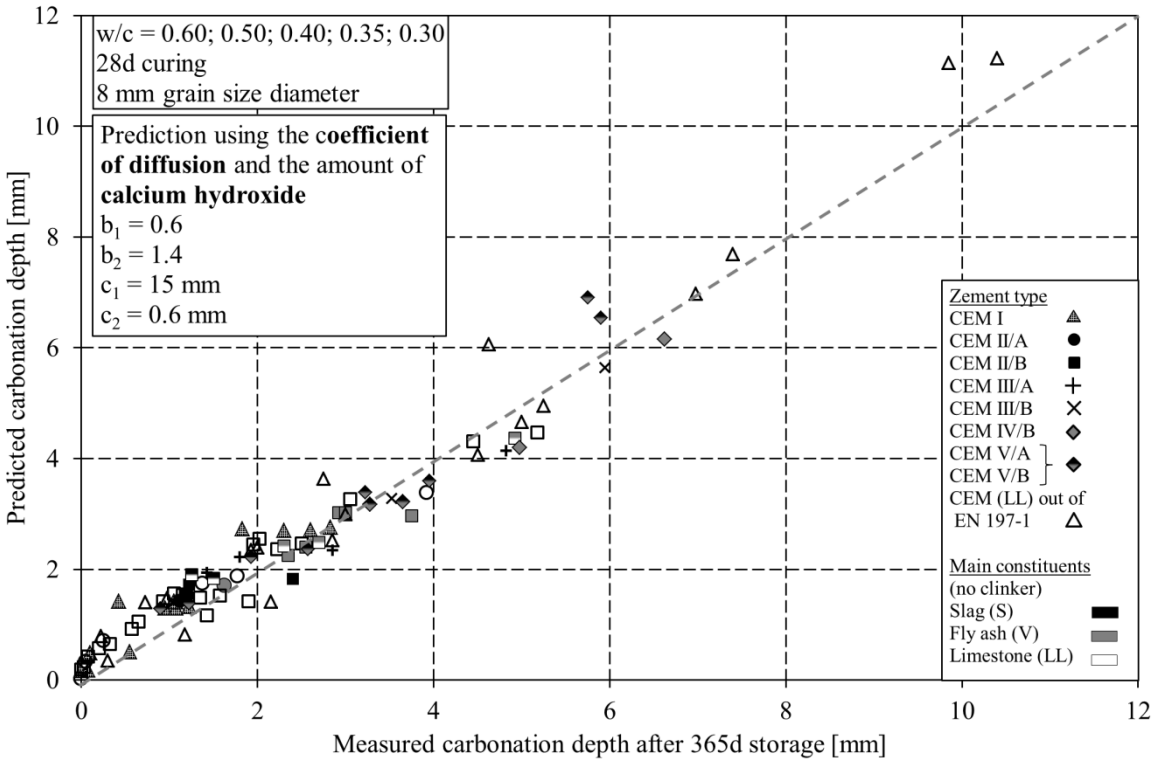


Figure 1: Comparison of measured and predicted carbonation depths

(1) Hainer, S.: Karbonatisierungsverhalten von Betonen unter Einbeziehung klinker-reduzierter Zusammensetzungen - Ein Modell zur Abschätzung des Karbonatisierungsfortschrittes. Dissertation, Institut für Massivbau, Technische Universität Darmstadt, 2015.

CONCRETES MADE OF CLINKER-REDUCED CEMENTS WITH LIMESTONE POWDER AND GROUND BLAST FURNACE SLAG

Moien Rezvani, Tilo Proske, Carl-Alexander Graubner

Within the joint project with Spenner Cement Co. and German Cement Work Association (VDZ) entitled as „Reduction of environmental impact of construction through new ground blast furnace slag (GBFS)-based cements and thereof concretes„ cements with low amount of Portland cement clinker and a high limestone and GBFS contents were developed and tested. Furthermore, the applicability of concretes made of such cements in both laboratory and practical scales is examined. Due to significant reduction of Portland cement clinker (up to 20 wt.-%) in such multi-composite cements, structural concretes with sufficient mechanical and durability properties cannot be achieved by applying conventional water-cement-ratios. Therefore, application of such resource efficient cements with reduced environmental impacts is possible only under a modified concrete technology condition, e.g. reduced water-cement-ratios and optimized packing density of solid particles.

In the first test series of experiments, concretes from various cements with different limestone and GBFS contents were cast in a laboratory scale. The workability, compressive strength and the carbonation depth of concretes were tested. Analysis on the plastic viscosity of investigated concrete (conducted by means of ICAR concrete rheometer) revealed that the plastic viscosity increases remarkably by decreasing the water-cement-ratio. It was observed that the water-cement-ratio below 0.35 seems to be critical regarding to the workability aspects. The results of the compressive strength of fine-grain concretes made of different cements with different water-cement-ratios are shown in Fig. 1.

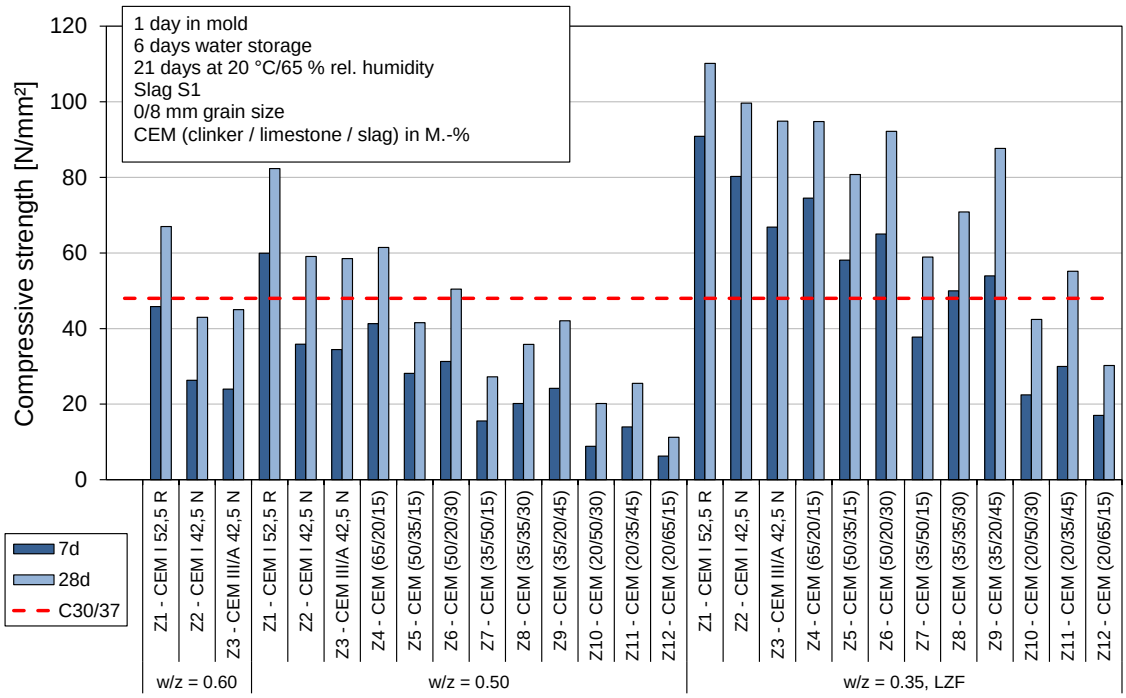


Figure 1: Compressive strength of fine-grain concretes after 7 and 28 days

Fig. 1 evidences that the concrete compressive strength reduces by reduction of clinker content. However, a positive influence of GBFS on the compressive strength was observed whereas the influence of $(CaO+MgO)/SiO_2$-ratio of GBFS on both 7 d and 28 d compressive strength was also remarkable.

It is concluded that through decrease in water-cement-ratio, the compressive strength of concretes with very low Portland cement clinker content can be significantly increased, whereas the workability became worse. Fine-grain concretes with cement composed of only 20 wt.-% Portland cement clinker content and 50 wt.-% limestone powder with a reduced water-cement-ratio of 0.35 could reach a compressive strength more than 40 N/mm² after 28 days.

DRYING SHRINKAGE OF CEMENT PASTE MADE OF LIMESTONE-RICH CEMENTS

Moien Rezvani, Tilo Proske

It is well agreed that a reduction Portland cement clinker demand in concrete can lead to a minimization of CO_2-emmision. Therefore, cements with high amount of limestone up to 70 wt.-% are developed within last few years. The reduced Portland cement clinker and water content as well as an increased packing density influence the meso- and microstructure of cementitious matrix which can influence the macroscopic hygral deformations.

Within this study, the drying shrinkage of hardened cement pastes (HCP) made of cements with high limestone contents was experimentally investigated. Thin HCP prisms (10×40×160 mm³) with different limestone contents of 0, 30, 50 and 70 wt.-% were cast in accordance to EN 196-1. Besides, the w/c-ratio and the type of limestone (LL1 to LL3) were varied. The specimens were demolded after 1 day and were stored in water for next 6 days. At the age of 7 days the specimens were removed from water and stored in climate chamber at 20 °C and a relative humidity of 65 %. The measurements were conducted by means of a mechanical extensometer.

Comparison of the shrinkage deformation of reference HCPs made of 100 wt.-% CEM I 52,5 R with different w/c-ratios shows that the shrinkage strain of samples increases by increasing the w/c-ratio (Fig. 1-(left)). Moreover, it evidences that the higher contents of limestone LL1 result in a lower shrinkage deformation. This can be explained by the lower gel content in limestone-rich systems and the restraining effect of limestone particles against shrinkage deformation of C-S-H particles. Fig. 1-(right) reveals the significant difference in shrinkage values for different limestones. It is obvious that the

HCP made of limestone LL3 exhibits a larger shrinks about twice than that made of limestone LL1, although they exhibit similar water desorption behavior [1]. It can be suggested that the hygral shrinkage deformation of HCPs with high limestone contents can be influenced by the presence of clay minerals and higher alkali content. This can be indirectly concluded by comparing their methylene blue values (measured after EN 933-9).

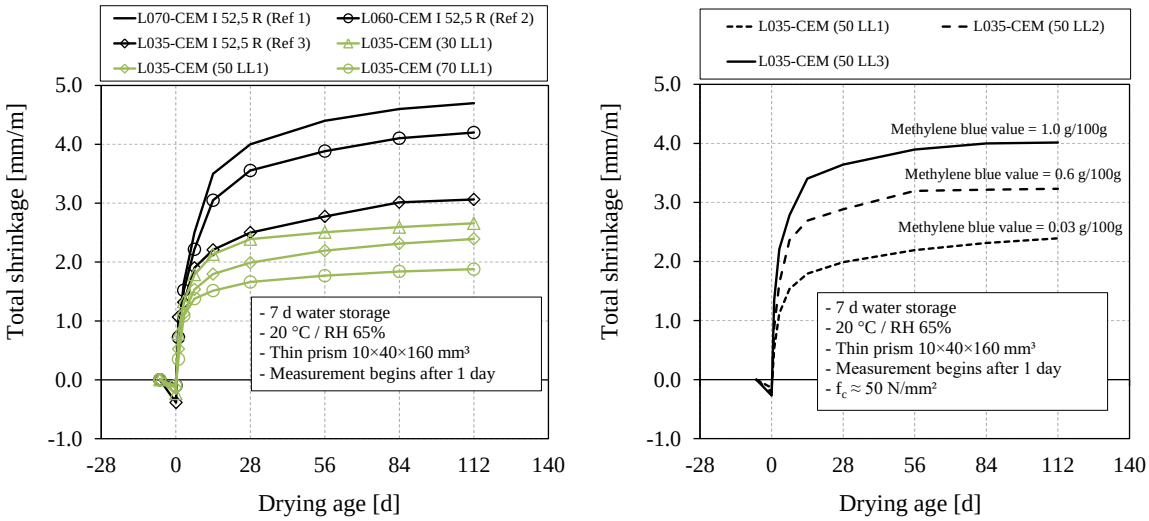


Figure 1: Shrinkage deformation of hardened cement pastes

A reason for that can be the strong swelling behavior of ton minerals. During mixing and fresh states the total disjoining pressure of cementitious gel increases additionally through repulsive hydraulic forces between clay particles. This results later during drying process to a higher shrinkage when the interlayer water between gel and clay particles is evaporated. In further experiments, the influence of relative humidity and the alkali content of limestone powder of cement on the shrinkage deformation of hardened cement pastes will be investigated.

(1) Rezvani, M.; Proske, T.; Graubner, C.-A.: Shrinkage of mortar samples made of limestone-rich cements. In: Proceedings of "Mechanics and physics of creep, shrinkage, and durability of concrete and concrete structures, CONCREEP-10, Wien, 2015.

INTERDISCIPLINARY OPTIMIZATION OF ENERGETIC RENOVATIONS IN HOUSING

Gerd Simsch

The interdisciplinary research project (1), performed by the Institute of Concrete and Masonry Structures and the Department of Real Estate Management and Construction Management, aims by a change of perspective and interdisciplinary approaches in evaluation to increase the sustainability and efficiency of energy renovation and refurbishment rate of current status less than one percent to more than two percent in short, medium and long term.

On the one hand first concepts of decision-oriented economic calculations were developed from the project view towards the perspective of real-estate sector stakeholders. On the other hand, general approaches to increase the profitability of energetic building renovations at the levels of individual projects and political strategy approaches have been identified.

In a closely coordinated iterative process jointly remediation strategies were developed by the two project partners and their effects were evaluated in terms of the marginal costs for final energy savings and the Global Warming Potential use under defined conditions. In the interdisciplinary cooperation in particular those instruments were identified, which make a particularly large contribution to climate protection, taking into account ecological, economic and technical effects in terms of cost-benefit efficiency.

On the basis of different remediation strategies, based on selected case studies, the most efficient measures from the perspective of the actors and displayed exemplary roadmaps

for renovating were identified. The research includes one family and multy family houses of different typologies of buildings.

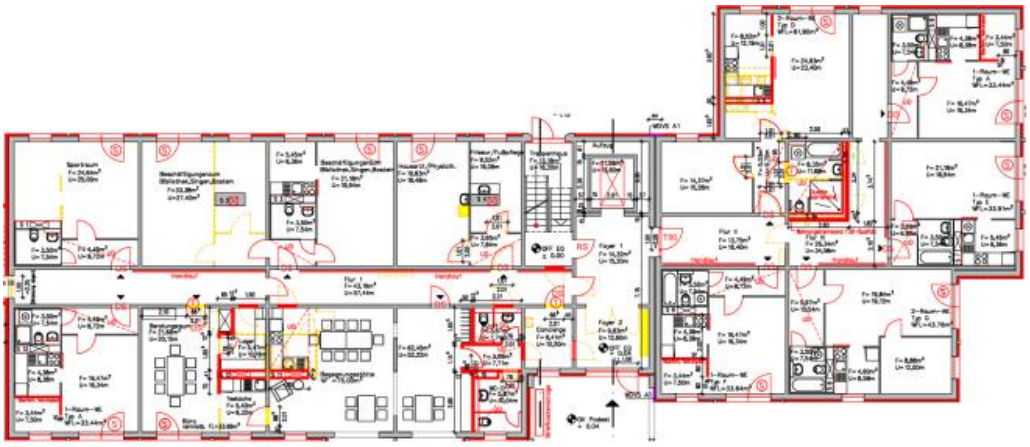


Figure 1: Example of a multy family house „MFH-age classification H“

Table 1: Parameters of the multy family house “MFH-age classification H“

year of construction	1988	exterior wall area	1857.29m²
living space	2901.42m²	basement ceiling area	841.78m²
A/V-relation	0.29	steep roof area	841.78m²
numbers of storey	4	window area	591.08m²

The basic remediation variations are oriented by the requirements of law, guidelines and sponsorship. In the cases of EnEV and KfW, the percental limits relating to the existing building in reference configuration of the EnEV 2014.

The project also provides first evidence for an adjustment of political approaches of support and challenge, and thus a basis for political implications.

(1) Pfnür, A., Simsch, G.; Müller, N.; Bewersdorff, D.: Entwicklung systemischer Instrumente zur Nachhaltigkeitsbewertung energetischer Gebäudesanierungen. Forschungsbericht Forum Interdisziplinäre Forschung. Darmstadt 2015

ASSESSMENT OF THE EFFICIENT RESOURCE USE IN THE BUILDING SECTOR

Katharina Fritz, Carl-Alexander Graubner

Commonly the discussion about resource efficiency or the efficient use of resources is reduced to a unilateral consideration of raw materials and their quantity. The German Resource Efficiency Programme (ProgRess) employs the indicator raw material productivity, which is defined by the ratio of gross domestic product to used abiotic primary material and consequently is also focused on selected raw materials only. To implement a holistic view, a lot of additional resources besides the raw materials have to be taken into account as well. Furthermore, the interactions of the different resources have to be considered, because a unilateral optimization of the use of a selected resource can lead to an adverse effect for another resource. These interactions can be demonstrated by the example of energy renovations of existing buildings, which is a current topic on many political agendas. Gaining energy savings in the building's operation phase by forcing the renovation rate is an objective of the Federal Government in Germany. Once again, the reduction of energy consumption is claimed unilateral, but an energy renovation of existing buildings always induces the use of other resources like raw materials for the production of insulating materials. Taking all this into account, the assessment of an efficient use of resources should be based on a wide resource definition, which includes all natural resources and additionally economic resources. The assessment should be able to address the interactions between the resources and subsequently force an optimization of the overall resource use.

Considering these findings, within the scope of a research project an evaluation method for resource efficiency in the building sector was developed by the Institute of Concrete and Masonry Structures. The evaluation method contains quantitative criteria and indicators

that enable everybody to evaluate the sectoral resource efficiency in a holistic perspective. The method is based on a broad resource definition that contains the natural resources raw materials, land and soils, water, air, energy and biodiversity plus the economic resources capital, labour and time. The appropriate criteria operationalize the protective targets, which have been defined for resource efficiency in the building sector. The indicators of the individual criteria could be evaluated by using data provided by official statistics or comparable sources. It is important, that the method is developed for a sectoral evaluation and accordingly the perspective is the whole value chain of the building sector, not only a single building or a single infrastructure element. Nevertheless it is possible to create recommendations for actions on single buildings or infrastructure elements using the findings of the assessment of the resource efficiency of the whole building sector.

To calculate an aggregated key figure for resource efficiency in the building sector it is necessary to assign the individual criteria to effort and benefit respectively. Besides the key figure the results of the individual criteria are additionally shown in a dashboard in order to ensure the transparency and the traceability for the stakeholders. In general, the developed evaluation method can be applied in practice, but the provision of data by the official statistics is a current hindrance. The data of the official statistics is structured by the national classification of economic activities. Due to this classification the collection of the required data for the use of resources in the value chain of the building sector is not as easy as initially expected. For example, the production of all metal products is summarized in one section, therefore it is not possible to divide the production of metal products into different economic sectors like the building sector and the value chains of other sectors. This hindrance should be overcome prospectively to assess the value chain of the whole building sector with the new evaluation method. This is important to increase the practical relevance of the evaluation method for resource efficiency in the building sector.

PROPOSAL FOR THE CATEGORIZATION OF CLIMATE-NEUTRAL BUILDINGS

Achim Knauff

Specialized media report on climate-neutral buildings since a couple of years now. But indeed interpretations of what represents a climate-neutral building differ. The climate-neutral character of a building can be given by the building construction itself (i.e. the building material and all related construction processes) or by the covered energy demand needed during the utilisation phase. In case the climate-neutral character of a building is given by the covered energy demand, it has to be defined, what is taken into account to obtain climate neutrality: i) are only certain room conditioning measures taken into account or ii) is the entire energy demand taken into account. Therefore, without giving a reference, it is not clear what is meant by just using the term “climate-neutral building”.

Compensation Measures / Type of Energy Demand	Purchase of Climate-Neutral Energy or CO_2 Certificates	Self-Sufficiency with Interaction with the Public Energy Infrastructure	Self-Sufficiency without Interaction with the Public Energy Infrastructure
Room Conditioning Measures EnEV	I	II	-
Operation of Building	I	II+	-
Operation of Building and Utilisation	I	II++	III
Construction of Building	I	IV	VI
Life Cycle of Building	I	V	VII

Table 1: Categorization of climate-neutral buildings by using a matrix-based approach

Table 1 proposes the categorization of climate-neutral buildings depending on the type of energy demand and the respective compensation measure. The “Room Conditioning Measures EnEV” comprise the energy demand for heating, ventilation, cooling, hot water supply and the lighting according to the German Energieeinsparverordnung (EnEV). The „Operation of Building“ reaches beyond the room conditioning measures and comprises

additionally the energy demand for the entire building services engineering (including transport technology, sanitary engineering, etc.). The “Utilisation” can be clearly separated from the “Operation of Building” and comprises solely the energy demand of the user(s) of the respective building (like workplace devices and catering). Beyond the previously stated types of energy demand, a significant proportion of energy consumption of a building is used by the “Construction of Building” (building material, transport processes, building construction itself and dismantling processes). The “Life Cycle of Building” comprises the energy demand during the utilisation phase as well as energy needed during the building construction. The matrix shown in Table 1 also contains the differentiation of the compensation measures. The “Purchase of Climate-Neutral Energy or CO_2 Certificates” are object-independent compensation measures. “Self-Sufficiency with Interaction with the Public Energy Infrastructure” is an object-specific designed generator system, which e.g. has the capability to compensate the fluctuating energy generation of renewable energy together with the public electricity grid. The “Self-Sufficiency without Interaction with the Public Energy Infrastructure” represents exclusively the isolated application instead.

The categorization of climate-neutral buildings is made according to the level of difficulty of reaching the respective category. Object-independent compensation measures are rated as “category I” in general, since they can be implemented without taking the energy efficiency into account. Hence these measures offer no further incentives in case of an optimization. If self-sufficiency of a building is given it is rated at least as “category II”. Depending on the scaling of the generator systems (and therefore depending on the energy demand which can be covered) a revaluation is done to either “category II+” or “category II++”. Self-sufficient buildings without any interaction with the public energy infrastructure must be rated as “category III”, because the own load management for securing permanent supply represents an additional level of difficulty. As soon as the building construction itself is taken into account, the respective building must be classified within the categorization range of “category IV to VII”. In such a case further evaluation is needed, for example the type of production processes of the building materials.

REFLECTIONS ON A SYSTEM OF INDICATORS FOR THE CONSTRUCTION LOGISTICS

André Tischer

The construction logistics focuses on the optimal and efficient planning, management and support of organizational tasks within the construction process. A key success factor for an optimally configured construction logistics is the early and proper planning of logistics processes. This requires information, which makes it possible to draw up an objective-oriented planning of construction logistics needs to optimally and project-specifically distribute logistical resources and capacities on construction sites. These include, for example, the determination of required construction logistics personnel, necessary logistical materials and equipment, or to be provided space for warehousing and material handling areas.

An important prerequisite for fulfilling this task is the secure and optimal requirement planning of construction logistics issues. However, and despite the information supplied by the client of a construction project, the problem is that the logistics demand is difficult to calculate or even unpredictable. Since very few provision and processing of information there is a lack of an appropriate planning of key parameters for the construction logistics, such as the estimation of the expected material deliveries to construction site or the amount of waste to be disposed from site. For this, an appropriate system of indicators for the construction logistics can find remedy, which provides for the logistics planning prepared information of already completed and similar construction projects.

For the preparation and implementation of a system of indicators for the construction logistics two major motivation strands can be identified. Firstly, it is essential for an optimal logistics planning, through retrieving project related master data, such as “gross

floor area”, “construction schedules” or “site plans”, to get detailed information about the logistics of a construction project by the client. Only thus, an optimal planning of the logistics demand, needed resources and capacity can be ensured. Here, it is important that from completed construction projects past values are provided, which give information about the expected material flows for a construction project; since only information to the values of parameters, such as the expected "number of material deliveries per project period" or the anticipated "total waste volumes per project period" can secure an appropriate demand forecast for logistics issues. Secondly, the logistics planning should be able to provide to the public an accurate forecast of the expected traffic flows and traffic-related burdens around the site of a construction project. Here, it must be ensured that the logistics can absorb traffic burdens around a site, by an optimally designed logistics concept for the expected material flows. To this end, the logistical needs and resources planning requires measures from a system of indicators at an early planning stage.

From the foregoing considerations it can be concluded that the preparation and implementation of a system of indicators for the logistics should be lead to the creation of an appropriate *construction logistics database system*. On the one hand, such a logistics database includes key figures as *input variables* of the database, which can be retrieved with minimal effort by the client of a construction project. These "*structural indicators*" are made up of parameters such as the "construction type", the "building type", the "gross floor area" or the "project volume" of a construction project. On the other hand, a construction logistics database includes key figures as *output variables* of the database, which provide main information of completed construction projects to the logistics planning. This is about "*planning indicators”*, such as the “total amount of to be disposed waste per square meter", or the "number of material deliveries per project phase" of a construction project.

The project-specific determination of construction logistic indicators by using an appropriate logistics database system can promote the optimal and right construction logistics demand, resource and capacity planning.

VALUATION OF FLEXIBILITY IN THE LIFE CYCLE COST CALCULATION

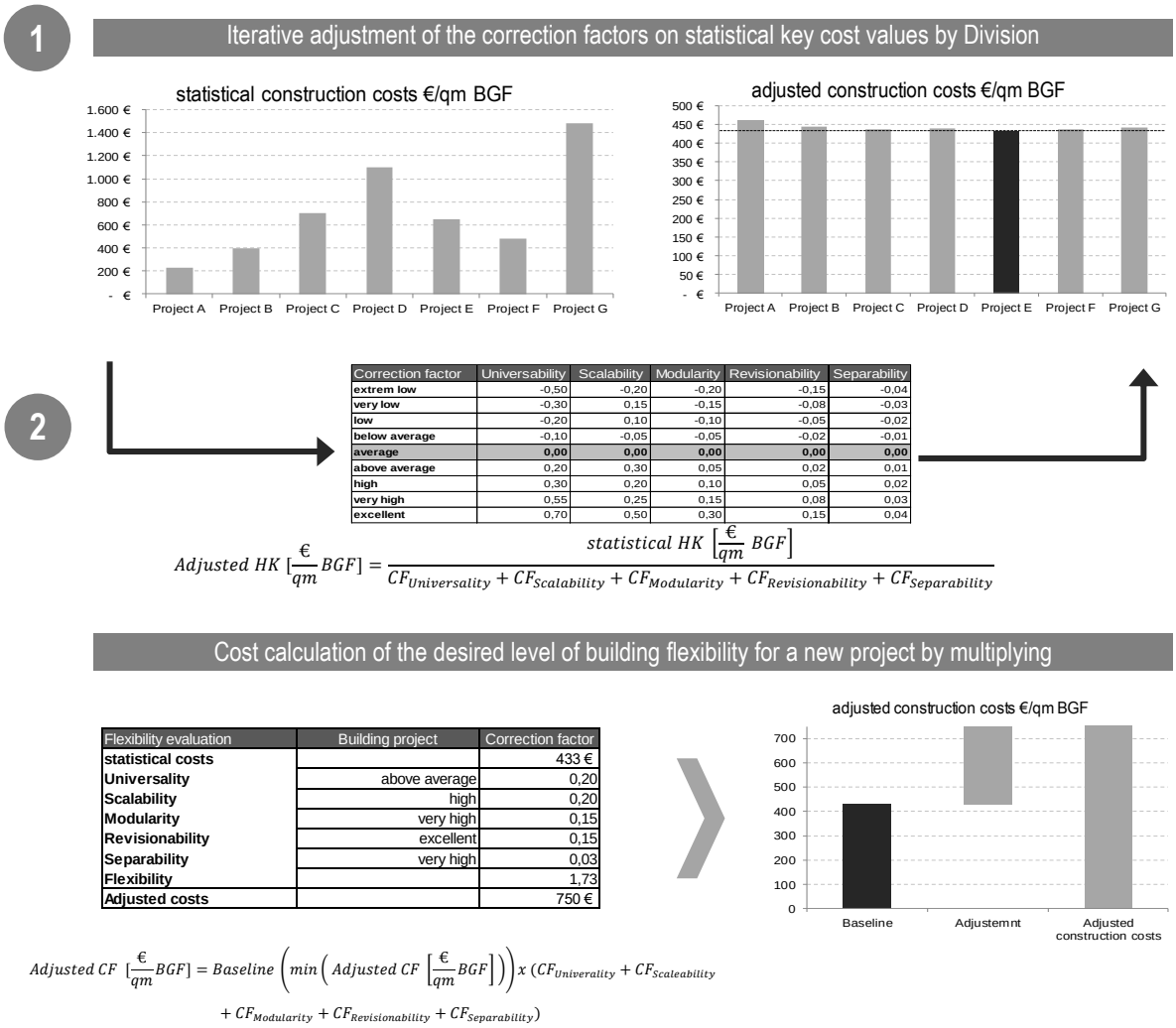
Gökhan Uysal, Carl-Alexander Graubner

In this present approach a method is developed to estimate robust correction factors. The method makes it possible to integrate the building flexibility in to the life cycle cost calculation of industrial Buildings. The main challenge with calculation models which works with factors is the valid evaluation of the altitude of correction factors. For example, this important topic is even in the relevant literature like the ISO 15686 not discussed, even though the altitude of the correction factor has the strongest influence on the calculation result of all parameters.

Since the impact of the cost driver building flexibility can just only hardly measured with conventional methods like the multiple regression analysis or the analytic hierarchy process method, a combined approach was necessary. The method works with a combination of statistics and expert evaluation. The calculation principle allows to determine and to validate correction factors by an iterative adjustment on existing statistical cost key values. In addition, it offers the possibility to integrate the desired level of flexibility in the life cycle cost calculation of future construction projects. The approach is structured in two calculation stages:

In the stage 1, the adjustment, the correction factors of flexibility drivers are estimated from experts with the AHP Method. The correction factors has to be iteratively adjusted (factor altitude and level of flexibility in the analyzed project) until all variances of the evaluated projects can be described by the correction factors to a given threshold value (e. g. + / - 5%). The result of the iterative adjustment is shown in the figure 1 under adjusted construction costs €/m² BGF. Based on the central limit theorem and the assumption that

costs have a normal distribution, all factors should be adjusted on at least 30 projects. After the robust adjustment of the factors, it is now possible, to calculate a new construction project in the stage 2. For this step an initial value is needed, which has to be multiplied with the correction factor for the level of building flexibility. For example the initial value can be the lowest (black bar in figure 1) or the average value of the corrected costs. Figure 1 gives an overview of the two-stage approach and the underlying calculation formulas.



Correction factor	Universability	Scalability	Modularity	Revisionability	Separability
extrem low	-0,50	-0,20	-0,20	-0,15	-0,04
very low	-0,30	0,15	-0,15	-0,08	-0,03
low	-0,20	0,10	-0,10	-0,05	-0,02
below average	-0,10	-0,05	-0,05	-0,02	-0,01
average	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**
above average	0,20	0,30	0,05	0,02	0,01
high	0,30	0,20	0,10	0,05	0,02
very high	0,55	0,25	0,15	0,08	0,03
excellent	0,70	0,50	0,30	0,15	0,04

$$Adjusted\ HK\ [\frac{€}{qm} BGF] = \frac{statistical\ HK\ \left[\frac{€}{qm}\ BGF\right]}{CF_{Universality} + CF_{Scalability} + CF_{Modularity} + CF_{Revisionability} + CF_{Separability}}$$

Flexibility evaluation	Building project	Correction factor
statistical costs		433 €
Universality	above average	0,20
Scalability	high	0,20
Modularity	very high	0,15
Revisionability	excellent	0,15
Separability	very high	0,03
Flexibility		1,73
Adjusted costs		750 €

$$Adjusted\ CF\ [\frac{€}{qm} BGF] = Baseline\left(min\left(Adjusted\ CF\ \left[\frac{€}{qm} BGF\right]\right)\right) x\ (CF_{Univerality} + CF_{Scaleability} + CF_{Modularity} + CF_{Revisionability} + CF_{Separability})$$

Figure 1: Calculation approach of determining correction factors for costs of building flexibility

LIFE CYCLE COSTING ANALYSIS OF A PLUS-ENERGY-BUILDING WITH ELECTRIC HEATING

Claudia Weißmann

Heating systems which are operated with electric energy were criticized to be inefficient in the past. However, if such a system is installed in a plus-energy-building, which produces more electricity than it consumes within one year, it might be energetically reasonable. This heating concept has been applied in a plus-energy-building in Lüneburg, which had been designed as a passive house (129 $m^2_{\text{Living Area}}$). Hence, it has a low heating demand of only 11 $kWh/m^2_{\text{Effective Area}}$.

The aim of the conducted analysis has been to test the economic quality of this building concept in installation and maintenance phase. Therefor the Life Cycle Costing (LCC) Analysis Methodology has been applied. The simplified approach of this methodology, developed by the German Sustainable Building Council (DGNB), has been adapted in order to compare the results with the DGNB benchmark for conventional buildings.

Regarding the energy balance of this building (see Fig. 1) the extreme production surplus in the summer season is remarkable (total yearly surplus of 7,300 kWh). However, the share of the direct used energy is very low. Only 30 % of the electric heating system demand is supplied by renewable energy. Likewise, the combination of photovoltaic system and electric heating is not ideal yet. Nevertheless, as the primary energy demand of 110.3 $kWh/m^2_{\text{Living Area}}$ is lower, than the required value defined by the German Passive House Institute (120 $kWh/m^2_{\text{Living Area}}$), the building can be classified as energy efficient regarding its total electricity demand.

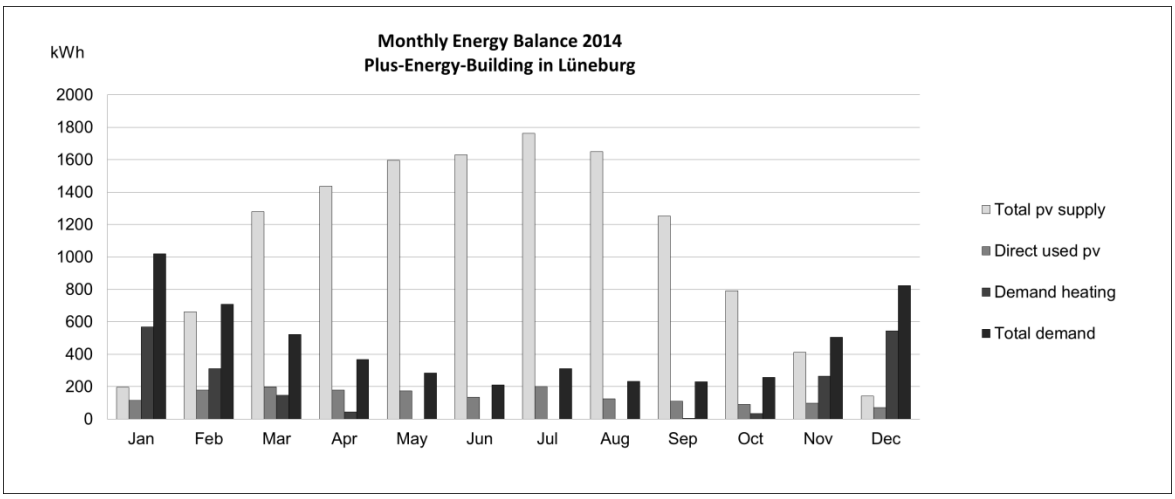


Figure 1: Monthly energy balance of the plus-energy-building in Lüneburg

The result of the LCC-analysis shows that the building accomplishes the minimal required value of the DGNB certificate and reaches 11 out of 100 points. Extending the scope of this analysis by implementing the earnings of the photovoltaic electricity feed-in tariff the result approaches the reference value of 50 points. This shows that the amount of produced electricity has a strong influence on the total result. Because of the high production costs (Fig. 2) there remains a big difference between the calculated Life Cycle Costs (2,390 €/$m^2_{LivingArea}$) and the target value of the DGNB-certificate (1,772 €/$m^2_{Wfl.}$) (Fig. 3). Even considering high feed-in tariffs (17.7 Cent/kWh, Commissioning in 2012) a high economic quality cannot be attested. Commissioning of the photovoltaic-system in 2015 would decline the result, as the feed-in tariff has sunk to only 11.97 Cent/kWh. According to EEG 2014 the building owner would have to pay an additional rate on the share of direct used electricity, as the installed photovoltaic capacity is greater than 10 kWp.

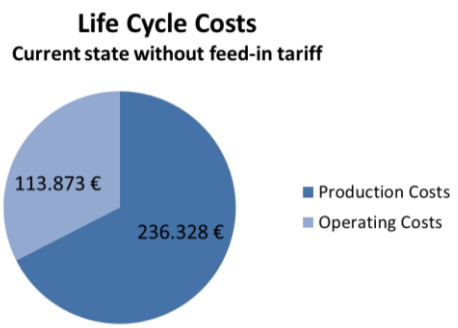


Figure 2: Life Cycle Costs over 50 years discounted to year 0

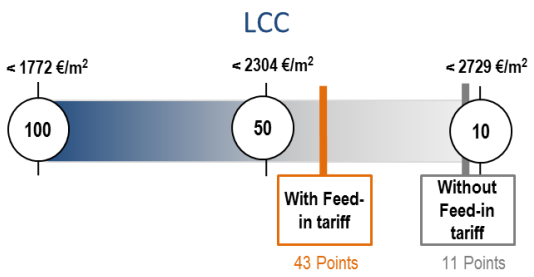


Figure 3: DGNB-Assessment

NEW CERTIFICATION SYSTEM FOR SUSTAINABILITY OF SECONDARY PROCESSES IN BUILDING CONSTRUCTION

Patrick Wörner, Fabian Staab, Sebastian Pohl

Buildings and structures contribute significantly to the overall economic net product and are of great importance as living and working environments (see 1). The processes of building construction make an existential and thus vital contribution towards creating a safe and comfortable built environment. At the same time construction sites pose a potential source of various negative global and local environmental impacts due to their original function as an open-air workplace. Neither a non-negligible level of energy consumption and emissions can be denied, nor the high amount of generated waste as well as certain noise and dust pollution. Furthermore, traffic jams and restrictions on the accessibility of public places are often the result of construction work. Many of these impacts can be ascribed to *secondary construction processes* which do not contribute to value creation and the final product of a building project, but rather have a supporting function. Corresponding optimisations in the context of sustainability are not only of social interest and needed due to legal requirements, but also serve as a starting point to increase efficiency and minimise cost.

The major national sustainability certification systems of the *Deutsches Gütesiegel Nachhaltiges Bauen (DGNB)* focus on buildings as the result of value-adding construction works. Non-value-adding, supporting secondary processes are in most cases explicitly excluded from the certification process or only part of rudimentary assessments and optimisations. Since the potential impact of secondary building processes on the sustainability of building construction can hardly be denied, the Institute of Concrete and

Masonry Structures, in cooperation with its spin-off LCEE Life Cycle Engineering Experts, designs a standardised certification system as part of the research initiative *Zukunft Bau*. The system closes the gap described above, enabling a complete review of construction activities in terms of their sustainability. For this purpose, it is substantial to develop a value system in which respective evaluation criteria can be derived from corresponding protective goals. These criteria are filled with quantitative indicators and qualitative checklists to evaluate sustainability in its entirety in a professional and impartial manner.

With regard to its content, the resulting system follows the popular "triple bottom line"-definition of sustainability, according to which sustainable development can only be achieved through simultaneous consideration of environmental, economic and socio-cultural objectives. Thus, the new system does not only aim for environmentally friendly designed building processes, but also covers studies on economic viability and the accomplishment of societal targets. The investigation of the environmental quality of construction processes includes not only assessments of their primary energy demand and emissions of greenhouse gases but also an analysis of the waste management on-site and measures to prevent impacts on soil and groundwater. For the purpose of economic optimisation cost and productivity are subject to further investigations. On the part of socio-cultural and functional quality issues of industrial safety, dust and noise protection as well as means to increase the efficiency and flexibility of construction process come to the fore. Finally, a forth kind of quality is assessed by considering organisational and personnel aspects of planning, tendering, procurement and management of secondary building processes.

(1) BMVBS (2013): Leitfaden Nachhaltiges Bauen. Bundesministerium für Verkehr, Bau und Stadtentwicklung, Berlin.

WHIT EXCURSION TO BERLIN

Benjamin Koob, Peter Ramge

Every year in the week after Whit, the joint excursion of the Institute of Concrete and Masonry Structures of the Technical University of Darmstadt and the Section of Concrete Structures and Structural Design of the Technical University of Kaiserslautern takes place. In this year, the destination of the excursion was Berlin and 43 students, four scientific assistants and three professors participated. From May 26th to May 29th the group visited a lot of interesting and curious construction sites on their way to and in Berlin

The excursion started punctually at 7^{30} h on Tuesday morning at the main railway station in Darmstadt, where the students of Darmstadt were collected by the students of Kaiserslautern by bus. Apart of the ride to Berlin, there were two stops in Würzburg and Grimma on the agenda. At the first stop in Würzburg we could visit the building of a new exercise hall for executive firefighter at the state firefighting school of Bavaria. In Grimma we focused on the rebuilt Pöppelmann bridge and the extensive precautions against flooding. On Wednesday there were several construction sites in Berlin waiting for the group. We started at the “50 Hertz”, an office block with twelve floors in which the pillars are inclined, then went on at the new bridge over the Spree in Treptow, which is built as truss out of steel and finished with the 16th construction section of the motorway A100. This section extends to about 3.2 kilometers and is built with basement floor and walls or with tunnels over its complete length. At the end of the day, we entered the roof of the Kollhoff-Tower at the Potsdamer Platz by a ride with the fastest elevator of Europe. The third day of the excursion was dominated by the ship lift in Niederfinow. After an extensive and very interesting guided tour on the construction site of and inside the new ship lift, the group took a boat trip including a lifting in the old ship lift. Back in Berlin, we

remembered the murdered Jews of Europe during a guided tour through the Holocaust Memorial, bevor we passed the last evening having dinner together. On our way back home, we stopped in Brehna and visited the factory of ArcelorMittal, where we got to know the producing of sandwich elements. Furthermore the students learned many things about the challenges concerning the building services if a hospital is to be built, when we stopped in Jena at the new building of the University hospital.

Figure 1: Picture of the participants from Darmstadt on the top of the ship lift

Looking back, the whole bandwidth from projects, which are still being planned, up to already completed buildings was covered. But also the cultural aspect was not missed out so that we had a healthy mix of all. We are very grateful for the financial support of the excursion through the „Verein der Freunde des Instituts für Massivbau der TU Darmstadt e.V." and we like to express hereby our sincere thanks again. The Whit excursion in 2016 is going to be planned by the Institute of Concrete and Masonry structures of the TU Darmstadt and will take place from May 17th to May 20th, 2016.

CONCRETE CANOE REGATTA 2015 – "CHAMÄLEON" WINS THIRD PRIZE IN THE CONSTRUCTION COMPETITION

Peter Ramge

From June 19th to 20th the 15th German Concrete Canoe Regatta took place in Brandenburg an der Havel on the Beetzsee. This year more than 1000 students and apprentices of 45 different institutions participated. Amongst them the team of the TU Darmstadt took part with their racing canoe "Chamäleon". The canoe was autonomously developed by the students from autumn 2014 onwards. The students neither came back on an existing formwork nor on a previous construction idea. This time the dominant design idea was the modularity. The canoe consists of several segmental elements, each one meter of length. The constant cross section of the middle part tapers continuously towards bow and stern, therefore a connecting element is needed between the middle part and the bow and stern elements. As the bow and stern elements are of equal shape, only three different formwork types are needed to produce all the segments for the canoe. Theoretically the length of the canoe can be extended on demand by adding further middle parts.

Figure 1: The concrete screws for the canoe: reinforcement (left), formwork (middle) and completed concrete screw with nut (right)

For the final assembling of the canoe the single segments, which are each equipped with tongue-and-groove joints, are firstly joined with concrete screws as shown in figure 1. The screws and nuts which consist of fine grained concrete were individually produced in self-made formworks. The full load-bearing capacity of the canoe is achieved by internal unbounded pre-stressing, wherefore a wire rope is fed through each of the upper edges and the keel.

This technically ambitious combination of screwed joints and internal pre-stress technique in conjunction with the accurate workmanship and the colour scheme made it possible for the TU Darmstadt team to win the third price in the construction competition. Like some other canoes of previous years, the “Chamäleon” can be admired at the campus “Lichtwiese” on the lawn between the new and the old civil engineering department building.

Figure 2: “Chamäleon” shortly before taking off to the regatta

On behalf of the whole team we would like to thank all the sponsors that supported us with donations in either money or kind. Especially the generous support of the “Verein der Freunde des Instituts für Massivbau der TU Darmstadt e.V.” is to be named in this regard.