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EDITORIAL AND REVIEW OF THE YEAR

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

At the turn of the year, this 31st issue of "Darmstadt Concrete" reports on the 2016 activities in research, teaching and committee work at our institute. In this editorial, we want to inform you about highlights, but also other developments in the last year. There is one obvious change that we need to address in particular: Starting with this issue, we have decided to release "Darmstadt Concrete" as an e-paper that is sent directly to you via e-mail. Thereby, we hope to provide an improved and likewise enjoyable reading experience for even more recipients.

At first, we would like to thank Dr.-Ing. Gerd Simsch who was a part-time professor in the field of sustainable construction in existing buildings at the Institute of Concrete and Masonry Structures from May 2013 to September 2016. For further information please see his farewell letter on page iv. On behalf of our Institute, we want to say thank you for his manifold support and the very productive cooperation in the last years. We wish Dr.-Ing. Simsch all the best and are grateful for his further support, in general and as a member of the Executive Board of the "Freundeverein".

In 2016, the Institute of Concrete and Masonry Structures organized two special events. On January 19th and 20th, the German Masonry Convention 2016 took place in collaboration with the German Society of Masonry and Domestic Construction. The topic "Affordable Housing" was discussed intensely in several top-class speeches. In the context of current housing shortage, this controversial issue was of particular interest among the participants. Another major event in this year was the "38. Darmstädter Massivbauseminar" on November 10th which was organized in cooperation with the "Freundeverein", the "Verband Beratender Ingenieure" (VBI) and the "Vereinigung der Prüfingenieure für Baustatik in Hessen e.V." (VPI Hessen). Under the slogan "Practice-oriented building codes", the participants were informed about current developments by the initiative PraxisRegelnBau (PRB), which supports practice-

oriented improvements of the Eurocodes. Further information to these two events and our other seminars can be found in our report section starting on page vii.

Regarding teaching activities, the institute offered a total of 12 lecture modules in 2016. In addition, more than 35 bachelor theses and over 30 master theses were supervised and completed. Currently, nearly 20 research projects are in progress. Furthermore, the Institute of Concrete and Masonry Structures has expanded its cooperation with international universities and research institutes. Two research assistants visited the Lawrence Berkely National Laboratory in Berkely, California respectively the Swiss Federal Laboratories for Materials Science and Technology (Empa) at ETH Zurich as guest researchers in the course of their dissertation projects. Moreover, six students have written their theses to cover a subject of sustainability certification of buildings at the Vietnam Green Building Council in Hanoi or the Panama Green Building Council in Panama City.

For Prof. Graubner it was a special privilege not only to be a member of the jury of the "1. Deutscher Ingenieurpreis" of BMUB, but also to be elected as the chairman of the jury. This gave him the opportunity to participate at the award ceremony in November 2016 and to hold the laudatory speech for the prize winner. Apart from that, Prof. Graubner acted as expert judge for the idea contest "B3 Südschnellweg" in Hannover, which was organized by the "Niedersächsische Landesbehörde für Straßenbau und Verkehr".

Aside from presenting what has been achieved, this end-of-year report also opens a chance to express our gratitude to our employees for their work and commitment. This year's achievements and success would have been impossible without the high quality and tireless work with which our scientists a well as our secretarial, technical and laboratory staff approach their tasks and projects. We congratulate Dr.-Ing. Achim Knauff who was able to finish his research project with the successful defense of his dissertation and welcome all new colleagues most heartily.

In order to allow you, dear friends and partners, the usual insight into our scientific work, you will find brief reports by our scientists on current research and development projects in both German and English.

Not least, we also would like to take this opportunity to thank the members of “Freunde des Instituts für Massivbau der TU Darmstadt e.V.”, whose support was crucial to realize some minor as well as some major measures at and for the Institute and its students. In particular, we would like to thank the chairman of the executive board Dr.-Ing. M. Six, the treasurer Dipl.-Ing. D. Hanek and the executive board members Dr.-Ing. K. Klemt-Albert, Dr.-Ing. G. Riegel and Dr.-Ing. G. Simsch, who constantly advise, encourage and generously support us in diverse ways.

This year’s achievements in research, the high attendance rate at our courses and our student’s commitment allow us to face future challenges with optimism.

On behalf of the entire Institute we wish you and your families peaceful and happy Christmas holidays and a good beginning for all your projects in the New Year.

Prof. Dr.-Ing. Carl-Alexander Graubner

Dr.-Ing. Tilo Proske

FAREWELL LETTER OF DR.-ING. GERD SIMSCH

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

With this 31st issue of "Darmstadt Concrete" I would like to inform you about my farewell as a professor of the Institute of Concrete and Masonry Structures and to express my gratitude. After the professorship has been set up on May 15th 2013 in a cooperation arrangement, my employment at TU Darmstadt as well as the professorship on sustainable construction design in existing buildings now ended on September 30th 2016. Since October 1st 2016 I am in the position of the head of business development at Dreßler Bau GmbH in Aschaffenburg. I will still support the Institute generally with my expertise and as a member of the executive board of the "Freundeverein".

Some words regarding the professorship: the focus was on the development of sustainable renovation methods in the field of solid construction whilst considering requirements of thermal comfort and building physics. It was top priority to teach the relevant technical and economic fundamentals as well as the expertise for the renovation of buildings in accordance with the sustainability concept. Following this goal, the lectures on sustainable constructions in existing buildings and on the basics of sustainability rating in the building sector were established, a research project on the development of a tool for the sustainability assessment of energy-oriented renovations was conducted and more than ten bachelor and master theses in this field were supervised. I was especially pleased to act as co-supervisor and member of the examination committee at six promotions at the Faculty of Civil and Environmental Engineering.

I would like to thank everybody who supported this professorship. I am very grateful for the warm and sincere welcome at the faculty, and of course for the manifold aid, in teaching and research as well as in setting up the new lectures.

My special thanks go to Prof. Motzko for his idea and promotion of my professorship and to Prof. Graubner, whose institute I was "appointed" to and where I was participating in many

interesting discussions. The institute also supported me in teaching and administrative issues. Here I want to mention particularly Mrs. Mohr and Ms. Weißmann.

Finally, I would like to wish you and your family a Merry Christmas and a Happy New Year and a good start to all your projects in the New Year.

Dr.-Ing. Gerd Simsch

COLLABORATION IN STANDARDIZATION COMMITTEES

In 2017, Prof. Graubner will continue his occupation as the chairman of the standardization committee NA 005-06-01 AA “Masonry Structures”, the leading national standards committee dealing with issues of standardization in the field of masonry structures. In this context, it should be mentioned that Prof. Graubner was elected as Vice Chairman of the Steering Board NABau Fachbereich 06 “Masonry Structures” in 2016. This board is the top level DIN standardization committee in the field of masonry structures and coordinates all national and international standardization activities. Prof. Graubner also acts as the German delegate on the European level and is member of the European standardization committees Scientific Committee 6 and Working Group 1 as well as of Project Team 2 in 2017. Furthermore, Prof. Graubner is Chairman of Project Group 5 of the initiative “Praxisgerechte Regelwerke im Bauwesen e.V.” Apart from that, he is elected member of standardization committee NA 005-07-01 AA “Design and Construction of Reinforced Concrete”. As a member of different expert groups, Prof. Graubner supports the German Center of Competence for Construction (DIBt) in Berlin.

Due to his high interest in the topic and his ongoing research activities regarding sustainable buildings, Prof. Graubner is counselling the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (round table “Sustainable Building”). Furthermore, he organizes the round table “Resource Efficiency in the Building Sector” of this Federal Ministry.

Following the aforementioned activities in the field of masonry structures, Prof. Graubner is editorial advisor for the journal “Mauerwerk” since 2012. Moreover, since 2016 he is author of the chapter “Masonry” in the well-known “Schneider Bautabellen” and he is editor and co-author of the book “Mauerwerksbau – Praxishandbuch für Tragwerksplaner”, which presents the newest developments in research and practice in the field of masonry structures.

Further on, Prof. Graubner is elected member of the university assembly of TU Darmstadt. In addition, he advices the “Förderinitiative Interdisziplinäre Forschung” at TU Darmstadt and is he representative expert of the “Graduate School of Energy Science and Engineering”.

SEMINARS AND EVENTS

Training seminar for structural engineers

The Institute of Concrete and Masonry Structures cordially invited engineering experts to the 2016 seminar series. Speakers from practise give 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 2016 gave an overview over the latest technical developments of civil engineering. In spring, the issues of welding and screw, corrosion of steel and concrete and special constructive issues were treated. In autumn, lectures were held about masonry, numerical examples for seismic design and updated regulations.

Due to the positive feedback from the past years, we will organise the seminar again in 2017. We are confident that the combination of interesting topics and renowned speakers will again attract many structural engineers. Below you find all six forthcoming seminars:

- Steel Composite Constructions – Numerical Examples | 15.02.2017
- Construction Errors and Structural Damages | 01.03.2017
- Dimensioning of Fastening Elements in Concrete Structures | 15.03.2017
- Tools for the Design of Concrete Structures | 13.09.2017
- Prestress in Structural Engineering – Numerical Examples | 27.09.2017
- New: “You ask, we answer” | 11.10.2017

Updates on the seminars, as well as the registration can be found on the homepage of the Institute of Concrete and Masonry Structures. (http://www.massivbau.tu-darmstadt.de/veranstaltungen_fgm/weiterbildungfrtragswerksplaner_fgm/index.de.jsp) In case of questions, please don’t hesitate to contact Mr. René Mazur, 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 2016. 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. Furthermore, stability considerations define a focal point with examples, such as lateral buckling and the design and construction of the connections. In this year, about 80 structural engineers and students participated in the event. The seminars were complemented by an exhibition of renowned manufactures of construction products related to the topic of precast construction.

In the upcoming year, the seminar series with top-notch papers, practical examples and our well-attended exhibition is going to celebrate its 10th anniversary. 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 expected to be discussed in the upcoming seminar series in spring 2017:

- Basic Principles of Planning | 16.03.2017
- Prefabricated Concrete Structures | 17.03.2017
- Fire Protection Requirements und Connections | 23.03.2017
- Concrete and Façade | 24.03.2017

Updates on the event can be found on the homepage of the Institute of Concrete and Masonry Structures. (http://www.massivbau.tu-darmstadt.de/veranstaltungen_fgm/darmstaedterbetonfertigteiltage_fgm/index.de.jsp) In case of questions, please don't hesitate to contact Mr. Redouan El Ghadioui, M.Sc.

German Masonry Convention 2016

In 2016, the 9th German Masonry Convention has taken place in Darmstadt on January 19th and 20th. It was 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. More than 200 participants followed the diversified and interesting agenda with well-known speakers in the range of politics, economy and science.

View of the field of participants at the 9th German Masonry Conference 2016

The German Masonry Convention was opened with the New Year's Reception of the German masonry industry at January 19th. After the 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 was awarded for the first time.

The prize-winner was Dr.-Ing. Ulf Schmidt, RWTH Aachen, with his dissertation concerning “Bruchmechanischer Beitrag zur Biegezugfestigkeit von Mauerwerk”.

The second day of the congress focused on affordable domestic construction. In several lectures the multi-story housing was regarded from different views and current developments were depicted. In any case, the central questions of urgent housing shortage and social domestic construction in Germany were discussed. Besides of constructive, creative and structural-physical aspects, political and social questions were illuminated as well. One of the highlights surely was the final lecture of Prof. Dr.-Ing. Thomas Jocher regarding the requirements on age-based living. Subsequent to the speeches as well as during the breaks, the Masonry Conference provided an ideal possibility for discussing with regards to content or to communicate individually with each other, what was actively used by the excited participants. Additionally, the technical exhibition with several corporations of the masonry industry found favor with the participants as well.

38th Darmstädter Massivbauseminar 2016 – “Practice-oriented building codes”

On November 10th 2016, the 38th edition of the Darmstädter Massivbauseminar took place on the “Lichtwiese” campus of Technische Universität Darmstadt. In the light of ongoing progress regarding building codes, this year's Massivbauseminar focused on the practice-oriented improvement of new standards in structural design. The seminar was hosted by “Freunde des Instituts für Massivbau der TU Darmstadt e.V.” in cooperation with “Verband Beratender Ingenieure” (VBI) and “Vereinigung der Prüfingenieure für Baustatik in Hessen e.V.” (VPI Hessen).

Under the slogan “Practice-oriented building codes”, the respective project group leaders of the initiative PraxisRegelnBau (PRB) presented concrete proposals for practical, simplified building standards and invited the attendees to exchange their experiences. Since its foundation in 2011, the PRB initiative has been developing suggestions for a user-friendly improvement of the Eurocodes. Even though these have been an important step towards a European standardization in structural design, the codes are sometimes too complicated and extensive for a practical application. Together with practitioners from engineering firms and construction companies as well as checking engineers for structural analysis and representatives of the construction industry’s umbrella associations, the initiative makes an essential contribution to the ongoing professionalization and simplification of national building codes.

After a consolidated introduction about the initiative’s activities by Dr.-Ing. Volker Cornelius, president of the VBI, the following speakers presented key findings and proposals from their respective field of expertise:

- Dr.-Ing. Eric Brehm: Basis of structural design and actions on structures (Project group 1)
- Prof. Dr.-Ing. Frank Fingerloos: Design of concrete structures (Project group 2)

- Dr.-Ing. Ines Prokop und Dr.-Ing. Johannes Naumes: Design of steel structures (Project group 3)
- Dipl.-Ing. (FH) Georg Keilholz: Design of timber structures (Project group 4)
- Prof. Dr.-Ing. Carl-Alexander Graubner: Design of masonry structures (Project group 5)
- Dr.-Ing. Bernd Schuppener: Geotechnical design (Project group 6)

The board of the association of "Freunde des Instituts für Massivbau der TU Darmstadt e.V." would like to thank the project group leaders of the PRB initiative, who volunteered as speakers for the 38th Darmstädter Massivbauseminar, as well as all participants for their high commitment, which significantly contributed to the event's success.

Dr.-Ing. Volker Cornelius presents the activities of the initiative PraxisregelnBau

EXCURSIONS

Site Excursion to the Rhine bridge construction site at Schierstein

On July 4th 2016, 22 students of the Institute of Concrete and Masonry Structures and their lecturer Mrs. Krieger met at the bridge construction site at Schierstein, where a steel composite bridge is being built. The excursion began with an introduction of the project by Mr. Stremmel of Hessen Mobil.

Bridge building site Schierstein

At the site, the students got an explanation of the works on the steel composite bridge as well as the corrosion-protection work and sealing work. This led to numerous interesting discussions and to intensive exchanges of views between students and scientific employees. We want to thank everybody for the support and the carrying out of the excursion. 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 Deutsche Bank Green Towers in Frankfurt a.M.

On November 27th 2015, 25 students of “Building Technology I” and “Facility Management & Sustainable Design” and 2 doctoral students of the Institute of Concrete and Masonry Structures visited “Deutsche Bank Greentowers” in Frankfurt a. M. The company headquarters of Deutsche Bank are certified for their green building and sustainability efforts under “LEED Existing Buildings Operations + Maintenance” on the platinum level and under the German DGNB system on the gold level.

As an introduction, some information on the renovation and sustainability strategy of the towers was presented to the participants of the study trip. Then, the students could take a look at the executive floor with the in-house television studio of Deutsche Bank and the so-called “green wall” – a wall covered with ivy and other plants. After that, the students went to the service floors where the central cooling facility with ice storage, a ventilation station and the systems for service water heating were shown and explained in detail. In particular, it was the complexity of these technical systems combined with their control and feedback control systems which left a lasting impression.

On behalf of all participants of this excursion, the Institute of Concrete and Masonry Structures would like to thank Mr. Dipl.-Ing. Thomas Heß for the organization of this event and his expert support during our visit.

PERSONAL MATTERS

Mrs. **Dipl.-Wirtsch.-Ing. Katharina Fritz** left the Institute of Concrete and Masonry Structures in late 2016 and is a project manager DB Netz AG in Frankfurt/Main from 2017 on. She plans to hand in her dissertation in 2017.

Mr. **Dipl.-Ing. Ulf Grziwa** left the Institute of Concrete and Masonry Structures in midyear 2016. He is now a constructional engineer at Kleinhofen + Schulenberg Beratende Ingenieure. Mr. Grziwa has handed in his dissertation at the PhD board in late 2016.

The employment of Mr. **Dipl.-Ing. Peter Ramge** ended in 2016 and since December 2016 he is working at the Federal Office for Economic Affairs and Export Control.

Mr. **Fabian Staab, M.Sc.** is leaving the Institute of Concrete and Masonry Structures with the end of 2016. From 2017 on, he will be working at GOLDBECK Südwest GmbH.




Dipl.-Wirtsch.-Ing. Katharina Fritz, Dipl.-Ing. Ulf Grziwa, Dipl.-Ing. Peter Ramge and Fabian Staab, M.Sc. (from left to right)

Mr. **Patrick Wörner, M.Sc.** is a doctoral student at the Institute of Concrete and Masonry Structures since April 1st, 2016. His position is connected to the research platform "Building Integration and Energy Self-Sustaining Settlement Areas" at the Darmstadt Graduate School of Excellence Energy Science and Enginieering. Mr. Wörner studied Civil Engineering and Business Administration at the Technische Universität Darmstadt and received his master's degree in January 2016. During his studies, the technical courses focused Facility Management and Building Technology. His master thesis dealt with the development of a sustainability rating system for non-value-adding support processes in building construction. The research for his doctoral grade deals with implications of the German "Energiewende" (energy transition) for the building sector and the hereby resulting demand for further integration of renewable energies in the heat supply of buildings. Mr. Wörner will be responsible for the lectures "Building Technology I and II".

Since April 1st 2016, Mr. **Dominik Müller, M.Sc.** is employed at the Institute of Concrete and Masonry Structures. Mr. Müller studied civil engineering with a focus on concrete structures at the Technical University of Darmstadt. After receiving his bachelor's degree he worked as a structural engineer at Stantec in Calgary, Canada, for eight months. In March 2016 he graduated by completing his master thesis on "reliability analyses of reinforced concrete elements in structural engineering". His research activities at the Institute of Concrete and Masonry Structures will also be within the field of structural reliability. Mr. Müller will be responsible for the lectures "Risk and Safety in Structural Engineering" and "Applied Structural Dynamics". Furthermore, he will be involved with the basic lectures on reinforced concrete.

Since Octobre 1st 2016, Mr. Redouan El Ghadioui, M.Sc. is employed as a doctoral student at the Institute of Concrete Structures. He completed his studies of civil engineering at the University of Applied Sciences in Cologne as well as at the Technical University of Darmstadt (specialization: structural engineering - concrete and steel structures). Within the framework of his master thesis, he analysed the lateral torsional buckling behaviour of steel sections with special connections using non-linear FE-simulations. After his graduation in Octobre 2014 he worked as a project engineer for the bridge construction department of the KHP König & Heunisch Planungsgesellschaft in Frankfurt am Main (Germany). His main tasks included static and dynamic analyses of bridge structures, the planning of bridge reinforcements using external prestressing and the inspection of calculations in the field of structural engineering. During his graduation at the Institute of Concrete Structures Mr. El Ghadioui will be in charge of the lectures “Concrete Structures II” and “Prefabricated Concrete Structures”.

AWARDS

Dreßler Bau Award 2016

The Dreßler Bau Prize has been awarded for the fourth time at the TU Darmstadt at November 16th 2016. The award is handed over for the outstanding bachelor thesis in the technical disciplines Concrete Structures and Construction Management. Ms. **Anna Gries, B.Sc.** submitted her bachelor's thesis entitled "Development of cement compositions for eco-friendly carbon reinforced concrete". We congratulate Ms. Gries on this success.

Heinrich und Margarete Liebig Award 2016

Since 2010, the Heinrich and Margarete Liebig Prize has been awarded annually by the Liebig group for an outstanding diploma or master thesis in the fields of civil, environmental, electrical and mechanical engineering. This year, **Dominik Müller, M.Sc.** received the award for his master thesis on "reliability analyses of reinforced concrete elements in structural engineering". We congratulate Mr. Müller on this success.

Tobias Mann, Managing Director of Dreßler Bau GmbH, Prof. Dr.-Ing. Carl-Alexander Graubner, Anna Gries, awardee of Dreßler Bau Award, Dominik Müller, laureate of Heinrich und Margarete Liebig Prize (from left to right)

Award of the association Freunde des Instituts für Massivbau der TU Darmstadt e.V. 2016

As in 2015, the "Freunde des Instituts für Massivbau der TU Darmstadt e.V." awards outstanding dissertations at the institute with a special prize. In 2016 this prize was awarded to Mr. **Dr.-Ing. Stefan Hainer** for his dissertation "Carbonation behavior of clinker-reduced concretes". We congratulate Mr. Dr.-Ing. Hainer on this success.

Besides, the association is also awarding the best master's thesis at the Institute of Concrete and Masonry Structures, supported by GOLDBECK. In 2016, the prize was given to Mr. **Dominik Müller, M.Sc.** for his thesis concerning "Reliability analyses of reinforced concrete elements in structural engineering". We congratulate Mr. Müller on this success.

DIA-Research Award 2016

In 2016 the Award of the German Real Estate Academy (DIA) has been awarded for the 18th time for outstanding theses. At October 5th, 2016 the master thesis of Mr. **Lasse Haarstark, M.Sc.** has been honored at the real estate trade fair Expo Real in Munich. His thesis with the title "Analysis of the influence of energy efficient building components on the life cycle costs of commercial properties for the example of the Siemens AG" has been written in the field of sustainable construction in cooperation with the institute of Accounting, Controlling and Auditing. The certificates were handed over by European Commissioner Günther Oettinger. We congratulate Mr. Haarstark on this success.

Laureate Lasse Haarstark, M.Sc. receives the DIA-Research Award 2016 from European Commissioner Günther Oettinger

ACKNOWLEDGEMENTS

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

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We want to express our gratitude for this support and hope for a successful cooperation in the future.

In teaching, a support by experts from the private sector, the industry, administration and 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. Thomas Heß	Technische Gebäudeausrüstung I + II
Dr.-Ing. Gert Riegel	Strategisches Facility Management & Sustainable Design
Dr.-Ing. Eric Brehm	Risiko und Sicherheit im konstruktiven Ingenieurbau
Dr.-Ing. Georg Geldmacher	Massivbrückenbau und Traggerüste

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 and Dipl.-Wirt.-Ing. (FH) Peter Schermuly (Fertigteilkonstruktionen); Dr.-Ing. Gerhard Zehetmaier and Dr.-Ing. Stefan Kempf (Massivbrückenbau und Traggerüste); Dr.-Ing. Stefan Daus, Dipl.-Ing. Rudolf Herz, Dipl.-Ing. Liane Prediger and Dipl.-Ing. (FH) Michael Pröll (Mauerwerksbau und Sonderfragen aus dem Betonbau); Dr.-Ing. Holger Schmidt (Risiko und Sicherheit im konstruktiven Ingenieurbau); Dr.-Ing. Torsten Mielecke, Dr.-Ing. Sebastian Pohl (Strategisches Facility Management & Sustainable Design); Dipl.-Ing. Herbert Schäfer, Dipl.-Ing. Rudi Becker, Prof. Dr.-Ing. Benjamin von Wolf-Zdekauer, Dipl.-Ing. Olaf Pielke, Dipl.-Ing. Frank Bieber, Dipl.-Ing. Robin Engelmann and Dipl.-Ing. Patrik Bös (Technische Gebäudeausrüstung).

PUBLICATIONS

Books:

Graubner, C.-A.; Rast, R. [Hrsg.]: Mauerwerksbau – Praxishandbuch für Tragwerksplaner, Bauwerk Beuth Verlag, Berlin, 2017, ISBN 978-3-410-26446-0.

Selected papers and book chapters:

Förster, V.; Graubner, C.-A.: Design of basement walls under lateral earth pressure, In: Brick and Block Masonry - Proceedings of the 16th International Brick and Block Masonry Conference, 26.-30. June 2016, Padova, Italy, S. 2225-2230, ISBN: 978-1-138-02999-6.

Graubner, C.-A.: Kommentierung DIN EN 1996-3/NA/A2 – Bemessung und Konstruktion von Mauerwerksbauten, In: Mauerwerksbau - Praxishandbuch für Tragwerksplaner. Graubner, C.-A.; Rast, R. [Hrsg.], 2017, Bauwerk Beuth Verlag, Berlin, ISBN: 978-3-410-26446-0.

Graubner, C.-A.: Mauerwerksbemessung nach DIN EN 1996-1-1/NA – Genaueres Nachweisverfahren, In: Mauerwerksbau - Praxishandbuch für Tragwerksplaner. Graubner, C.-A.; Rast, R. [Hrsg.], 2017, Bauwerk Beuth Verlag, Berlin, ISBN: 978-3-410-26446-0.

Graubner, C.-A.; Förster, V.; Mazur, R.; Müller, D.; Purkert, B.: Projektgruppe 5 – Mauerwerksbau - Praxisnahe Vorschläge zur Überarbeitung von DIN EN 1996/NA, In: 38. Darmstädter Massivbauseminar - Praxisgerechte Regelwerke im Bauwesen, 10. November 2016, Freunde des Instituts für Massivbau der TU Darmstadt e. V., Darmstadt, S. 51-66.

Graubner, C.-A.; Förster, V.; Purkert, B.: Bemessung von Ziegelmauerwerk, In: Bauplaner - Supplement im Deutschen IngenieurBlatt, 2016, Schiele & Schön, Berlin, S. 8-9, ISBN: 0946-2422.

Graubner, C.-A.; Freund, B.: Frischbetondruck bei frei geformten Betonbauteilen – Ein neuartiges Bemessungskonzept für Schalungssysteme, In: BFT International, Heft 2, 2016.

Graubner, C.-A.; Koob, B.: Analysis of Nationally Determined Parameters of EN 1996-1-1, In: Brick and Block Masonry - Proceedings of the 16th International Brick and Block Masonry Conference, 26.-30. June 2016, Padova, Italy, S. 681-687, ISBN: 978-1-138-02999-6.

Graubner, C.-A.; Pohl, S.; Förster, V.; Schmitt, M.; Koob, B.: Sustainable building with masonry - Nachhaltiges Bauen mit Mauerwerk, In: Mauerwerk - European Journal of Masonry , Vol. 20, Issue 1, 2016, Ernst & Sohn, Berlin, DOI: 10.1002/dama.201600690.

Graubner, C.-A.; Ramge, P.; Hess, R.; Ditter, M.; Lohmeier, M.: Pre-Check der Nachhaltigkeitsbewertung für Brückenbauwerke, In: Schriftenreihe: Berichte der Bundesanstalt für Straßenwesen, Reihe B: Brücken- und Ingenieurbau, Heft 132, 2016, Bergisch Gladbach, ISBN: 978-3-95606-254-4.

Graubner, C.-A.; Schmitt, M.; Förster, V.: Nachweis von Aussteifungsscheiben aus unbewehrtem Mauerwerk nach DIN EN 1996-1-1/NA, In: Mauerwerksbau - Praxishandbuch für Tragwerksplaner. Graubner, C.-A.; Rast, R. [Hrsg.], 2017, Bauwerk Beuth Verlag, Berlin, ISBN: 978-3-410-26446-0.

Graubner, C.-A.; Schmitt, M.; Förster, V.: Tragfähigkeitstafeln für unbewehrtes Mauerwerk nach DIN EN 1996-3/NA, In: Mauerwerksbau - Praxishandbuch für Tragwerksplaner. Graubner, C.-A.; Rast, R. [Hrsg.], 2017, Bauwerk Beuth Verlag, Berlin, ISBN: 978-3-410-26446-0.

Kranzler, T.; Graubner, C.-A.: Mauerwerksbemessung nach DIN EN 1996-3/NA - Vereinfachte Berechnungsmethoden, In: Mauerwerksbau - Praxishandbuch für Tragwerksplaner. Graubner, C.-A.; Rast, R. [Hrsg.], 2017, Bauwerk Beuth Verlag, Berlin, ISBN: 978-3-410-26446-0.

Mielecke, T.; Graubner, C.-A.; Ramge, P.; Hess, R.; Pola, V.; Caspari, W.: Anforderungen an Baustoffe, Bauwerke und Realisierungsprozesse der Straßeninfrastrukturen im Hinblick auf Nachhaltigkeit, In: Schriftenreihe: Berichte der Bundesanstalt für Straßenwesen, Reihe B: Brücken- und Ingenieurbau, Heft 133, 2016, Bergisch Gladbach, ISBN: 978-3-95606-257-5.

Palm, S.; Proske, T.; Rezvani, M.; Hainer, S.; Christoph, M.; Graubner, C.-A.: Cements with high limestone content - Mechanical properties, durability and ecological characteristics of the concrete, In: Construction and Building Materials, Vol. 119, 2016, S. 308-318, DOI: 10.1016/j.conbuildmat.2016.05.009.

Weißmann, C.; Kumpf, L.; Graubner, C.-A.: Entwicklung von Strom-Lastprofilen für Schulgebäude und Anwendung für die energetische Bewertung auf Quartiersebene, In: Bauphysik, Band 38, Heft 4, 2016, Ernst & Sohn, Berlin, S. 212-221, DOI: DOI: 10.1002/bapi.201610021.

Weißmann, C.; Staab, F.; Graubner, C.-A.: Development of a simple approach for applying LCA analysis to compare decentralized energy supply options for urban areas, In: Proceedings SBE 16 Hamburg - International Conference on Sustainable Built Environment, 2016, Hamburg, S. 370-379.

Selected presentations:

Förster, V.; Graubner, C.-A.: Design of basement walls under lateral earth pressure, 16th International Brick and Block Masonry Conference, Padova, Italy, 29.06.2016

Graubner, C.-A.; Förster, V.; Mazur, R.; Müller, D.; Benjamin, P.: Praxisnahe Vorschläge zur Überarbeitung von DIN EN 1996/NA, 38. Darmstädter Massivbauseminar - Praxisgerechte Regelwerke im Bauwesen, Darmstadt, 10. November 2016

Graubner, C.-A.; Fritz, K.: Systematisierte Bewertung der Ressourceneffizienz im Bauwesen: Nächste Schritte für eine Etablierung in Politik und Gesellschaft, 7. Sitzung Runder Tisch Ressourceneffizienz im Bauwesen, Berlin, 28.04.2016

Graubner, C.-A.; Koob, B.: Analysis of Nationally Determined Parameters of EN 1996-1-1, 16th International Brick and Block Masonry Conference, Padova, Italy, 27.06.2016

Graubner, C.-A.; Mazur, R.: Grundlagen zur Bemessung von unbewehrtem Mauerwerk nach DIN EN 1996/NA, Weiterbildung für Tragwerksplaner, Darmstadt, 14.09.2016; Kaiserslautern, 17.09.2016

Graubner, C.-A.; Mazur, R.: Unbewehrtes Mauerwerk nach DIN EN 1996-3/NA - Beispiele - Vereinfachte Berechnungsmethode, Weiterbildung für Tragwerksplaner, Darmstadt, 14.09.2016; Kaiserslautern, 17.09.2016

Graubner, C.-A.; Pohl, S.; Förster, V.; Schmitt, M.; Koob, B.: Mauerwerk - Fit für die Zukunft!, Deutscher Mauerwerkskongress 2016, Darmstadt 20.01.2016

Rezvani, M.: Absenkung des Klinkeranteils im Zement zur Verminderung der CO2 - Emissionen, 22. Internationale DBU Sommerakademie, Ostritz-St. Marienthal, 21.06.2016

Staab, F.; Weißmann, C.; Graubner, C.-A.: Development of a simple approach for applying LCA analysis to compare decentralized energy supply options for urban areas, SBE 16 Hamburg - International Conference on Sustainable Built Environment, Hamburg, 08.-11. March 2016

Weißmann, C.; Kumpf, L.; Graubner, C.-A.: Entwicklung von Referenz-Lastprofilen für Schulen und KiTas, 8. Sitzung des Richtlinienausschusses zur Überarbeitung der Richtlinie VDI 4655, 12.10.16; Düsseldorf, 12.10.2016

SIMPLIFIED PROPOSAL FOR THE DESIGN OF BASEMENT WALLS UNDER LATERAL EARTH PRESSURE

Valentin Förster

Basement walls need to carry horizontal (out-of-plane) loads from adjacent soil. Usually, the flexural strength perpendicular to the bed joints has to be neglected for the design of unreinforced masonry walls. In order to warrant the load bearing capacity of basement walls under predominant bending loads due to horizontal earth pressure, a minimal load in vertical direction is required. Thereby, the compressed arch within the wall responds to the lateral earth pressure, see Figure 1. To determine the minimum required normal force, EN 1996-3 provides a simplified calculation approach which only takes into account an earth pressure coefficient of Ke ≤ 1/3. The earth pressure coefficient Ke is defined as the ratio of the effective horizontal stress to the effective vertical stress. If a higher earth pressure coefficient (e.g. earth pressure at rest) has to be considered, the more accurate verification method specified in the German national annex of DIN EN 1996-1-1 should be applied. However, in this case it is mandatory to verify adequate shear resistance in addition to the verification of a sufficient flexural bearing strength.

Along the revision of the Eurocodes, the related national regulations shall be reduced as much as possible and harmonized in a reasonable way. In order to enable a simple and economic design of basement walls with earth pressure coefficients of the in-situ soil that exceed 1/3, an improved design proposal for a simplified calculation according to Part 3 of Eurocode 6 was recently submitted to the responsible European Standardization Committee (CEN/TC250/SC6). The proposal is visualized in (1). To verify the submitted proposal, a more realistic design model was developed, see also (1).

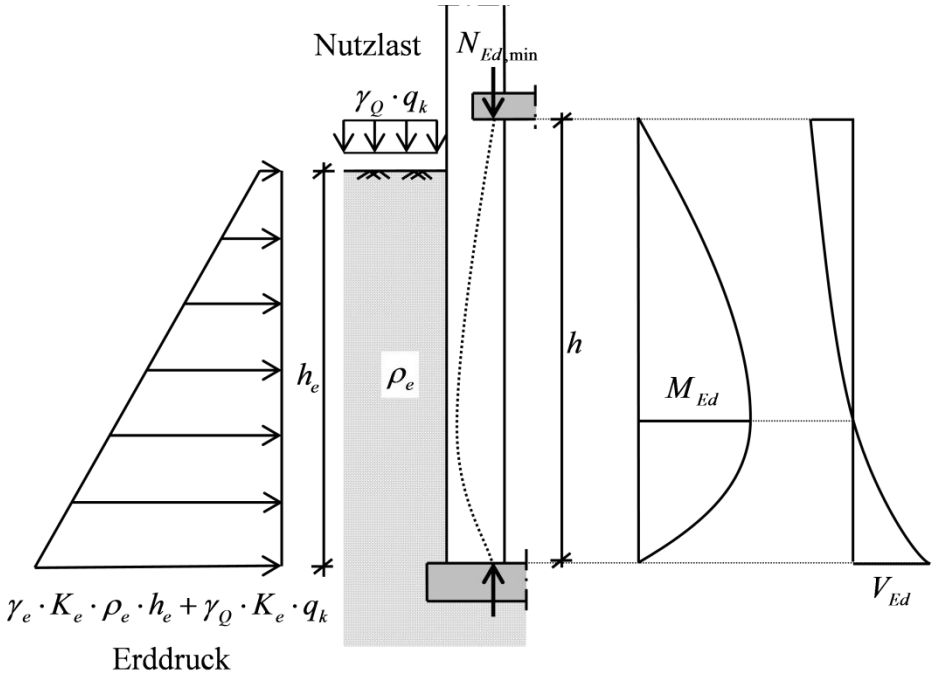

Figure 1: Arch model with loads and internal forces (1)

The benefit of the new proposal compared to EN 1996–3 is that not only active earth pressure with a coefficient of $K_e = 1/3$ but any earth pressure coefficient can now be taken into account. Another advantage is defined by bending and shear failure, which can be incorporated in the calculation in addition to various earth pressure coefficients. Furthermore, this simple and user-friendly proposal extends current application limits. For example, the approach allows the verification of walls with clear heights greater than 2.6 m.

(1) Förster, V.; Graubner, C.-A.: Design of basement walls under lateral earth pressure, In: Brick and Block Masonry – Proceedings of the 16th International Brick and Block Masonry Conference, 26.-30. June 2016, Padova, Italy, p. 2225-2230, ISBN: 978-1-138-02999-6.

PRESSURE OF FRESH CONCRETE OF VERTICAL, INCLINED AND CURVED WALLS

Björn Freund

The pressure of fresh concrete of inclined and curved walls was previously uninvestigated. Normative regulations for the design of inclined or curved formwork systems do not exist. In a research project founded by the DFG (Deutsche Forschungsgemeinschaft) the pressure of fresh concrete of inclined and curved walls was investigated experimentally and theoretically (1).

With a theoretical model based on FE-method, the pressure of fresh concrete can be calculated for free-form formwork systems (2). Comparative calculations show a good correlation between the calculated results and the measured values of the full-scale tests (2).

Based on calculation results of extensive parameter studies and considering safety and reliability issues, a calculation proposal for determining the pressure of fresh concrete of vertical, inclined and curved walls for the design of formwork systems has been developed (2).

Figure 1 shows characteristic values of the pressure of fresh concrete walls by use of concrete of consistency class F6 according to the calculation proposal in (2) and according to DIN 18218 (3). The diagram shows that the values of the new approach are significantly smaller compared with DIN 18218 (3). This results primarily from the inclusion of the reinforcement and the wall thickness, and this allows to design a formwork system significantly more efficient or the concreting process can be carried out faster.

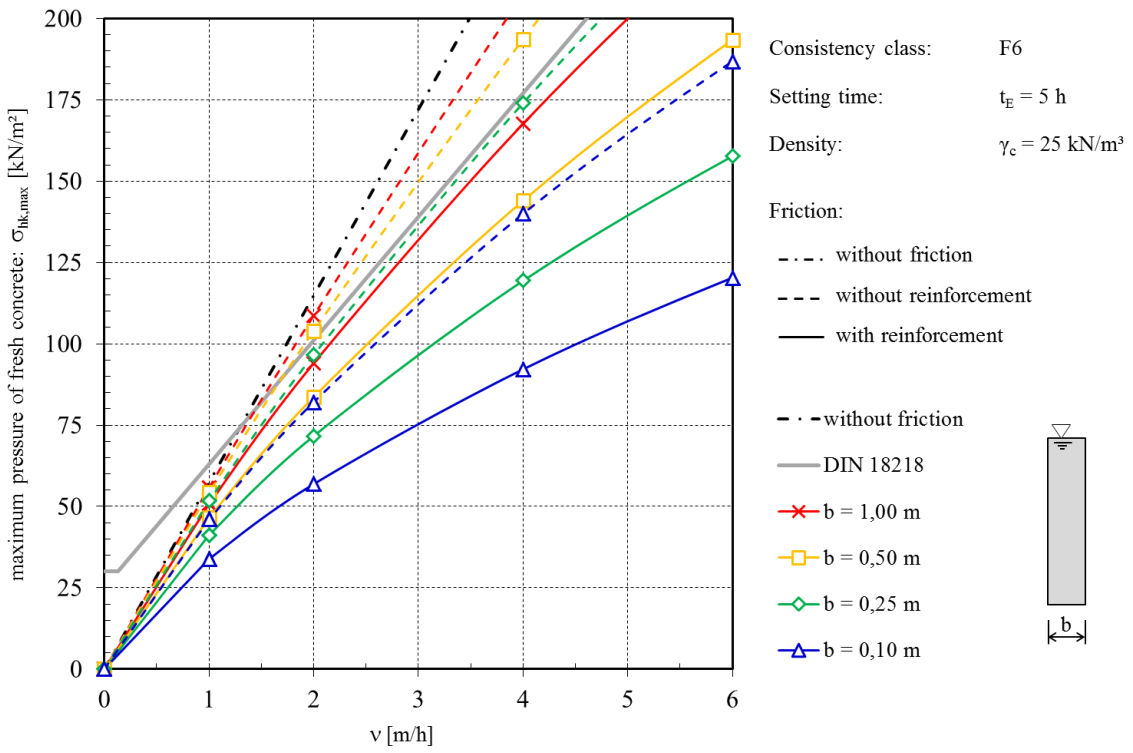

Figure 1: Characteristic values of maximum pressure of fresh concrete of vertical walls acc. calculation proposal (acc. (2)) and DIN 18218 (3) acc. (2) (diagram from (2))

(1) Freund, B.; Proske, T.; Graubner, C.-A.: 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. (2016): Dissertation in Vorbereitung. TU Darmstadt - Institut für Massivbau, Darmstadt.

(3) DIN 18218:2010-01: Frischbetondruck auf lotrechte Schalungen. Deutsches Institut für Normung, Beuth Verlag GmbH, Berlin, 2010.

INFLUENCE OF MATERIAL INHOMOGENEITY ON THE STRUCTURAL RELIABILITY OF SLENDER UHPC COMPRESSION MEMBERS

Ulf Grziwa

Studies conducted at the Institute of Concrete and Masonry Structures show that, for small eccentricities of the normal force, mean value and standard deviation of the elasticity modulus of concrete have the most significant influence on the structural reliability (see 1). For large load eccentricities though, the reliability index is sensitive to mean value and standard deviation of the tensile strength of concrete. Reliability analyses reveal that especially for slender and almost centrically loaded compression members made from UHPC the reliability index is lower than required by code. All of these analyses are based on the assumption of homogenous material parameters which means that the inhomogeneity of the material (i.e. the spatial variation of material properties) is neglected. The objective of a current research project at the Institute of Concrete and Masonry structures is to identify the spatial variation of material parameters that determine the load-bearing capacity and to describe it with mathematical functions and the method of random fields. The findings are implemented in a numerical and stochastic model and then used for reliability analyses. A small extract of the results can be found in fig. 1. Beside the specification of boundary conditions, the reliability index resulting from analyses with and without the consideration of the spatial variation is shown as a function of slenderness for load eccentricities of e/h = 0,1 and e/h = 2,0.

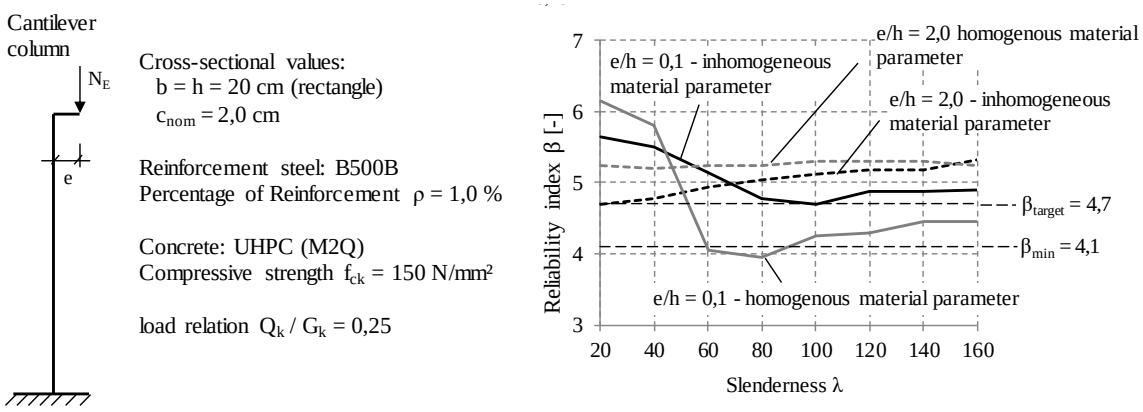

Figure 1: Results of reliability analyses – cantilever column with consideration of the spatial variation of material parameters from (2))

As it can be seen in fig. 1, the required reliability index of $\beta = 4{,}7$ is always achieved for columns designed by using the nonlinear method as specified by code and a partial safety factor of $\gamma_{calc} = 1{,}3$. By applying the method of random fields, which can describe the behaviour of materials and structural members much more realistic compared to a homogenous model, it is shown that the lack of safety for compression members with a slenderness between $60 \leq \lambda \leq 90$ and a load eccentricity of $e/h \leq 0{,}2$, which was described in past research projects, is not existing. Furthermore, a slenderness can be determined for which, dependent on the eccentricity e/h, an excess of safety is existent. Therefore, a reduction of the required partial safety factory could be considered for these cases. The authors thank the DFG for supporting this research project at the Institute of Concrete and Masonry Structures.

(1) Heimann, M. (2013): Tragwerkszuverlässigkeit hochbeanspruchter Druckglieder aus ultrahochfestem Beton, Dissertation, TU Darmstadt - Institut für Massivbau, Darmstadt 2013.

(2) Grziwa, U. (2016): Dissertation in Vorbereitung. TU Darmstadt - Institut für Massivbau, Darmstadt.

LOAD-BEARING BEHAVIOUR OF CARBON-REINFORCED PLATES

Larissa Krieger

With no corrosion risk, very high strength properties and thin layer thickness, textile reinforcements such as carbon fibres extend the application range of concrete, especially for thinner and lighter designs. The research project “C³ - Carbon Concrete Composite” is supposed to create the basis for the broad use of fibre-reinforced concrete. Therefore an extensive knowledge about the different load-bearing behaviours under static and cyclic load is necessary. The Institute of Concrete and Masonry Structures will be involved in 2017 with the investigation of the creep resistance and the fatigue behaviour of carbon-reinforced plates. First experimental investigations on the bending load capacity on carbon-reinforced and steel-reinforced plates under static load have been analysed.

The diagram in figure 1 shows the moment-deformation graphs of three bending tests on 0.1 m thick carbon-reinforced concrete plates with a span of 2.2 m. In state I, the component behaves according to the stiffness of the uncracked concrete cross section. When the concrete tensile strength is exceeded, the crack formation begins and the component passes to the state IIa. In the final crack state, the transition to state IIb is reached. If the load is then further increased, the reinforcement is expanded simultaneously with the enlargement of the crack widths. In contrast to steel reinforced concrete, there are no plastic reserves in carbon reinforced concrete due to the linear-elastic behavior of the carbon fibres. Nevertheless the plates have a ductile behaviour. The experimental studies also include first investigations on the fatigue strength with load cycles up to $N = 10^6$.

A continuous deformation increase was observed whereas there was no influence on the maximum load bearing capacity (Figure 2).

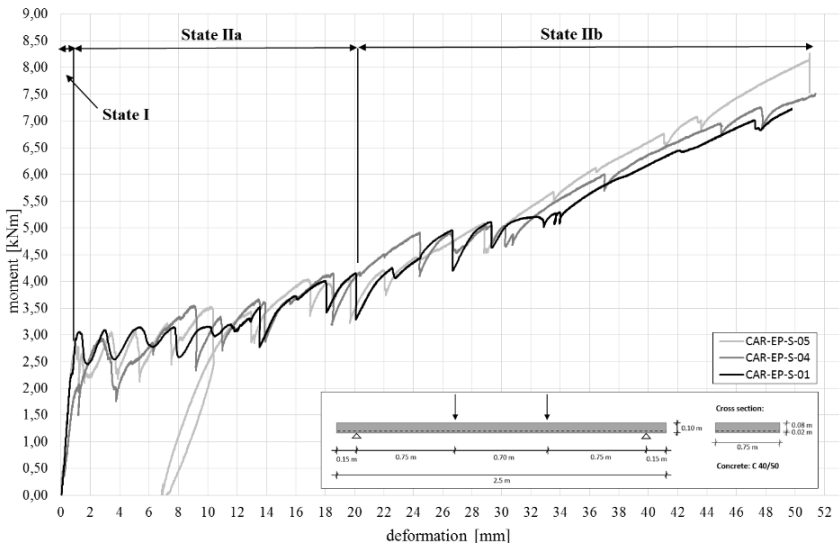

Figure 1: Moment-deformation behaviour of carbon reinforced plates under static load

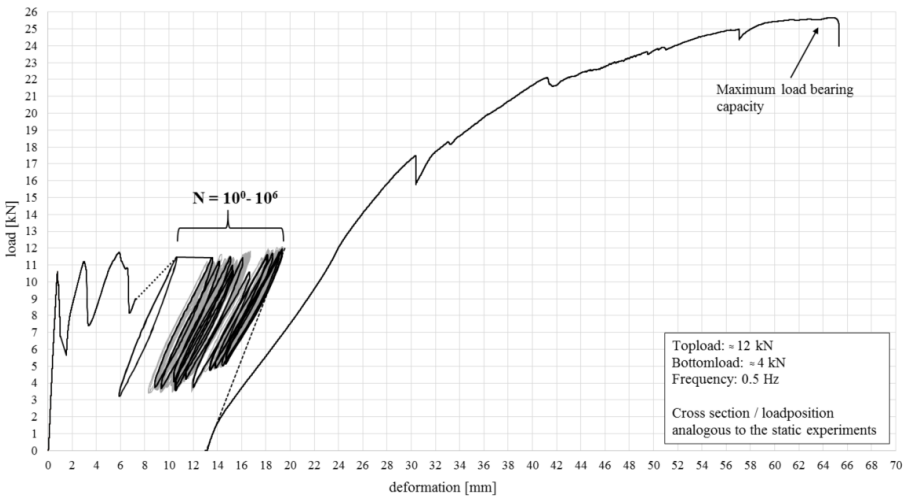

Figure 2: Load-bearing capacity of carbon reinforced plates under cyclic load

The author would like to thank the company solidian for providing the textile reinforcement as well as GOLDBECK for the production and delivery of the carbon-reinforced plates.

COMPARISON OF THE DESIGN METHODS FOR MASONRY WALLS ACCORDING TO DIN EN 1996-1-1/NA AND DIN EN 1996-3/NA

René Mazur

In general, the target of standardization work is to shorten existing regulations and to make them more practicable and user-friendly. An example of a very user-friendly design method is the simplified calculation methods for unreinforced masonry walls according to DIN EN 1996-3/NA. This design method leads to results much faster than the general rules according to DIN EN 1996-1-1/NA, but it is limited by fixed criteria for using. A current research deals with an extension of these criteria for using the simplified design methods.

In order to check the possibility of extending the criteria for using the simplified calculation methods, extensive comparative calculations have to be carried out. The first reflections of the analysis already showed that a comparison of these two design methods is not possible simply by comparing the results. The simplified calculation methods provide a maximum load bearing capacity of a previously defined wall without knowledge of the acting loads. When applying the general rules, the load bearing capacity is strongly depending on the existing load eccentricity e = M/N. The determination of the acting bending moment and the applied normal force is in parts very complex for general cases. By skillful standardizing of the design equations and using general approaches to solve equations with higher order, it was possible to determine the maximum load bearing capacity according to the general rules without any iteration and to compare it with the results of the simplified calculation methods. While the valid wall height is usually determined by stability failure, the results of the extension of the possible slab span are mainly influenced by the verification on the top or bottom of a wall, especially for walls with low height.

The evaluation of the comparative calculations leads for exterior walls to a first proposal for the extension of the criteria for using the simplified calculation methods, which is shown in figure 1. All limits of the possible extension were chosen on the safe side, i.e. the simplified calculation methods lead to a lower load bearing capacity than the general rules. Due to the complexity of the comparison and the results itself, this first proposal is valid exclusively for single-leaf walls of calcium silicate units, clay masonry units and autoclaved aerated concrete units.

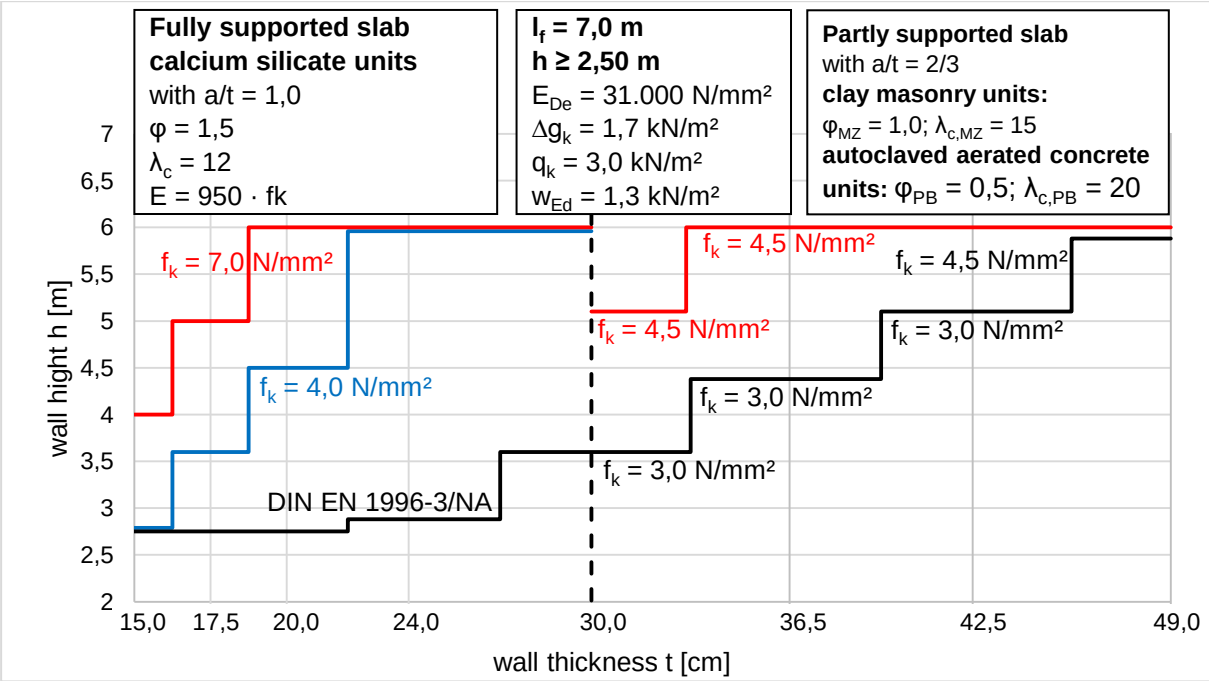

Figure 1: First proposal for the extension of the criteria for using the simplified calculation methods for exterior walls

DETERMINATION OF LIVE LOAD REDUCTION FACTORS BY STOCHASTIC SIMULATION

Dominik Müller, Ngoc Linh Tran

Together with dead loads, live loads are the most important loads acting in buildings. Thus, they significantly influence material consumption and costs for the structure. According to DIN EN 1991-1-1/NA, live loads for the design of columns and walls may be reduced by the factor α_n, which is a function of the number n of floors supported by the member:

$$\alpha_n = 0.7 + 0.6/n \leq 1 \qquad \text{(a)}$$

Live loads may be reduced by this factor because the coefficient of variation of the total load acting on a column or wall decreases with an increasing number of floors being supported by this member. The live load reduction factor α_n as defined in DIN EN 1991-1-1/NA was checked by performing a stochastic load simulation. For this purpose, live loads were modelled as a random field which is described by the following equation:

$$W(x, y) = m + B + F + U(x, y) \qquad \text{(b)}$$

Herein, m is a deterministic value describing the mean value of the load. B and F are random variables with a mean value of zero. B describes the deviation of the live load of a whole building from the mean m and F is the deviation of the live load on a given floor from the mean $m + B$ of a specific building. The random field $U(x,y)$, also having a mean of zero, describes the variation on the floor itself. The sum $W(x,y)$ can be described by a gamma distribution. For the determination of live load reduction factors it is important to know the ratio of the standard deviations of the components of $W(x,y)$ since this ration defines the correlation of live loads. Furthermore, live loads can be divided into sustained loads which include the weight of furniture plus its content and extraordinary loads occurring in situations like gatherings or emergencies

which could lead to the crowding of people. Sustained loads can be modelled as constant during an occupation time that is of random length, extraordinary loads appear intermittently with a randomly distributed length between two appearances.

The loads were simulated for an exemplary ten-storey building structure and the two occupancy types office and residential. Stochastic parameters chosen for the simulation are based on existing load surveys. A more detailed explanation of the procedure can be found in (1). The simulation results were used to determine the distribution of the column axial forces. Then, the corresponding 98%-quantiles and possible live load reduction factors were derived. In figure 1 they are compared to the live load reduction factor α_n according to DIN EN 1991-1-1/NA. Especially for residential buildings, the reduction factor α_n seems to be too conservative. However, for a comprehensive evaluation other exemplary buildings have to be analysed.

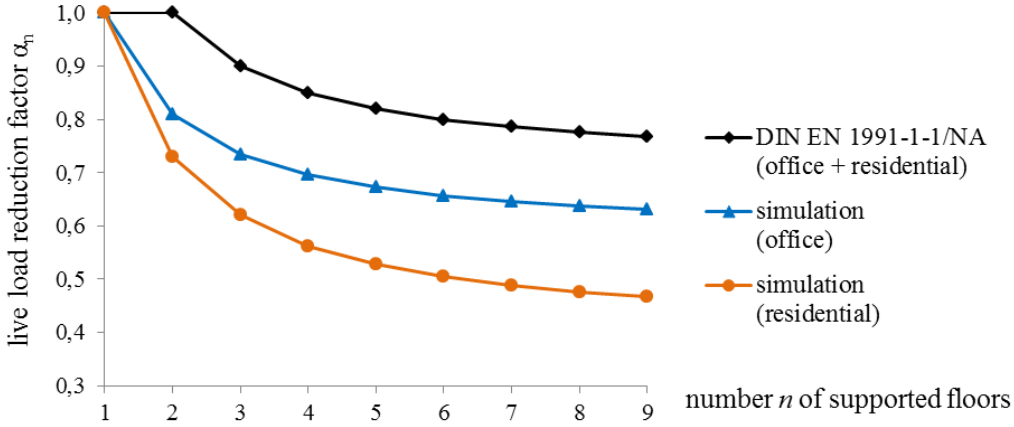

Figure 1: Comparison of live load reduction factors

(1) Tran, N.L.; Müller, D.; Graubner, C.-A.: Floor Live Loads of Building Structures. In: Proceedings of the 14th International Probabilistic Workshop, Ghent, 5–7 December 2016.

ANALYSIS OF THE VERIFICATION METHOD OF THE SHEAR RESISTANCE OF REINFORCED MASONRY STRUCTURES ACCORDING TO EN 1996-1-1

Benjamin Purkert

Currently, reinforced masonry is almost not used at all in Germany, because an efficient use is not possible due to the nationally determined high material safety factor of $\gamma_M = 10$. Exceptions are door and window lintels, which are regulated in national technical approvals and not verified according to the currently valid European Standard EN 1996-1-1. The unrealistically high safety factor $\gamma_M = 10$ considers that the verification methods in Eurocode 6 – especially concerning the shear verification – do not respect some essential circumstances, which are typical for masonry constructions, and that wrong material and geometry values are considered punctually.

To be able to work towards a correction of these mistakes and inaccuracies during the currently ongoing "systematic review" of EN 1996-1-1 the weak points of the actual normative verification of the shear resistance were identified and worked out, also to make the first step towards an application of reinforced masonry in Germany in the future.

For example, the verification of the shear resistance without shear reinforcement regarding reinforced masonry walls is managed with the clear wall length l instead of the compressed length l_c (see Eq. (a)), while the shear strength of unreinforced masonry, which considers only the compressed part of the wall, is used at the same time. Furthermore, a fixed angle of inclination of the compressive struts of $\theta = 45°$ is assumed, without considering the kind or the length of the overlapping of the units. As another point, regarding the verification of the limitation of the inclined main compressive stress, it was not observed that the inclined compressive strength is not identical with the vertical masonry strength.

$$V_{Ed} \leq V_{Rd1} = f_{vd} \cdot t \cdot l \qquad \text{(a)}$$

Similar results can be found regarding the verification method of reinforced masonry beams, where the vertical masonry strength has to be used too instead of calculating with the horizontal compressive strength of the units. However, a more severe problem is that in case of beams, the horizontal shear strength parallel to the bed joints of unreinforced masonry has to be applied, because regarding beams, the shear force acts in vertical direction parallel to the perpend joints (see Figure 1). Therefore and because of the orthotropy of masonry, a different (lower) value has to be used for the shear strength essentially. Beyond that, it is very interesting, that even inclined shear reinforcement can be considered in the verification method according to EN 1996-1-1. Here, you have to ask at least, how inclined reinforcement bars shall be integrated in masonry units with particular vertical webs and holes.

Overall, it gets clear that there are several points which necessarily need a revision and that the high safety factor reflects these uncertainties.

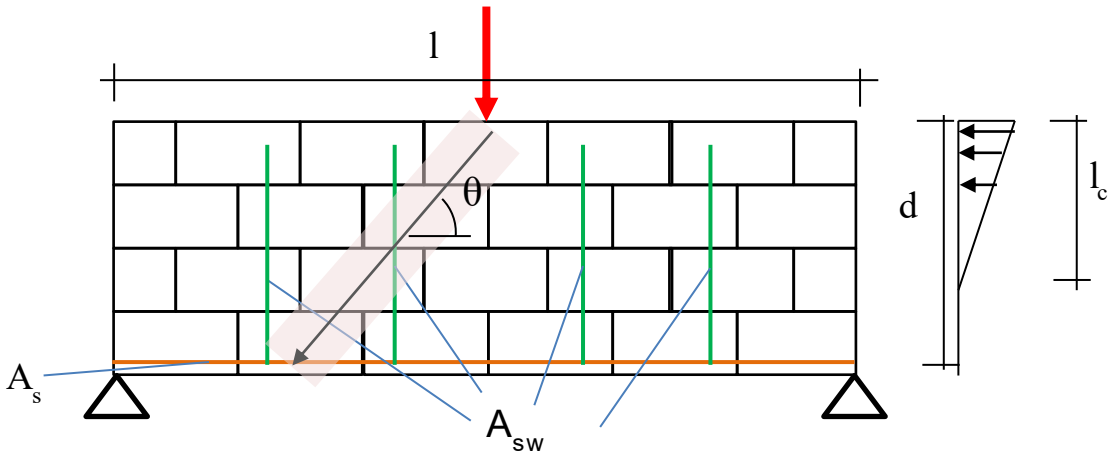

Figure 1: Model of a shear loaded reinforced masonry beam

LOAD-BEARING CAPACITY OF MASONRY INFILL WALLS CONSIDERING MEMBRANE EFFECTS

Michael Schmitt

The construction of buildings with masonry of man-made bricks is a successful building type since millenniums. Nevertheless, for some special constructions no adequate validated solution processes – based on geometrical, mechanical or mathematical background – are available to determine the carrying capacity including the failure modes and deformation states. The membrane effect, which occurs in unreinforced masonry infill walls under certain basic conditions, influences the load-bearing behavior significantly and is one of these unexplored fields. Today, masonry infill walls are often used in reinforced concrete frame constructions of buildings, industry and power stations. Using a friction-type connection for the joints between the non-load-bearing masonry wall and the adjacent reinforced concrete structural elements, membrane compressive stresses can be activated in an appreciable size. In this case, it has to be taken into account that the masonry wall under flexural stress (e.g. wind) is additionally strained in vertical direction. The occurring normal force is not a typical external vertical load, but – because of the constraint and the resulting normal force – a resulting reaction. One condition of the development of this force is a horizontal deflection of the wall, which leads to a vertical deformation of the top of the wall. For this reason, besides the condition of equilibrium compatibility – e.g. deformation of the wall – has to be analyzed. The flexural stiffness of the adjacent reinforced concrete slabs ($k_{T,m}/f_m$) has essential influence of the carrying capacity. Additionally, it does not only occur a second order phenomenon, but also due to the snap through effect aspects of the third order theory have to be taken into account.

With extensive analytical and numerical analysis under consideration of the numerated aspects and influences it was possible to develop an analytical model and a design model at the

Institute of Concrete and Masonry Structures. With this model the maximum horizontal load q_{Rd} can be determined (see Fig. 1). First results are presented in (1). A detailed analysis is carried out in (2).

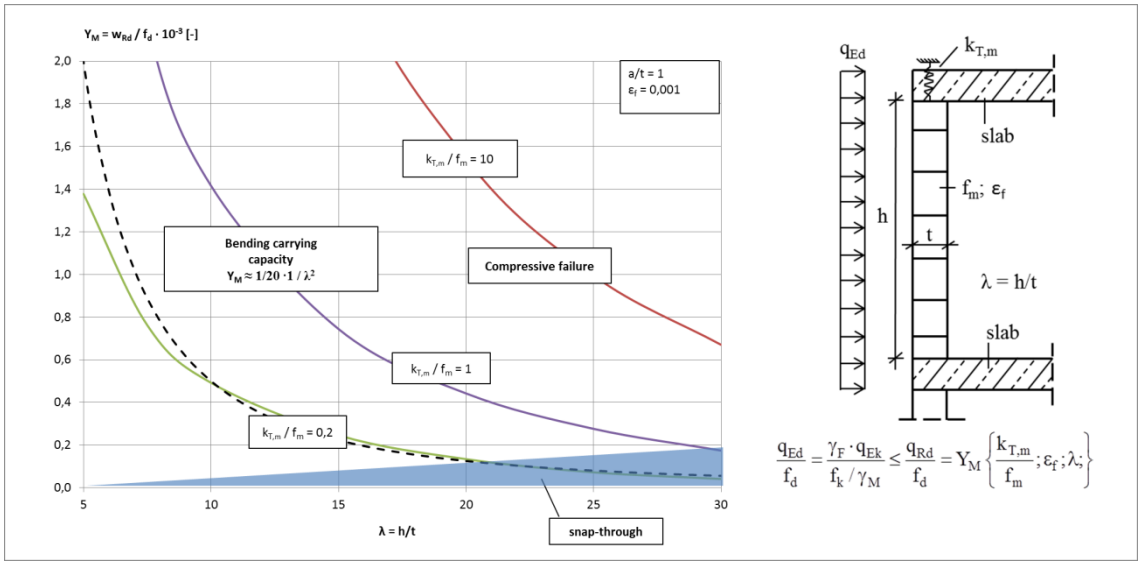

Figure 1: Carrying capacity according to the slenderness of the wall λ and the stiffness of the slab $k_{K,m}/f_m$

(1) Graubner, C.-A.; Schmitt, M. (2016): Loadbearing Capacity of Masonry Walls under predominant Bending due to Wind. In: Proceedings 16th International brick and block masonry conference, 2016, Padua, Italien

(2) Schmitt, M. (2017): Dissertation in Vorbereitung. TU Darmstadt – Institut für Massivbau, Darmstadt

THERMAL SEPARATION OF REINFORCED CONCRETE COLUMNS

Jochen Zeier, Tilo Proske

A further improvement of the building envelope with regard to heat transfer is required in new buildings, because of the steadily tightening of the Energy-Saving Ordinance (EnEV). This leads to an increasing influence of thermal bridges on the overall heat loss of the building. An avoidance or reduction of these heat bridges can significantly contribute to an increase in the quality of buildings and thus to the future requirements of energy-efficient construction (Fig. 1). For thermal separation of reinforced concrete connections, which are mainly subjected to bending and transverse forces (balconies), products from different manufacturers are available on the market, whereas there is still no suitable solution for columns under predominant compression. The aim of the research project is the development of a structural element which allows sufficient thermal decoupling of reinforced concrete columns (in the area of cold outside air) from reinforced concrete ceilings (warm interior) and at the same time being capable to transfer high normal forces. The main application area is seen in residential and office buildings with underground car parks.

In the theoretical part of the project, the structural requirements for column connections were first compiled. In addition statical specifications and limitations could be worked out. Materials identified by means of a literature search were evaluated on the basis of static, physical and economic criteria, while lightweight concrete and ultrahigh-strength concrete (UHPC) proved to be suitable materials. Based on these materials, basic variants for load transfer have been developed and compared.

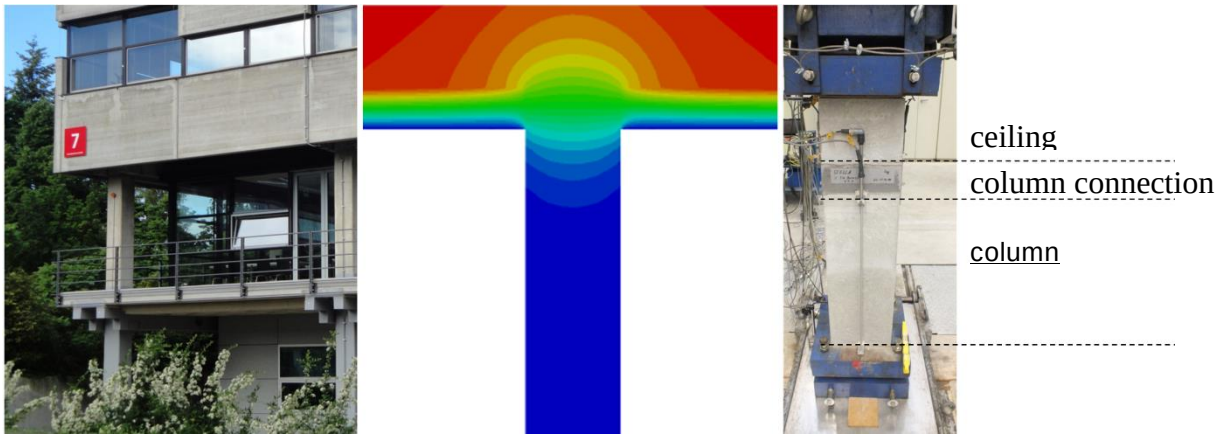

Figure 1: Building with columns (left), thermal modelling (center) and test specimen (right)

A simulation model (basic FEM) of the column connection (Fig. 1) was developed to determine the thermal characteristics. In the experimental section, the two most suitable design variants of the column connection (flat light-weight concrete as well as light-weight concrete with UHPC-core) were analyzed with regard to the load-bearing behavior in an extensive test program. The goal was to achieve a high utilization factor of the cross-section resistance of the column. Furthermore, an FEM model for the numerical analysis of the bearing behavior of the column connection was designed and calibrated on the basis of the test results. Extensive parameter studies were carried out using this FEM model. Based on this, a reliable prediction of the failure load is made possible by using the proposed design concept.

In summary, it can be said that the novel column connection has a high load bearing capacity and is cost-effective. A transfer of 80% to 100% of the cross section load-bearing capacity is achievable for standard supports. For these reasons, an implementation of the research results into an approved construction product is expected. The project was thankfully supported by Schöck Bauteile GmbH with know-how and material supplies.

CARBON CONCRETE COMPOSITE – SHRINKAGE OF C³-CONCRETES

Peter Ramge, Tilo Proske

As already reported in last year's issue of the DACON, the Institute of Concrete and Masonry Structures (IfM) is involved in the research project "C³ – Carbon Concrete Composite", presently Germany's largest building research project. Last year, this project was honored with several awards, for example with the "Deutscher Rohstoffeffizienzpreis 2015" and the "Deutscher Nachhaltigkeitspreis 2015".

The first project phase has ended now and thus the sub-project TP15 "mix design for eco-friendly cement and concrete, creep and shrinkage, life cycle assessment", in which the IfM was involved, was also completed in August 2016. Extensive experimental investigations were carried out to determine the creep and shrinkage behavior of the newly invented C³-concrete compositions. Furthermore, the ecological properties of these concrete mixtures were evaluated by means of life cycle assessments. One of the most effective measures to reduce creep and shrinkage deformations, which at the same time has a positive effect on the ecological assessment, is the substitution of cement clinker with other inert and/or reactive ingredients. In the present case, limestone powder and granulated blast furnace slag were used as cement clinker substitutes. The shrinkage behavior of cement-based building materials is a highly complex issue, which is affected by various interdependencies. Amongst the many factors of influence, the CSH phases formation during the hydration process takes a key role. The larger the amount of CSH phases, the larger are the expected shrinkage deformations. By substituting cement clinker with inert limestone powder, the amount of CSH phases that form during the hydration can be lowered and thus the shrinkage deformations can be reduced significantly. Granulated blast furnace slag, however, also contributes to the hydration process

and to the development of CSH phases. Regarding the shrinkage reduction the substitution of cement clinker with granulated blast furnace slag is, therefore, less effective than the substitution with limestone powder. The fact that exactly these CSH phases are the actual source of concrete's integrity and its strength indicates already the limited optimization of certain concrete properties by means of CSH phase reduction. Regarding creep and shrinkage and the ecological optimization, there would still be a further potential of cement clinker substitution in the case of the newly developed C^3-concrete compositions. However, this potential could not be utilized because of the limiting factors of other requirements and set boundary conditions, for example, the desire of high concrete strength values, the choice of a limited grain size and the demand for a flowable, almost self-consolidating concrete consistency.

Regarding the results, it becomes obvious that the contribution of the autogenous shrinkage to the overall shrinkage is significantly higher for the high-strength and higher-strength mixtures than for the normal and low-strength mixtures. For some of the concrete compositions comparative calculations for the prediction of the shrinkage deformations according to DIN EN 1992-1-1 (EC2) Appendix B were conducted. The normative approach, however, seems to be only of limited adequacy. The prediction of the autogenous shrinkage, for which the prediction preciseness decreases significantly for rising concrete strength values, is mostly problematic in this respect. The data available in the scope of the sub-project TP15, however, was not enough to allow the determination of adjusted model parameters or corrective factors. There is still a need for further research in this field.

For the prediction of the creep deformations, however, the model approach according to DIN EN 1992-1-1 (EC2) Appendix B seems to be well applicable. Comparative calculations matching the creep coefficients $\varphi(t,t_0)$ derived from the experimental measurements with those calculated by the model provide satisfactory results.

CREEP AND SHRINKAGE BEHAVIORS OF CONCRETE MADE OF ECO-FRIENDLY COMPOSITE CEMENTS

Moien Rezvani, Tilo Proske

Within the joint research project "Reduction of environmental impact of construction through new ground granulated blast furnace slag (GGBFS) cements and concretes thereof" with Spenner Cement Co. and German Cement Work Association (VDZ), cements with low amount of Portland cement clinker and high limestone and GGBFS contents were developed and tested. Because of low clinker content, structural concretes with sufficient mechanical and durability properties can be achieved only through a modified concrete technology approach, e.g. reduced water-cement-ratio. This could lead to a CO_2 cut-off of about 60% for concrete made of cement with only 20 wt.-% Portland cement clinker. Within a comprehensive experimental program, the applicability of concretes made of such cements in both laboratory and practical scales is examined, including mechanical properties, e.g. compressive and tensile strengths and modulus of elasticity, as well as durability issues, e.g. shrinkage and creep deformations, carbonation, frost and chloride resistance.

Long-term creep and shrinkage tests were conducted on Ø = 158 mm, h = 300 mm concrete cylinders with cement paste volume of 275 ± 5 l/m³ in accordance with DAfStb Heft 422. Specimens were left for one day in mold and afterward 6 days in water. The specimens were removed from water and placed in climate chamber under T = 20 °C and RH = 65% condition. Concrete cylinders for creep test were loaded up to $\sigma_c = 1/3\ f_{c,cyl}$ at the age of 35 days. Measured shrinkage history of concrete with different w/c-ratios of 0.35, 0.40 and 0.50 made of cements with different clinker contents (K), GGBFS (S) and limestone (LL) are pictured in Figure 1 (left). Comparison of the reference concretes made of CEM I 52.5 R with concretes with CEM III/A 42.5 N and CEM (50K, 30S, 20LL) with the same w/c of 0.50 reveals the re-

ducing effect of GGBFS and limestone on the drying shrinkage, whereas the impact of GGBFS is more remarkable. It was observed that a comparable shrinkage as reference concrete made of CEM III/A 42,5 N can be achieved if the w/c-ratio is reduced to 0.35 in concrete B035-CEM (20K, 30S, 50LL).

The measured history of specific creep deformations of investigated concretes (creep deformation divided by the applied stress) is illustrated in Figure 1 (right). It should be noticed that the shrinkage and elastic strains were subtracted from total deformation to achieve the net creep deformations. It shows that at the same w/c-ratio, replacement of Portland cement clinker with GGBFS and limestone results in a significant reduction in specific creep deformation. From comparison of concretes B050-CEM III/A and B050-CEM (50K, 30S, 20LL) it can be deduced that at the same w/c-ratio the application of GGBFS leads to slightly smaller creep deformation. However, at w/c = 0.40 and 0.35 limestone and GGBFS behave similarly.

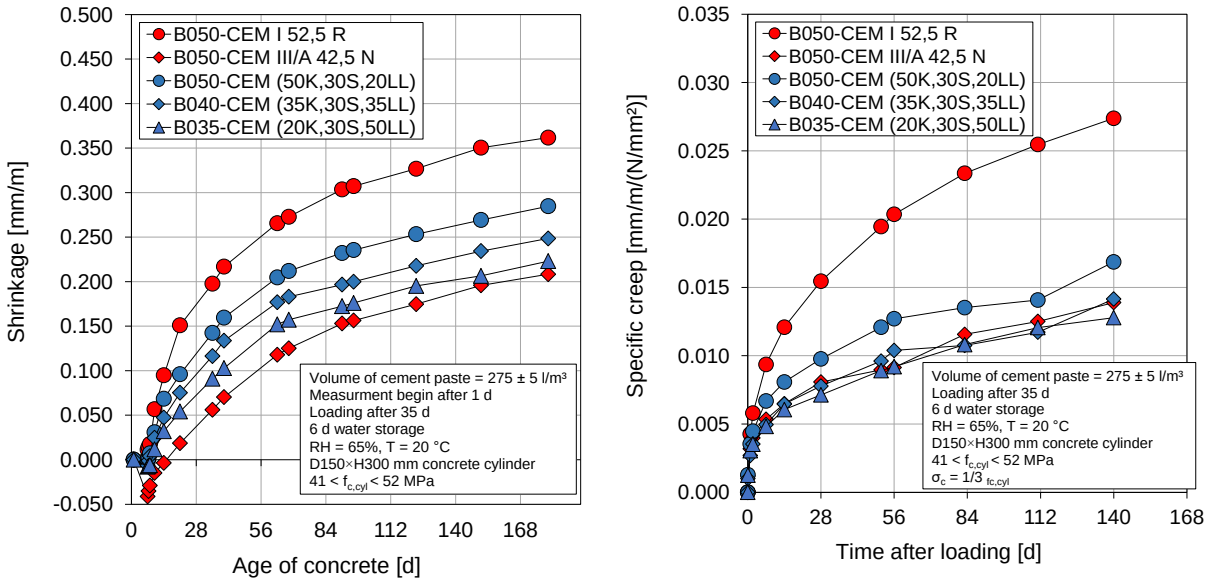

Figure 1: Shrinkage deformation (left) and specific creep deformation (right) of concretes made of reference and clinker reduced cements

INVESTIGATION OF CARBONATION PROFILES IN CLINKER-REDUCED CONCRETES

Sarah Steiner, Barbara Lothenbach (Empa), Tilo Proske, Frank Winnefeld (Empa)

The replacement of Portland cement clinker by limestone is a promising way to improve the environmental performance of concrete. However, high limestone contents can affect the durability negatively, especially its resistance against carbonation (1). The presented work was developed in cooperation with the Laboratory for Concrete & Construction Chemistry in Swiss Federal Laboratories for Materials Science and Technology (Empa). It deals with chemical analysis along carbonation profiles in order to explore the limit of limestone replacement in Portland cement.

The cement used in this study is a Portland cement clinker (CEM I 52.5 R) blended with various amounts of limestone (LL: 0 % to 60 % limestone by mass). Cylindrical paste samples with w/b-ratios (b: cement + limestone) from 0.75 to 0.3 were prepared. The curved surface area and the bottom of the pastes were covered with epoxy to ensure oriented carbonation from top to bottom before beginning accelerated carbonation in 2 % CO_2 or 20 % CO_2 and 65 % R.H. In order to study the carbonation profile with thermogravimetric analysis (TGA), the pastes were sawn into 4 mm thick slices with 2 slices below and 2 slices above the carbonation front induced by phenolphthalein. The sample material for Fourier transform infrared spectroscopy (FTIR) measurements was directly collected along the carbonation profile by using a 1 mm drill after splitting the pastes lengthwise.

The contents of Portlandite (CH) and calcium carbonate (Cc) were determined by using TGA. DTG curves of carbonated limestone-containing cements showed a rather sharp change in phase assemblage near the carbonation front. Especially in pastes with high limestone con-

tents (LL ≥ 20 % for w/b-ratios ≤ 0.6 and LL ≥ 40 % for w/b-ratios ≤ 0.4) the CH seemed to be consumed directly beneath the carbonation front. However, plain portland cement pastes exhibit a broader carbonation front with respect to consumption of portlandite. TGA data indicates a gradual consumption of CH to an extent of 20 mm beneath the carbonation front. The area in which such diffuse carbonation occurs seems to be reduced with increasing water content. The carbonation of C-S-H contains a two-step decalcification process which leads to a reduction of C/S ratios (2). The development from C-S-H with high C/S to amorphous silica can be detected by FTIR (Fig. 1 A). FTIR Measurements of the pastes showed the presence of C-S-H directly at the carbonation front as well as in the carbonated zone slightly above the carbonation front, whereas no CH could be observed at the carbonated area (Fig 1 B).

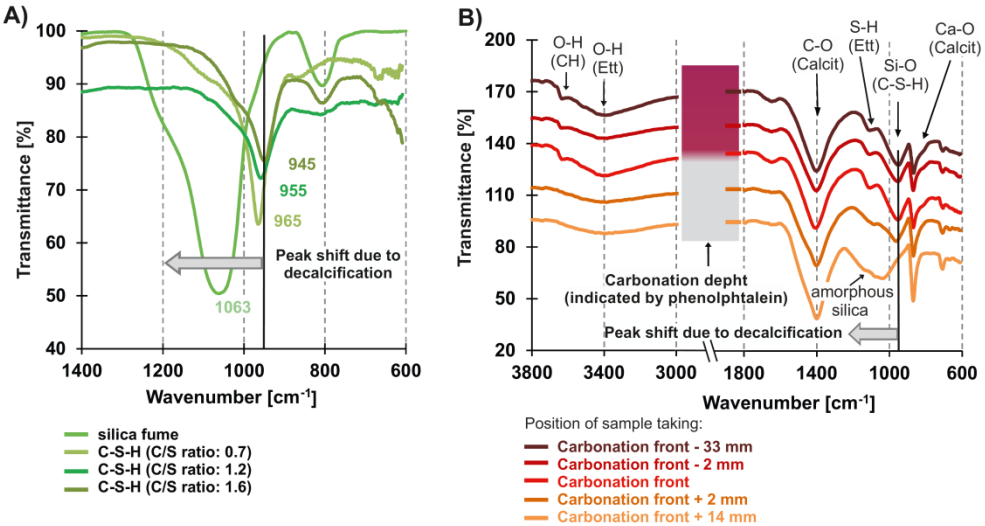

Figure 1: A) FTIR spectra of C-S-H phases at different C/S ratios; B) FTIR spectra of Portland - limestone blended cement paste (LL: 60 %; w/c: 0.5; carbonated for 53 d at 2 % CO_2).

(1) S. Hainer; Dauerhaftigkeit klinkerreduzierter Betone - Ein Modell zur Bestimmung des Karbonatisierungsfortschrittes, Dissertation TU Darmstadt (2015)

(2) T. Sevelsted, J. Skibsted; Carbonation of C–S–H and C–A–S–H samples studied by 13C, 27Al and 29Si MAS NMR spectroscopy, Cem. Concr. Res. 71 (2015) 56–65

MODELLING THE MATERIAL FLOWS IN THE VALUE CHAIN OF THE BUILDING SECTOR

Katharina Fritz

Along the entire value chain of the building sector, which is extended from the extraction and processing of raw materials, the product manufacturing and the entire life cycle of the built environment to the recycling, waste disposal and production of secondary raw materials, there is a huge demand for resources. Due to the current provision of data and time series by the official statistics or comparable sources it is currently not possible to assess the resource use of this value chain completely. In order to calculate the material flows in the value chain of the building sector from a bottom-up perspective instead, a modelling approach for the material flows of the built environment is necessary. As a first step, only the resulting material flows are modelled, additional flows will be added prospectively. For example, the material flows can be combined with LCA-data to identify the demand for resources besides the materials by assessing the material flow related emissions into the environment.

The built environment including all buildings (residential and non-residential buildings) and the entire technical infrastructures for traffic, energy, water and information and communication technology with their different components (like bridges, masts of overhead lines, sewage treatment plants etc.) is initially defined for the model. For the calculation of the material flows in the built environment statistical data on stock changes and material indicators for new constructions, expansions, renovations and deconstruction for the different components of the built environment are required. In order to specify the necessary data on stock changes as an input parameter for the model an analysis of official statistics, various studies and additional literature was carried out. Furthermore, material indicators were defined using actual studies and literature. The input parameters and the material indicators with their individual

data source were compiled in a profile for every component of the built environment. Despite of necessary assumptions for some parameters like maintenance cycles and rates, the quality of the input parameters and the material indicators is satisfactory for several components of the built environment. In contrast, due to the poor quality of the input parameters and the material indicators some components can only be represented as an approximation based on many assumptions. Considering these findings, especially the material indicators are a field for further research.

The material flows can be calculated by combining the input parameters and the stock changes between two defined reference years (Figure 1). Due to the fact that the material indicators currently used are related to certain building materials and products like concrete or metal only these material flows were calculated. To use the results for an assessment of a sparing and efficient use of resources it is necessary to capture the related raw material flows instead. By application of indicators for the related raw material consumption of materials a conversion of material flows into related raw material flows is possible. Unfortunately, these indicators for the related raw material consumption of materials are currently not available for every building material and product.

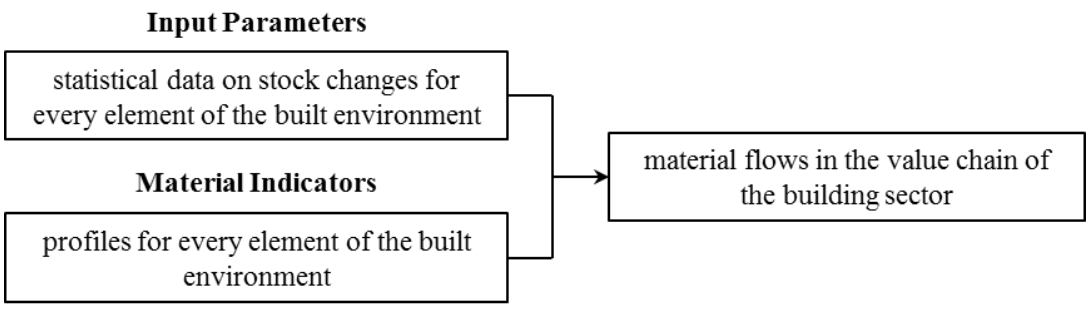

Figure 1: Calculating the material flows in the value chain of the building sector

In conclusion, the modelling of the material flows and the entire resource demand along the value chain of the building sector is possible if the identified problems can prospectively be solved with further research.

SUSTAINABILITY OF WOODEN CONSTRUCTIONS | PART 1

Sebastian Pohl (LCEE), Astrid Reuber (LCEE)

The general sustainability trend in the construction industry results in lobbying activities as well; *e.g.* aiming at a promotion of particular construction methods' exclusive sustainability. Especially the wood industry acts quite bustlingly and tries to place its "greenwashed", but in fact fragile chains of arguments with (in terms of sustainability) naive addressees.

In different joint research studies the Institute of Concrete and Masonry Structures (IfM) and its spinoff LCEE Life Cycle Engineering Experts made clear that sustainability does certainly not comply with the narrowed interpretation of the wood industry. In fact, sustainability (i) has to be an environmental as well as economic and social balance which (ii) has to show over the entire life cycle of (iii) an expedient unit considered (here: a building). Furthermore, the study underlines that masonry buildings are characterised by such a holistic sustainability quality without disadvantages vis-à-vis buildings made of wooden constructions. At present, IfM/LCEE conduct a further study analysing the commonly propagated general sustainability qualities of wooden constructions from different perspectives. The first part of these myths of wooden constructions – presented here in a compressed form – focusses on the following key questions:

- Has Germany sufficient wood resources and is it able to cover an exorbitantly enlarged demand of the construction industry without cancelling principles of a sustainable forestry?
- Do scenarios of using foreign import wood and wood composites have an effect on a building's ecological quality (life cycle assessment)?

The study's answers are quite definite. With regard to the domestic wood resources and their exploitation it has to be stated that *already today*

- the usage of (the) coniferous forests/wood inventory (as determinant for the construction industry) is up to 15 % higher than the natural growth rate,
- Germany is simultaneously depending on the import of coniferous wood and
- the construction industry has to compete on wooden resources especially with the energy sector (see figure 1).

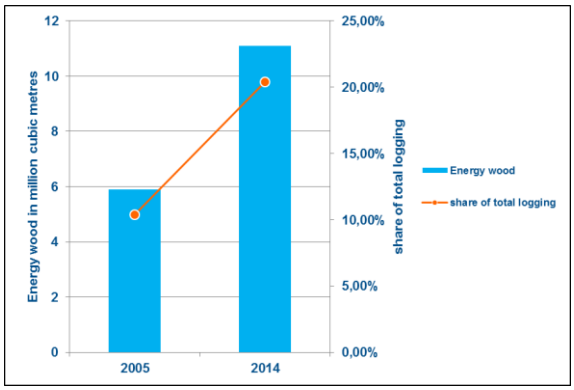

Figure 1: Energy wood in Germany and its share of total logging

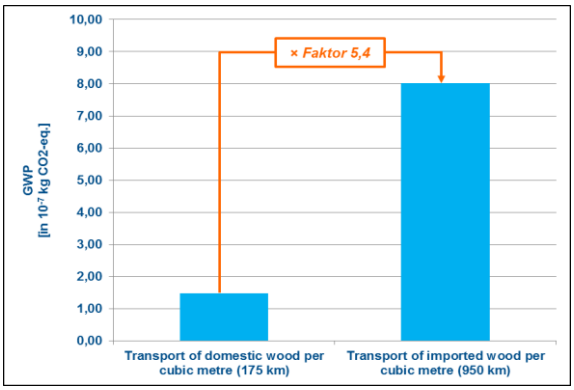

Figure 2: Import effects on transport life cycle assessment

Concerning the ecological impacts of import wood and wood composites one has to say that

- the transport's life cycle assessment increases by an average factor of more than 5 (see figure 2),
- even though this effect influences the overall results of a life cycle assessment only slightly due to other main drivers,
- whereas the differences between domestic and foreign life cycle assessment basis data have a huge influence on life cycle assessment results up to double-digit percentages.

The scheduled second part of the study will examine *inter alia* the sustainability quality of wood-based buildings from a technical/constructional perspective.

SIMPLE APPROACH FOR APPLYING LCA ANALYSIS TO COMPARE DECENTRALIZED ENERGY SUPPLY OPTIONS

Fabian Staab, Claudia Weißmann

Decentralized energy supply options are widely regarded as crucial for increasing the share of renewable energy within total energy consumption. If energy supply is interlinked on a district level, the use of fossil fuels can be significantly mitigated and an ecological benefit is created. However, this ecological benefit comes at the prize of an ecological impact, for example from the production and maintenance of additional building technology. The assessment of the ecological implications of energy supply on a district level cannot be conducted appropriately with the common, single-building approach of German BNB/DGNB-system, whose system boundary compulsorily includes only one building. Though, in a district context energy is shared and used across building boundaries, which makes it inevitable to assess the whole settlement, taking into account collectively used energy technology like storages or photovoltaic systems with their permanent interaction. Therefore, the Institute of Concrete and Masonry Structures has developed a simple approach for applying LCA analysis to compare decentralized energy supply options (1). While the common LCA approach of BNB/DGNB assesses building materials, building technology and heat supply of a single building, the new approach excludes the building materials and assesses the building technology, heat supply and also the electricity supply of the whole district instead.

The advantages of the new approach shall be outlined by the following example. Two scenarios regarding the energy supply of a small district which consists of five buildings are being compared. Scenario 1 comprises five EnEV 2014 buildings which use solar thermal collectors for domestic hot water and gas condensing boilers for room heating. In contrast, scenario 2 consists of three EnEV 2014 buildings as defined in scenario 1, but there are two additional

plus-energy buildings with electrical heat pumps for domestic hot water and room heating. The photovoltaic systems of the plus-energy buildings produce a significant temporary electricity surplus, which is fed into a battery storage and can be distributed to all buildings of the district when needed. A conventional LCA would not allow the comparison of the scenarios since it is unable to capture the interactions between buildings and storage. Furthermore, the photovoltaic systems would be assigned only to the respective building and the ecological benefit for the neighboring buildings could not be measured. The new LCA approach, in contrast, is able to assess the ecological implications properly, which shall be shown for the exemplary impact category "Global Warming Potential" (see Fig. 1): While scenario 2 causes much higher ecological impacts from the production of the building technology, these additional impacts are negligible compared to the distinctly diminished CO_2 emissions for gas and electricity supply. Consequently, the realization of scenario 2 would be highly recommendable according to this analysis.

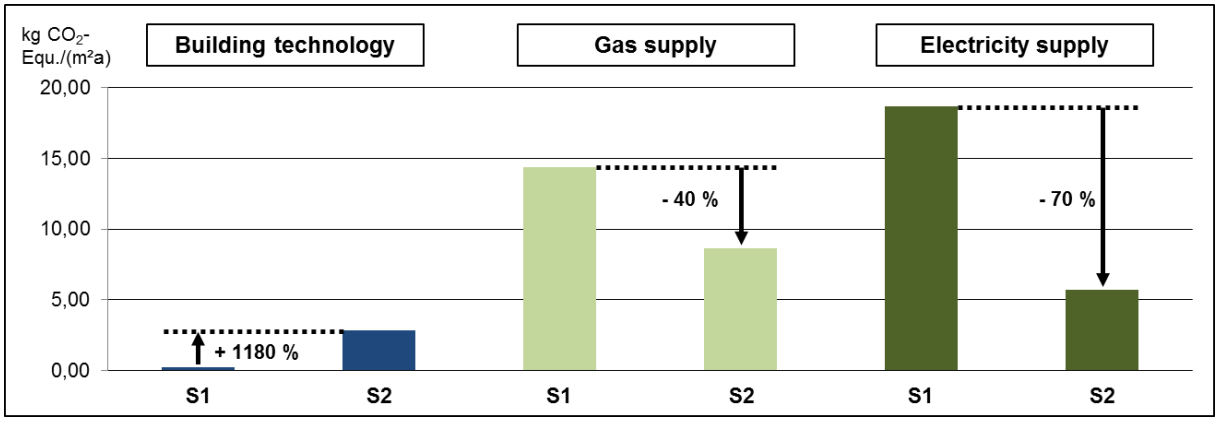

Figure 1: Comparison of Global Warming Potential for scenarios 1 (S1) and 2 (S2)

(1) Weißmann, C.; Staab, F.; Graubner, C.-A.: Development of a simple approach for applying LCA analysis to compare decentralized energy supply options for urban areas, In: Proceedings SBE 16 Hamburg – International Conference on Sustainable Built Environment, 2016, Hamburg, pp. 370-379.

IMPLICATIONS OF THE EEG 2017 FOR THE USAGE OF RENEWABLE ENERGY IN THE BUILDING SECTOR

Fabian Staab, Patrick Wörner

On July 8th, 2016, the German parliament has passed a law for the implementation of tendering procedures for electricity from renewable energy sources and further changes in the legislation of renewable energies (1) which amends the German Erneuerbare-Energie-Gesetz (EEG). Accordingly, the legal framework for producing and subsidizing renewable energy in Germany will change significantly when the EEG 2017 comes into force on January 1st, 2017. The role of this act as a key factor for the implementation of the German "Energiewende" remains unaffected since its success depends strongly on the effectiveness of government subsidies and social acceptance concerning compensation mechanisms like the EEG surcharge. The impacts of the EEG amendment on the production and usage of renewable energy in the building sector shall be outlined subsequently.

The first important change caused by the amendment concerns the subsidy system and the coordination of the expansion of new renewable energy systems (RES). Until 2014, the funding of RES was driven by legally determined feed-in remunerations which made the breakthrough of RES possible in the first place. The current EEG 2014 already implemented tendering procedures for open space photovoltaic plants, which are now fundamentally extended to photovoltaic systems in general, on-shore wind power plants and biomass power plants. However, there are exceptions to the mandatory use of tendering procedures for photovoltaic systems with an installed capacity less than 750 kW, which excludes most photovoltaic systems in the building sector from tendering. If these systems have a capacity less than 100 kW, they are still funded with legally determined feed-in remunerations, whereas the systems with a capacity more than 100 kW are obliged to sell their power directly to electricity markets and are

compensated with a market premium. To further outline the effects of the tendering obligation, a look at the past seems helpful. In 2015, approximately 21 % of the capacity of all photovoltaic systems which were reported to the German Federal Network Agency after their completion would have been affected by the obligation. Therefore, the implementation of tendering procedures can be seen as the first step to a more market-oriented coordination of RES, although only having slight effects on photovoltaic systems on building or district level in the short run, given the usual capacity of these systems under 750 kW. Additionally, an extension of the tendering obligation seems unlikely because the German government considers such an extension as harmful for integrating a wide diversity of parties in the German energy markets as well as causing high administrative effort (2).

The second fundamental change in the amended EEG 2017 related to buildings and districts concerns the use of electricity storage. Such devices are decisive for increasing the own consumption of electricity generated by RES. Hitherto, the consumption of electricity from storage systems has been burdened basically with the double EEG surcharge since the processes of charging and discharging of energy were considered as two separate consumption processes. This double burden is largely eliminated with the amendment of the EEG 2017 and might support a cost-efficient application of storage technologies. As a consequence, the use of storage technology could become more common so that f. e. photovoltaic electricity generated in the afternoon can be used in evening peak load hours without straining the public electricity grid due to the feed-in process.

(1) Official document of German Bundesrat 355/16 of 08.07.2016: Gesetzesbeschluss des Deutschen Bundestags – Gesetz zur Einführung von Ausschreibungen für Strom aus erneuerbaren Energien und zu weiteren Änderungen des Rechts der erneuerbaren Energien.

(2) Official document of German Bundestag 18/8860 of 21.06.2016: Gesetzentwurf der Fraktionen der CDU/CSU und SPD – Entwurf eines Gesetzes zur Einführung von Ausschreibungen für Strom aus erneuerbaren Energien und zu weiteren Änderungen des Rechts der erneuerbaren Energien.

REFLECTIONS ON STAKEHOLDER SPECIFIC REQUIREMENTS FOR CONSTRUCTION LOGISTICS

André Tischer

The optimal planning and operations of logistics issues of construction projects has always to consider a number of industry-specific constraints and characteristics, as for example the construction project's high degree of individuality, or the number of location-bound specifications of any construction project. Beside such constrains the construction logistics has also to reflect a wide range of requirements determined by different stakeholders from the direct environment of a site. Stakeholders - that always should be considered within the design and operations of construction logistics - are, in particular: (i) the building owner or one of his representatives, (ii) the public and public authorities, (iii) the construction companies (contractors) and their suppliers, and (iv) the disposal contractors.

(i) The building owner usually is the initiator of a construction project; thus, logistics constraints such as the location, type and size of a construction project are defined by him. Furthermore, he or one of his representatives is the main contact for all stakeholders of a project, and he sets up the main project targets. Cost-effectiveness, compliance with legal minimum requirements, or an efficient and smooth progress of construction are essential parameters by which the success of construction logistics from the perspective of the building owner is measured.

(ii) The public, including directly affected neighbors of a construction project, and public authorities lay down requirements to comply with laws and regulations on construction projects. Indeed, this has to be considered by the construction logistics when developing and implementing a logistics concept that is compliant to the respective legislations and regulations. This applies, for example, to the coordination and unloading process of material transports on

the site, as it is usually desirable not to disrupt public transport in the immediate environment of a construction site. Another example is that construction waste has to be separated and disposed in accordance to the legal requirements.

(iii) Construction companies and contractors commit themselves towards the client to provide the contractually agreed scope of manufacturing services. That is why each of them is sometimes strongly interested in a smooth and uninterrupted construction progress of their own work. Thus, requirements from these stakeholders to construction logistics are strongly stated to the smooth support and coordination of material transports to site, and to the proper material handling and transportation from the unloading area to the point of installation on-site. Furthermore, the suppliers that are commissioned by the contractors to deliver goods of logistics such as building materials or site equipment require from the construction logistics to ensure a smooth material handling and unloading process of their incoming material deliveries to a construction site.

(iv) Within the construction logistics of disposal, the disposal contractors require the implementation and controlling of the waste management concept - such as a proper collection and separation of the construction waste - as it is defined in the design phase of a construction project. In particular, waste contractors demand for a smooth transportation process of the construction waste from site to their disposal option.

In the light of the considerations made above, it can be stated that a large number of stakeholder-specific requirements influences the preparation and implementation of logistics issues for a construction project both from the viewpoint of the construction logistics of delivery and from the viewpoint of the construction logistics of disposal.

EVALUATION OF THE COST RISKS IN THE LIFE CYCLE OF INDUSTRIAL BUILDINGS

Gökhan Uysal, Carl-Alexander Graubner

Despite the continuously rising sales volumes of industrial products, companies are increasingly confronted with saturated markets and turbulent market situations. Companies respond to this volatile demand situation with a diversification of the product range and increase the individualization options. However, this increases also the complexity of the production system and the factory buildings. In contrast, the increase of complexity is offset by the trend of shortening the product life cycle. In order to keep the ability to respond on today's markets the product development times and production durations are significantly shortened. Through these changes an additional time pressure arises for the planning and construction of industrial buildings. Particularly, in consumer products which are characterized by a synchronous development of product and production system the early planning phases are crucial, because of the highest ability to influence the life cycle costs. However, due to the higher uncertainty in the planning phases and short planning periods, the planning basics und information are going to be increasingly inaccurate. So it is necessary to work at the start of the construction planning phase with fuzzy information regarding the product and the production system. Especially, this leads to cost risks in the life cycle of industrial buildings. In the past, buildings were usually planned after the planning of the production system was finished. Therefore, the architectural planning was placed over the production layout and the needed floor spaces were determined, amongst other things, for the life cycle cost analysis. In contrast to that, these days the construction of the building is often started before the actual definition of the production system is finished. Figure 1 shows the described conflicts in the early planning phases of industrial buildings.

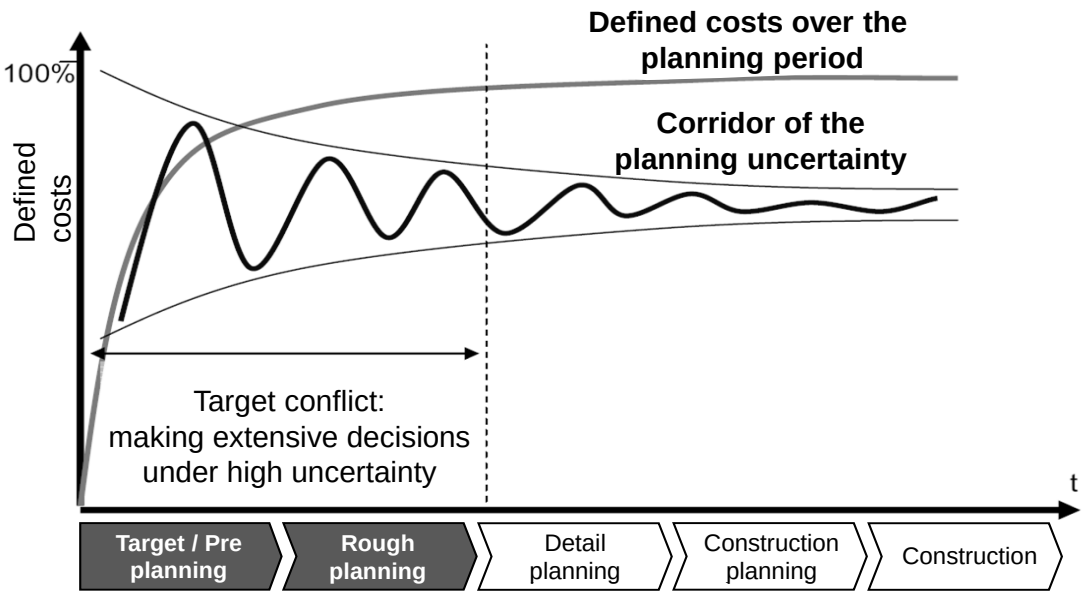

Figure 1: Decision under uncertainty in the factory planning

To address the described uncertainties and to quantify cost risks over the entire life cycle, a method to calculate life cycle costs with a probabilistic approach is currently being developed at the Institute of Concrete and Masonry Structures. This allows for the first time to combine the two target fields of economic sustainability "life cycle costs" and "convertibility" in one costing model. The model is especially designed for the early planning phases and requires for the calculation of life cycle costs a minimum of building information, due to a new type of calculation method. Furthermore, the method allows an objective measurement and determination of the building flexibility level. In this approach the life cycle costs incl. the costs of conversions are estimated in dependence of the building flexibility level with the help of statistically normed correction factors. The calculations are also embedded in a probabilistic decision tree. This means that cost risks due to fuzzy input variables can be quantified by the use of probability distributions, as well as cost risks due to uncertain life cycles and usage scenarios by state dependent calculations of expected values. Finally these cost risks can be taken into account as part of the investment selection decision.

DEVELOPMENT OF ELECTRICITY LOAD PROFILES FOR EDUCATIONAL BUILDINGS

Claudia Weißmann

Realizing the turnaround in energy policy is one of the most important goals in achieving a reliable, environmentally friendly and efficient energy supply in the future. Because of the high fluctuation of electricity production from renewable energy sources, the energy demand of buildings has to be determined in small time steps. For this purpose, load profiles can be applied, which describe typical variations in electricity demand over the day. Load profiles for homes, office buildings, and retail have already been developed by the German Association for the Energy and Water industries (BDEW) and in the German standard VDI 4655. However, representative profiles for educational buildings do not exist yet. The development of such profiles for secondary schools, based on real-time data of six educational buildings (1), is described in the following.

First of all, the necessary number of typical day categories is to be defined. One can assume that the electricity demand of school buildings is driven by seasonal influences. Therefore, in accordance to the BDEW and VDI 4655 profile methodology a categorization in winter (W), transition (Ü) and summer (S) is being applied. As in VDI 4655, the criterion for the differentiation is the average daily outdoor air temperature. Another necessary distinction results from the different occupancy behavior during the workdays from Monday to Friday (W) and the weekend days Saturday and Sunday (S). Hence, this results in six different typical day categories. As the monitoring data is based on a 15-minutes time step, a quarter hour resembles the minimum optional time step for the developed profiles. The BDEW standard load profiles, as well as the VDI 4655 profiles for multi-family houses, consist of the same time step. This aspect simplifies the conjunction of the different profiles in future research. After the typical

day categorization, the monitoring data is normalized, cumulated and the average load profile is determined. The final representative school load profile is the real dataset that is most equal to the average profile. This dataset can be identified with the least squares method.

Figure 1 shows the developed school profile applied on the seasonal varying, average daily demand. The maximum demand peak appears during winter season work days, which can be explained by the increased use of lights and auxiliary energy of the heating system. On the weekend days, the average daily load decreases distinctly because of the building disuse. During operation hours the variability of the electricity load (i.e. between lessons) is represented well by the developed profiles. Hence, the load profiles are applicable for the assessment of electricity producing building technology (photovoltaic or combined heat and power systems) in schools, as well as for the analysis of interlinked supply systems on the district level.

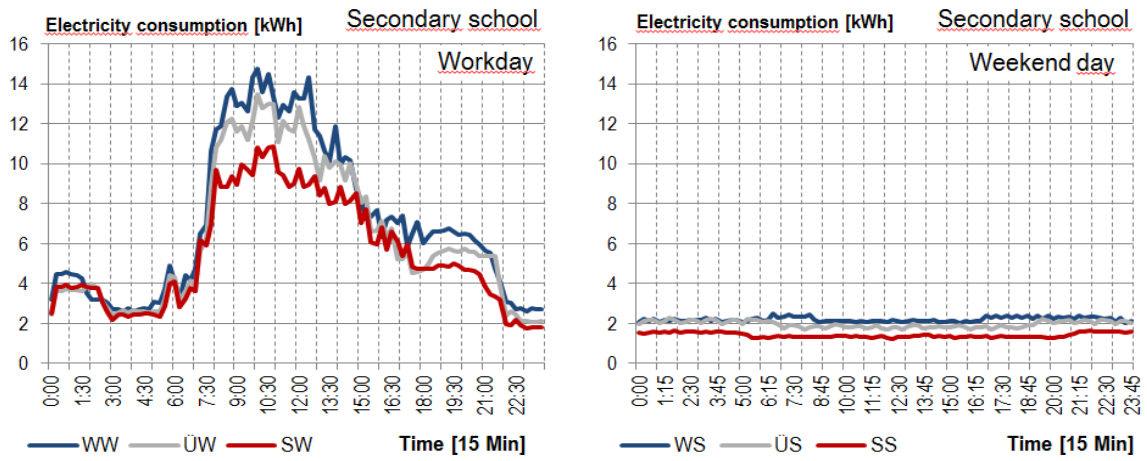

Figure 1: Electricity load profiles – Secondary school: Workday (left), Weekend day (right), applied on the average daily load

(1) Stadt Frankfurt am Main: Hochbauamt, Abteilung Energiemanagement: Automatische Verbrauchserfassung. Online: http://www.energiemanagement.stadt-frankfurt.de.

PUSHING FORWARD THE ENERGY TRANSITION IN BUILDINGS BY ELECTRIFYING THE HEATING SECTOR

Patrick Wörner, Fabian Staab

In the light of energy transition, the use of fossil fuels is supposed to be strongly reduced in the next years whereas the share of renewable energy shall be expanded significantly. Today, more than a quarter of the German electricity production is based on renewable energy, but the share in the heat supply is only 10%. (1) Therefore, while integrating more renewable energies in the electricity sector, the absolute precondition for energy transition is a further substitution of fossil fuels in the heating sector, where oil and gas are still the prevalent energy sources. However, the main problem to achieve this comes down to the fluctuating presence of solar or wind power, which needs to be handled in order to balance energy production and consumption, as it can be done relatively unproblematic in conventional energy systems. Besides shortages in times of peak demand, especially supply peaks will increasingly strain the German power grid if the share of these energy carriers continues to rise. As a consequence, the connection of the electricity and heating sector becomes necessary to enhance the flexibility of energy systems and to put energy surpluses from renewable energy to another use.

By implementing appropriate electricity-based heating systems as part of other energy-saving measures, thereby causing additional demand for electricity, the above mentioned supply peaks could be used reasonably, while simultaneously pursuing the energy transition in the building sector. In the past, the application of resistance heating (for example in the form of electric floor heating) and night storage heaters appeared to be extremely inefficient and led to a sceptical attitude towards electric heating systems. Meanwhile, especially heat pump systems have been proven suitable for broad usage. (2) In addition, regenerative energy surpluses may be exploited through methods such as power-to-heat. Last but not least, these surpluses

can be utilised in cogeneration plants to cover peak heat loads. (3) These exemplary technologies pave the way for a flexible and efficient use of electricity in the context of heating. In combination with an energy storage, the ecological and economic advantage will be even bigger as electricity supply and demand can be decoupled temporally over various periods. In the long run, the building mass itself might serve as a thermal storage absorbing heat energy during periods with high regenerative energy supply and providing a comfortable indoor climate in times of low supply. Particularly massive building materials, such as reinforced concrete or masonry, are suitable as they are characterized by high specific heat capacities.

As soon as reliable studies are able to demonstrate the effectiveness of these diverse individual technologies and technology combinations, electric power from renewable sources will become the dominant form of energy in the future, as well in the heating sector. (4) Due to the electrification of the heating sector, the resulting beneficial use of supply peaks and the consequent synchronisation of energy production and demand through intelligent electric heating systems, the energy transition is moving from an electricity-focused development to a fundamental change in the way buildings are heated.

(1) European Commission (2016): EU Energy in Figures: Statistical Pocketbook 2016. Publications Office of the European Union, Luxembourg, S. 27.

(2) Günther, M. (2015): Energieeffizienz durch Erneuerbare Energien. Möglichkeiten, Potenziale, Systeme. 1. Aufl., Springer Vieweg, Wiesbaden, S. 103 und S. 108 ff.

(3) Lund, H. et al. (2012): From electricity smart grids to smart energy systems – A market operation based approach and understanding. In: Energy, Vol. 42, Issue 1, S. 96-102, S. 97 f.

(4) Williams, J. H. et al. (2012): The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity. In: Science, Vol. 335, Issue 6064, S. 53-59.

WHIT EXCURSION TO NUREMBERG

René Mazur, Benjamin Purkert

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 Nuremberg, and 42 students, four scientific assistants and three professors participated. From May 17th to May 20th the group visited a lot of interesting and fascinating construction sites on their way to and in Nuremberg.

The excursion started on time at 07:45 AM on Tuesday morning at the Lichtwiese in front of the faculty building, where the bus with the students from Kaiserslautern collected the Darmstadt students. Apart from the ride to Nuremberg, there were two stops in Würzburg and Großreuth bei Schweinau on the agenda. At the first stop in Würzburg we could visit the construction site of a new steel composite freeway bridge and the Würzburger Residenz. In Großreuth we focused on the construction of a new school complex. On Wednesday there were various interesting locations in Nuremberg waiting for the group. We started with a special guided tour about the building history of the Reichsparteitagsgelände, then went to the sand-lime brick factory of the company Zapf and to the construction site of a new subway tunnel. The special challenge on this construction site was to comply with very high requirements on noise protection. Therefore, the construction company had to deal with extra noise protection arrangements, like temporary noise barriers or low-noise machinery. The day ended with a collective visit of the Erlanger Bergkirchweih. The third day started with a tour on the factory site of the company LUXHAUS which produces prefabricated houses. Here the students could see every fabrication step through the production of a prefabricated house. In the following we drove to Ingolstadt to see a virtual tour through the production halls of Audi

and we visited the construction site of a huge office building. Back in Nuremberg we passed the last evening having dinner together. On our way back home, we stopped at the construction site of the new railway tracks near to Breitengüßbach/Zapfendorf. Furthermore, the students learned many things about building a prestressed concrete bridge, when we stopped at the construction site of the Aurachtalbrücke.

Figure 1: Picture of the participants from Darmstadt on the Zeppelintribüne

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 aspects. We are very grateful for the financial support of the excursion through the “Freunde des Instituts für Massivbau der TU Darmstadt e.V.” and we like to express hereby our sincere thanks again. The Whit excursion in 2017 is going to be planned by the assistants of the TU Kaiserslautern. For further information you are welcome to contact the person in charge Mr. René Mazur, M.Sc.