DARMSTADT CONCRETE

DACON 2012 001-069 engl.indd 1 13.12.12 12:03

DACON 2012 001-069 engl.indd 2 13.12.12 12:03

DARMSTADT CONCRETE

Vol. 27, 2012

DACON 2012 001-069 engl.indd 3 13.12.12 12:03

CONTENTS

Editorial i

Review of the Year's Events iv

Construction

FULL-SCALE EXPERIMENTS TO INVESTIGATE THE PRESSURE OF FRESH CONCRETE BY INCLINED FORMWORKS 1
Björn Freund, Tilo Proske, Carl-Alexander Graubner

EXPERIMENTAL DETERMINATION OF THE LOAD CAPACITY RESERVES OF EXISTING BUILDINGS 3
Ulf Grziwa, Carl-Alexander Graubner

ALTERNATIVE METHOD FOR EVALUATION OF ANCHOR CHANNELS UNDER FATIGUE LOADS 5
Andreas Heck, Karl-Heinz Lieberum, Harald Garrecht

RELIABILITY OF INNOVATIVE UHPC-COLUMNS 7
Martin Heimann, Carl-Alexander Graubner

MEMBRANE COMPRESSIVE STRESSES IN MASONRY CONSTRUCTION 9
Michael Schmitt, Carl-Alexander Graubner

EFFICIENT CONSTRUCTION LOGISTIC: PRINCIPALS AND RESEARCH APPROACH 11
André Tischer, Carl-Alexander Graubner

BENCHMARKING ON STOCHASTIC SIMULATION-METHODS 13
Ngoc Linh Tran, Martin Heimann, Carl-Alexander Graubner

A NEW ALGORITHM FOR LATIN HYPERCUBE SAMPLING 15
Ngoc Linh Tran, Carl-Alexander Graubner

DACON 2012 001-069 engl.indd 5 13.12.12 12:03

Materials

DETERMINATION OF RHEOLOGICAL PROPERTIES OF WATER-REDUCED FRESH CONCRETE USING A RHEOMETER 17
Stefan Hainer, Tilo Proske, Moien Rezvani, Carl-Alexander Graubner

CONCRETE MADE WITH ADVANCED CEMENTS FOR ENVIRONMENTALLY FRIENDLY CONCRETE CONSTRUCTION 19
Stefan Hainer, Tilo Proske, Moien Rezvani, Carl-Alexander Graubner

INFLUENCE OF AGGREGATES ON THE RHEOLOGICAL PROPERTIES OF LOW WATER CONCRETE MADE OF CLINKER REDUCED CEMENT 21
Moien Rezvani, Stefan Hainer, Tilo Proske, Carl-Alexander Graubner

DEVELOPING AN ULTRA HIGH PERFOMANCE CONCRETE FOR EXTREME FILIGREE PRECAST CONCRETE ELEMENTS 23
Frank Röser, Andreas Heck, Harald Garrecht

DEVELOPMENT OF NEW TECHNOLOGY OF LIGHTWEIGHT GLASS CERAMIC MATERIALS FROM PRIMARY AND RECYCLING RAW MATERIALS 25
Svetlana Volland, Vladimir Vereshchagin, Olga Kazmina

Energy Efficient Building Operation

MONITORING AND ENERGETIC REFURBISHMENT BY THE EXAMPLE OF A HISTORIC STRICKBAU IN APPENZELL 27
Elena Alexandrakis, Andreas Heck, Christian Renner, Simone Reeb, Harald Garrecht

NON-INVESTMENT-RELATED MEASURES OF OPTIMIZATION FOR ENERGY EFFICIENT BUILDING OPERATIONS 29
Christian Siegel

Sustainability

SUSTAINABILITY ASSESSMENT OF HOUSES 31
Torsten Mielecke

SUSTAINABILITY IN BUILDINGS' OPERATION 33
Sebastian Pohl, Carl-Alexander Graubner

Student Activities

PENTECOSTAL EXCURSION TO KRAKOW,
WROCLAW AND PRAGUE FROM 28/05/2012 TO 06/02/2012 35
Jaroslav Kohoutek, Carl-Alexander Graubner

Volumes published to date

An overview of the volumes published to date can be found at *www.darmstadt-concrete.de*.

DACON 2012 001-069 engl.indd 8 13.12.12 12:03

EDITORIAL

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

With this, the 27th issue of "Darmstadt Concrete", we would like to inform you of the Institute's manifold activities in the past year. The year 2012 was marked not only by important political events but also saw significant personnel changes in our Institute with which this foreword intends to acquaint you.

Harald Garrecht, Prof. Dr.-Ing., Professor of "Werkstoffe im Bauwesen" and a long-standing member of our Institute, has decided, after much thought and a long personal struggle, to accept a call to the University of Stuttgart to take up the Chair of Construction Materials with effect from the summer semester 2012. At the same time he was appointed Scientific Director of the Materials Testing Institute of Stuttgart (Otto-Graf-Institut), one of the largest facilities of its kind in Germany. His colleagues at the Institute wish to thank Professor Garrecht for his great commitment to the University and in particular to our institute. The scientific impetus he has given and the research funds raised by him have contributed decisively to our Institute becoming one of the most significant scientific facilities of Darmstadt TU in terms of its academic staff. Professor Garrecht has kindly offered to ensure, in parallel to his manifold new tasks in Stuttgart, the teaching in his charge at Darmstadt until the start of the summer semester 2013. This demonstrates again his extraordinary willingness to offer co-operation which we will undoubtedly continue in the years ahead. In the meantime the Chair of "Werkstoffe im Bauwesen" has been advertised and we hope to fill the position in due time.

In the course of the year, Dr.-Ing. Holger Schmidt, Head of our Research and Test Laboratory for many years, unfortunately decided to look for new professional challenges in engineering practice and to leave our Institute with effect from 01.08.2012. Dr. Schmidt had a leading role in the work of the Research and Test Laboratory in recent years and played an instrumental part in creating also the requisite economic conditions for such a laboratory. His ideas and his commitment to gaining new clients but also to realigning content will be much missed, even though we have agreed also with him close collaboration in the future. We all wish Dr. Schmidt great success in his new professional environment.

The abolition of military service, shorter grammar school education and a constantly rising proportion of graduates with qualification for university entrance have again this year led to a rise in university applicants, making it necessary to maintain entrance restrictions for undergraduate courses of the faculty of "Bauingenieurwesen und Geodäsie". It remains to be seen whether the students selected will indeed allow an improvement in the quality of education and in particular the body of knowledge of graduates. At any rate, with shrinking staff capacities the burden put on those employed in teaching has risen dramatically and can be offset only in part by cross-subsidisation from funds earmarked for research. Particularly annoying in this connection are the ever increasing bureaucratic interventions in teaching and research procedures combined with simultaneous cut-backs in public sub-

DACON 2012 001-069 engl.indd 9 13.12.12 12:03

sidies for higher education. This leads not only to important staff capacities, which are more than ever needed in research and teaching, being taken up unnecessarily and ineffectually but also to potential frustration of employees and managerial staff. We will have to consistently counteract this in future and pay greater attention to content so that we continue to win the best junior people for scientific development at the University.

In the following we wish to inform you first about general activities with which our Institute presented itself to the sector's public. In addition to our tasks in research and teaching we consider it indispensable to develop further through an ongoing exchange with the sector. In this connection we would like to draw your attention to the "2. Ingenieurkongress" to be held at Darmstadt TU on 12th and 13th March 2013, in which our Institute plays an important part. Do take the opportunity to meet again with Friends of the Institute and use this unique occasion of ongoing professional development with renowned experts.

The information on our memberships in standardisation bodies and associations will tell you where and from whom you can get technical support at the Institute. Should you have any queries or suggestions, please contact us at any time. We will be pleased to help you.

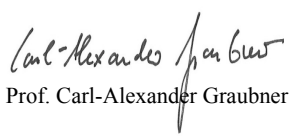
One of our particular aims with this publication is to give you an insight into current or recently completed research projects. Therefore, as in previous years, you will find in this volume brief reports by our scientists on current activities and development projects, both in German and in English. The departments aim to scientifically address problems related to solid construction and to work out solutions in the framework of basic and application-oriented research.

We would like to take the opportunity of this annual review to thank our colleagues for their performance. The success of our Institute would be inconceivable without the high quality and great commitment which our academic and administrative staff but also the employees in the laboratories put into the projects and the performance of their tasks. At the same time we congratulate those academic colleagues who have gained their doctorate.

Our special thanks go to the Friends of the Institut für Massivbau der TU Darmstadt e.V. and in particular to the committee members Dr. Simsch, Mr. Hanek and Dr. Six for their constant and kind support. They not only assist us as organisers of the Darmstädter Massivbau Seminars but sponsor our Institute as well as our students in a highly committed way.

This past year's successes of our research and the high level of acceptance of our work among students let us face the future with optimism. On behalf of the entire Institute we wish you and your families a happy and peaceful Christmas and a good start into the New Year.

Prof. Harald Garrecht



Prof. Carl-Alexander Graubner

DACON 2012 001-069 engl.indd 10 13.12.12 12:03

DACON 2012 001-069 engl.indd 11 13.12.12 12:03

REVIEW OF THE YEAR´S EVENTS

Seminars and further education

On March 7th and 8th, 2012 the 36th "Darmstädter Massivbauseminar" of the Friends of the Institute of Concrete and Masonry Structures and building Materials of the TU Darmstadt was taking place. The title was: „Eurocodes 2012 compactly – Use the chance". With nearly 300 participants, the seminar was a great success, which was confirmed by the positive feedback from the participants. Significantly to the success have contributed renowned speakers. On the evening of the first day in the Karolinen Saal of the Hessischen Staatsarchiv was given a commemorative event. The keynote of the commemorative event spoke Mr. Dipl.-Ing. Stefan Klos from PROPROJEKT Planungsmanagement & Projektberatung GmbH, Frankfurt. At this point we want to thank the speakers for they great articles and presentations. Following an overview of the speakers:

Dipl.-Ing. G. Breitschaft; Official boundary conditions of the Eurocodes

Prof. Dr.-Ing. C.-A. Graubner ; EC 0 – Basis of structural design + EC 1 – Action on structures and EC 6 – Masonry Structures

Dr.-Ing. F. Fingerloos; EC 2 – Concrete Structures

Prof. Dr.-Ing. J. Hegger; EC 2 – Concrete Structures

Prof. Dr.-Ing. R. Stroetmann; EC 3 – Steel structures

Prof. Dr.-Ing. G. Hanswille; EC 4 – Composite steel and concrete structures

Prof. Dr.-Ing. S. Winter; EC 5 – Timber structures

Dr.-Ing. B. Schuppener; EC 7 – Geotechnical design

Dr.-Ing. C. Butenweg; EC 8 – Earthquake design

DACON 2012 001-069 engl.indd 12 13.12.12 12:03

Further education for structural engineers – from practice for practice

- Review on the series of seminars 2012 and outlook on the series of seminars 2013

In the year 2012 the department of solid construction invited once more to the series of seminars called: „Further education for structural engineers – from practice for practice". Over the course of one year we were able to invite over 600 structural engineers from regional building companies and engineering companies. Therefore the series of seminars was booked up again and a tremendous success.

During the 6 single sessions, which were divided into 3 sessions in spring and 3 sessions in fall, the participating engineers got informed about topics in civil engineering that are related to practice.

- The agenda of our meetings had the following contents:
- Building physics: heat, sound | 15th February 2012
- Special problems of designing | 29th February 2012
- Design of bridges in accordance with Eurocode | 28th March 2012
- Non-destructive inspection for structural planning | 12th September 2012
- Steel construction in the built environment | 26th September 2012
- Sandwich panels and double walls | 10th October 2012

After the success of last year we will host the series of seminars again next year. We already received applications for next year's seminars, so that we are looking forward to repeat last year's success. As last year, there will be 6 sessions and this time the focus lies on related to practice examples of assessments concerning the new Eurocode, which came into operation on 1th of July 2012. In detail the agenda for 2013 looks like this:

- Examples of calculation following Eurocode 6 – Masonry | 13.02.2013
- Facade technology and glass building | 20.02.2013
- Examples of calculation following Eurocode 3 – Stahlbau | 06.03.2013
- Examples of calculation following Eurocode 2 – Stahlbetonbau | 18.09.2013
- Examples of calculation following Eurocode 7 – Geotechnik | 25.09.2013
- Calculation in case of fire | 09.10.2013

As in the previous year, we already have convinced renowned speakers from science and industry to speak at our seminars. Therefore we hope that the attractive contents and the renowned speakers are reason enough to repeat last year's success and get as many structural engineers interested in our seminars as last year.

DACON 2012 001-069 engl.indd 13 13.12.12 12:03

Workshop “Darmstadt days of prefabricated concrete elements 2012”

In cooperation with the professional association „Deutscher Betonfertigteilbau e.V.“ and the „Beton Marketing West GmbH“ a lecture on prefabricated construction pieces takes place at the departement of solid construction within the workshops of the Darmstadt days of prefabricated concrete elements since 2008. It implies four single events and an extra student day, in which the lectures of renowned speakers from science and practice will be deepened in a practical part. The workshop addresses not only students but engineers, too.

The students have to participate fully, while engineers can choose from different themes on prefabricated construction pieces. Therefore topics are arranged in groups on a daily basis . This will be continued in the workshop series in 2013:

- Day 1: „Planning/Creating/Production“, 2013-02-21
- Day 2: „Pre-dimensioning and pre-stressing “, 2013-02-22
- Day 3: „Calculation and concrete“, 2013-02-28
- Day 4: „Assemblies: construction and assessment“, 2013-03-01

Additionally a fair on prefabricated construction elements with well-known producers will accompany the workshop.

Ready-made construction already starts with the sketch. It contains special construction elements respectively methods, such as job-mixed concrete additions or biased constructions, consideration of stability, for example steadiness and bracing, and assessment and construction of assemblies. The last year’s event offered the more than 100 students and engineers a diversified and interesting spectrum of themes. It was a successful event with interesting lectures, practical life examples and a popular trade show, which we hopefully can continue as successful in 2012.

For information on subjects, dates or application please contact Michael Schmitt M.Sc.

DACON 2012 001-069 engl.indd 14 13.12.12 12:04

Eurocode 2 for technical drawers

The new generation of standards introduced by the building inspectorate on 1th of July will not only pose as challenge to the planning and operating engineer. Especially since at the same time the national standards are annulled. With the introduction of DIN EN 1992 other rules became effective, that are important in the construction of concrete buildings and are therefore especially crucial for technical drawers. In view of the above the department of solid construction hosted a seminar with the title „Eurocode 2 for technical drawers“ at the Gewerkschaftshaus in Frankfurt. Following an introduction into standardising of reinforced concrete construction, Mr. Prof. Dr.-Ing. Jürgen Schnell from the University of Kaiserslautern presented the EC2 with national annex to the audience. The focus of the seminar was: Basic structural planning. Die focal subjects of the seminar consisted of: Basics of structural design planning, building materials, durability, concrete cover, reinforcement and constructional rules and prefabricated parts as well as lightweight concrete.

We have to thank Mr. Prof. Dr.-Ing. Schnell, who not only initiated and planned the seminar, but also made himself available as speaker at the afternoons of the seminar.

DACON 2012 001-069 engl.indd 15 13.12.12 12:04

Collaboration in university bodies

In April of this year, Prof. Graubner was elected as new chairman of the standardisation committee NA 005-06-01 AA "Mauerwerksbau", the foremost national body dealing with issues of standardisation in the field of masonry, and simultaneously as German delegate at European level. He is therefore responsible for all tasks leading to the introduction of the European design regulations in the field of masonry. Prof. Graubner was also recently confirmed in his second term as representative of DIN-Committee NA 005-51-01 AA "Grundlagen für Entwurf, Berechnung und Bemessung von Tragwerken". This standardisation committee deals with basic aspects of calculation and design of structures and thus is also of key significance for the introduction of the European standards. In addition, Prof. Graubner is a member of the standardisation committee NA 005-07-01 AA " Bemessung und Konstruktion" (design) of the concrete and reinforced-concrete construction sector. Finally, he is a member of the advisory panel of the Federal Ministry for Transport, Construction and Urban Development in matters of sustainable construction ("Runder Tisch für Nachhaltiges Bauen") and is active in the working party on "Nachhaltigkeitsbewertung der Straßeninfrastruktur" (sustainability assessment of road infrastructure) at the Federal Highways Research Institute.

Prof. Graubner continues to be an elected member of the "Universitätsversammlung" of Darmstadt TU. In addition, he collaborates with the "Förderinitiative Interdisziplinäre Forschung" at Darmstadt Technical University. The FiF links scientists, bundles interdisciplinary activities and transfers research results to teaching. At the same time, Prof. Graubner is involved, in a leading position, in the "Energy Science and Engineering" graduate school recently acquired by Darmstadt TU and financed by the Deutsche Forschungsgemeinschaft.

DACON 2012 001-069 engl.indd 16 13.12.12 12:04

Excursions

On 15.06.2012 the solid bridges excursion to the two highway viaducts Windelbach and Ambach near Herborn took place. Among those attending were about 20 students, Professor Graubner and 3 scientific employees. The steel composite bridge Windelsbach consists of two steel box girders with a concrete deck. The tour participants were able to witness both the reinforcement works of the bridge deck as well as the production of the bridge parapets using the continuous casting method.

Construction site of the viaduct Windelbach

Then we went to the Viaduct Ambach, which is just 300 meters away. The Viaduct Ambach consists of a prestressed concrete box girder which was reinforced by additional tendons. Walking through the box girder the students got not only explanations of the technical details of the bridge, but also a fascinating piece of detective story, for the box girder of the bridge is a former site of a kidnapping case. This trip was only possible with the generous support from the "Freunde des Instituts für Massivbau". We would like to thank the members at this point sincerely.

This year the large excursion from 28.05. to 02.06.2012 of the Institute of Concrete and Masonry Structures of the TU Darmstadt and the Institutes of Concrete and Masonry Structures and Steel Construction of the TU Kaiserslautern led the participants to Poland and the Czech Republic (see detailed report by Jaroslav Kohoutek).

The excursion, which was organized by the Institute of Concrete and Masonry Structures of the TU Darmstadt facilitated in addition to the professional development the cultural exchange with the people of our neighboring countries. The excursion was sponsored by the

DACON 2012 001-069 engl.indd 17 13.12.12 12:04

“Verein der Freunde des Instituts für Massivbau der TU Darmstadt e.V.”, for which we are grateful.

Within the courses „Technische Gebäudeausrüstung I und II“ as well as „Facility Management & Sustainable Design“ students received in 2012 a unique opportunity to visit the construction project to the sustainable modernization of the "Greentowers" of Deutsche Bank AG in Frankfurt am Main. The students got a direct view of the extent and of the technical features of this highly regarded construction project, which has led to one of the world's most environmentally friendly high-rises.

The lecture course "Structural Damages and Construction Chemicals" under the responsibility of Dr. Steindlberger included a three-day excursion (May 30th to June 1st) which took the students of the Technical University of Darmstadt to Wolfenbüttel, Brunswick and Hildesheim. Invited by Prof. Leimer from the HAWK Hildesheim numerous participants also from the University of Stuttgart (Prof. Garrecht) and the Jade University (Prof. Wigger) came together.

The effects of climate-related influences inside as well as outside for example by moisture or salt contamination on buildings or inventory were focused. On the one hand technical capabilities of logging climatic data (monitoring), controlling and stabilisation of climate inside churches or museums were presented, on the other hand corresponding case studies were studied and discussed in detail afterwards. Inside the buildings special guidance were offered dealing with restoration concepts or installation engineering. Altogether more than 30 students took part of the excursion.

The first day started with a guided tour through the old town of Wolfenbüttel followed by the visitation of Herzog August Library and Lessing House. Under the reign of Duke August (1579-1666) the library developed to the largest collection of books in Europe containing almost 35,000 volumes of the medieval and early modern literature. A long-lasting and damage-free storage of books requires an adjusted climate controlling which was explained there in detail. Adjacent to the library the so called Lessing House (residential house during his time as a librarian) is now a museum, in which the life and work of Gotthold Ephraim Lessing (1729-1781) in Wolfenbüttel is presented. Other interesting destinations in Wolfenbüttel were the Holy Trinity Church and the Protestant Church of St. Mary which is considered as the oldest most significant Protestant church in the world.

DACON 2012 001-069 engl.indd 18 13.12.12 12:04

Some students in front of the castle in Wolfenbüttel

The Herzog Anton Ulrich Museum in Brunswick is one of the oldest and most important art museums in Germany, its foundation dates back to 1754. Since 2007 restoration work is ongoing also including an improvement of the indoor climate and the renovation of building technology.

On the third and final day the Michaelis Church has been examined prior considering of the construction material, restoration and stabilisation the climate. The former Benedictine Abbey of St. Michael was built in 1010-1020. In 1985 it became a world heritage site. The final location of the excursion, the Roemer and Pelizaeus Museum in Hildesheim, included an interesting guidance through the exhibition rooms and installation engineering.

Additional to the workshops the evening events also enabled numerous contacts and exchange of experiences.

We would like to thank the Friends of the Institut für Massivbau for sponsoring.

DACON 2012 001-069 engl.indd 19 13.12.12 12:04

Personal Matters

Mr. Dipl.-Ing. Markus Hengst ended his long career as a lecturer in the subject Concrete Bridges. For his support in teaching we thank Mr. Dipl.-Ing. Markus Hengst cordially and wish him well for his future. We also thank Mr. Dr.-Ing. Gerhard Zehetmaier, Head of Corporate Development and Technology of the company Bilfinger SE, for his willingness to take over the lectures of Mr. Dipl.-Ing. Markus Hengst.

Wolfgang Klein, CEO of Li-Tec Battery GmbH, has completed his years of work as lecturer in „Technische Gebäudeausrüstung". For his many years of service we thank Mr Klein and wish him all the best for his future. At the same time, we thank Mr Thomas Hess of the Facility and Process GmbH for his willingness to continue the position of lecturer of Mr Klein.

Mr. Dr.-Ing. Michael Six ended his career as a lecturer in the subject Concrete Bridges. For his support in teaching we thank Mr. Dr.-Ing. Michael Six cordially and wish him well for his future. We also thank Mr. Dr.-Ing. Stefan Kempf, CEO of the company Hochreither Vorndran Ingenieurgesellschaft, for his willingness to take over the lectures of Mr. Dr.-Ing. Michael Six.

Mr. Dipl.-Ing. Achim Knauff finished his career at the Fachgebiet Massivbau and is now employed at the company HSG Zander GmbH. Also Mrs. Dipl.-Ing. Clanget-Hulin is not working at the Fachgebiet Massivbau anymore but supports in the future our Spin-off LCEE GmbH.

Our colleagues Dipl.-Ing. Mirko Klein and Dipl.-Wirtsch.-Ing. Kjell Bettgenhäuser have left the Chair of Building Materials, Building Physics and Building Chemistry due to yielding their expertise in industrial enterprises.

DACON 2012 001-069 engl.indd 20 13.12.12 12:04

Doctorate

Intensive research needs the exceptional commitment of the scientific staff. With the completion of a thesis the staff documents the most important results of their scientific work and the achieved gain knowledge of research. This year, we want to congratulate the following employees for successful doctoral degree:

Fachgebiet Werkstoffe im Bauwesen:

Dr.-Ing. Mohammed Morsy
Dr.-Ing. André Klatt
Dr.-Ing. Christian Baumert

DACON 2012 001-069 engl.indd 21 13.12.12 12:04

New Colleagues

Mr. Moien Rezvanie M.Sc. is employed at the Fachgebiet Massivbau since February 1st, 2012. He studied construction engineering at the Mazandaran/Iran und graduated in 2007 with the degree of Master of Science. He worked after this time as a structural engineer in Iran. From 2010 to 2012 he was a scientific assistant at Universität Duisburg-Essen. Mr. Rezvanie works in the field of eco-friendly building material. His current research project aims the development of new cements with high limestone content.

Mr. Dipl.-Ing.(FH) Valentin Förster M.Sc. is employed at the Fachgebiet Massivbau since December 1st, 2012. He studied construction engineering at the University of Applied Sciences Würzburg-Schweinfurt, and worked during this time in the engineering company OBERMEYER Planen + Beraten GmbH. In October 2010 he completed his degree in construction engineering. In 2011 and 2012 he studied construction engineering at the Technical University of Darmstadt and graduated in November 2012 with the degree of Master of Science. Mr. Förster cares the lecture "Mauerwerksbau" and organizes the seminar "Weiterbildung für Tragwerksplaner".

DACON 2012 001-069 engl.indd 22 13.12.12 12:04

Guest Researchers

International Research Experience Program (IREP) Summer 2012

As part of the "IREP Summer 2012 Program" the Department of Concrete and Masonry Structures continued its research cooperation with US-American universities. During their three-monthly research stay Katharina Antje McLaughlin (University of California, Berkeley) and Savannah Claire Goodmann (University of Illinois) addressed the sustainability performance of the institute building concerning the calculation and assessment methodology of the international rating systems LEED and BREEAM.

Development of new production of lightweight glass ceramic materials from primary and recycling raw materials

The science year 2012 has succeeded in showing more visibility to the German Russian science relationship. Within the scope of the joint German Russian research project „Development of new production of lightweight glass ceramic materials from primary and recycling raw materials" (is financed by the Federal Ministry of Education and Research, project manager S. Volland) two Project Planning Workshops have taken place in 2012. Prof. Olga Kazmina from the Tomsk Polytechnic University has worked as a guest scientist in Chair of Building Materials, Building Physics and Building Chemistry.

Awards and Competitions

Award of the Hessian Building Sector 2012

For the 29th time the Association of Construction Enterprises awarded the prize „Förderpreis des Hessischen Baugewerbes" in Wiesbaden on 9th November 2012 for the best theses from the departments of Architecture, Civil Engineering and Construction Industry Management of Hessian universities. The graduate Katharina Fritz was awarded the third prize for her diploma thesis "Realization of sustainability in buildings' operation - development of criteria, assessment methodology and weighting matrix as basic elements of a sustainability guideline". The Department of Concrete and Masonry Structures congratulates its laureate most cordially.

DACON 2012 001-069 engl.indd 23 13.12.12 12:04

The 9th fib International PhD-Symposium in Civil Engineering 2012

With the Intention to support young scientists, the tradition of the fib International Ph.D. Symposium since 1996 continued this year from 22 to 25 July at the Karlsruhe Institute of Technology (KIT). This highly successful event brought together 150 participants from 21 countries. This year the Department of Concrete and Masonry Structures IfM was represented by Mr. Dipl.-Ing. Björn Freund, Mr. Dipl.-Ing. Stefan Hainer, Mr. Dipl.-Ing. Achim Knauff and Mr. Dipl.-Ing. Martin Heimann. In recognition of his research activities in "Reliability of highly stressed UHPC Slender Columns" at the IfM, Mr. Dipl.-Ing. Martin Heimann was awarded as one of the prize-winners this year.

Bilfinger Berger Award 2011

At the TU Darmstadt every Year, excellent young engineers will be awarded for special services with the Bilfinger Berger Award. This Year, Mr. Lukas Stallmeister was awarded the first price for his thesis „Investigations regarding the load bearing behaviour of joints of precast-elements made from cement-reduced concrete“.

Concrete table CONjoin in anthracite grey

Competition DFG SPP - Lightweight Concrete Structures – Concrete Table

Within the priority program 1542 "Lightweight Concrete Structures" of the DFG – German research foundation, a competition under the principle of "form follows force" was announced. It should a product be developed on how the motto "Lightweight Concrete Structures" is just and in its form, the principle of "form follows force" reflects. Restrictions such as maximum weight and size of the items and a cost limit were to be considered in the design. In addition, all participants had to build a prototype and as part of an exhibition presenting.

The Fachgebiet Massivbau had decided to develop a high table. The developed high table has the name: get CONjoin. The CONjoin is made of a Dyckerhoff FLOWSTONE high-

DACON 2012 001-069 engl.indd 24 13.12.12 12:04

performance concrete. It consists of three components: two leg pairs and a table top. The leg pairs can be easily through a connector without connecting means to connect with each other and form a standing proof soles. The table top is placed on the legs and secured with Velcro fasteners in place. Conjoin the high table is weather resistant, durable, easy to clean, non-flammable and are elegant and visually appealing. At this point again the Dyckerhoff be thanked, both for assistance in developing an appropriate mix design, as well as for the provision of the required cement.

Concrete table CONjoin in anthracite grey

OTHER INSTITUTE´S ACTIVITIES

Summer festival

On June 14th, 2012 the general meeting of the "Association of friends of the Institute of Concrete and Masonry Structures and Buildings Materials of the TU Darmstadt" and following the summer festival took place. After the official part of the event Dr. Simsch, the chairman of the association , welcomed numerous members, which used the possibility of reunion and the conversation in a comfortable atmosphere while grilling and playing games.

DACON 2012 001-069 engl.indd 25 13.12.12 12:04

ACKNOWWLEDGEMENTS

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

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DACON 2012 001-069 engl.indd 26 13.12.12 12:04

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Dr.-Ing. Gert Riegel	Facility Management
Dr.-Ing. Holger Schmidt	Risiko und Sicherheit im konstruktiven Ingenieurbau
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OUTLOOK:

36th "DARMSTÄDTER MASSIVBAUSEMINAR" (07.-08.03.2012)

On March 12th and 13th, 2013 the 2nd "Darmstädter Ingenieurkongress – Bau und Umwelt" is taking place in the *darmstadtium*, the conference center in Darmstadt . The congress is hosted by the department Civil engineering and Geodesy. Recent topics in the field of civil engineering and environmental science will be discussed.

The Fachgebiet Massivbau organizes the session "Klima- und ressourcenschonendes Bauen mit Beton" – „Development and application of Eco-friendly Concretes" which takes place during the first day of the conference. The outstanding experts inform about the state-of-the-art as well as the further developments in the field of sustainable concretes.

- **Nachhaltiger Beton - Stand der Technik und künftige Entwicklungen**
  Prof. Dr.-Ing. Harald S. Müller, Institut für Massivbau und Baustofftechnologie, Karlsruher Institut für Technologie (KIT)

- **Neuartige klimafreundliche Zemente**
  Dr.-Ing. Christoph Müller, VDZ gGmbH Forschungsinstitut der Zementindustrie

- **Nachhaltigkeitsbewertung von Bauwerken**
  Prof. Dr.-Ing. Carl-Alexander Graubner, Institut für Massivbau, Technische Universität Darmstadt

- **Gesteinskörnungen für ressourcenschonende Betone**
  Prof. Dr.-Ing. Horst-Michael Ludwig, F.A. Finger-Institut für Baustoffkunde, Bauhaus-Universität Weimar

- **Klima- und ressourcenschonende Stahlbetonteile durch innovative Betontechnologie**
  Dr.-Ing. Tilo Proske, Institut für Massivbau, Technische Universität Darmstadt

DACON 2012 001-069 engl.indd 27 13.12.12 12:04

- **Dauerhaftigkeit von Betonen mit industriellen Nebenprodukten**
  Prof. Dr.-Ing. Wolfgang Brameshuber, Institut für Bauforschung, RWTH Aachen

- **Beton aus nachwachsenden Rohstoffen**
  Prof. Dr.-Ing. Harald Garrecht, Institut für Werkstoffe im Bauwesen, Universität Stuttgart

Further information about the conference program, the venue and the registration is available online on www.bauingenieurkongress.de or our homepage www.massivbau.to. We would be pleased, when you are interested in the conference.

DACON 2012 001-069 engl.indd 28 13.12.12 12:04

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DACON 2012 001-069 engl.indd 29 13.12.12 12:04

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DACON 2012 001-069 engl.indd 30 13.12.12 12:04

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DACON 2012 001-069 engl.indd 31 13.12.12 12:04

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DACON 2012 001-069 engl.indd 32 13.12.12 12:04

FULL-SCALE EXPERIMENTS TO INVESTIGATE THE PRESSURE OF FRESH CONCRETE BY INCLINED FORMWORKS

Björn Freund, Tilo Proske, Carl-Alexander Graubner

As part of the research project "basics for the development of adaptive formwork systems for free-formed concrete structures" full-scale tests for the experimental investigation of concrete pressure on sloping wall formwork was executed. The project is funded by the DFG within the priority program 1542. In the research and testing laboratory of the Institut für Massivbau, a test set was arranged. The formwork components were provided by Güteschutzverband Betonschalungen.

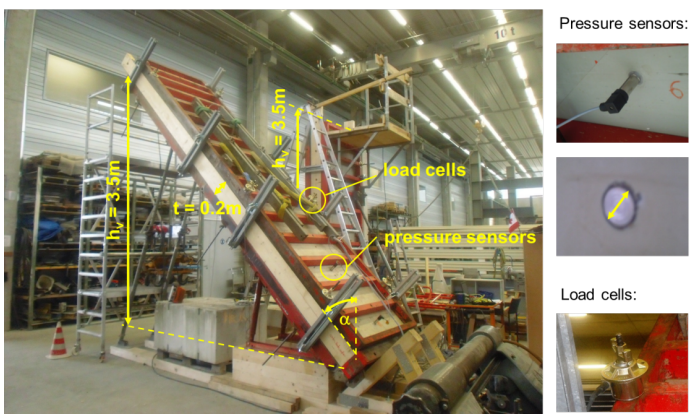


Figure 1: Test set up with inclinded andvertical formwork (left), Sensors (right)

DACON 2012 001-069 engl.indd 33 13.12.12 12:04

In the experimental procedures always a vertical wall and an inclined wall has been concreted parallel to within a test pair to work out the differences in pressure between the vertical and the inclined formwork due to the inclination. In the numerous experiments the following parameters were varied: consistency class (F3, F4, F5, F6 and SCC), setting time, inclination of the formwork, wall thickness, reinforcement ratio.

During a test the pressure of the fresh concrete was measure by pressure sensors and the anchor forces with force sensors. Parallel to the full scale tests small scale experiments were performed: Flowtable test, determination of the density of the fresh concrete and the concrete temperature, measurement of setting time with the setting bag test acc.to DIN 18218 and with the ultrasonic device USM from MEVA. Further measurements to determine the yield stress of the fresh concrete with the rheometer BT 2 (Schleibinger) were conducted. Parallel to the concreting measurements at different time points were performed.

The results of the full-scale tests will be used to verify the numerical model. Further, extensive parametric studies are planned.

First comparisons between the measured pressure and existing conservative calculation methods have shown that the measured pressures are significantly below the calculated values. Exception was the experiment with a self-compacting concrete. In this test the pressure of the vertical and the inclined formwork was hydrostatic (casting rate: v = 2.0 m/h, wall thickness: 20 cm).

DACON 2012 001-069 engl.indd 34 13.12.12 12:04

EXPERIMENTAL DETERMINATION OF THE LOAD CAPACITY RESERVES OF EXISTING BUILDINGS

Ulf Grziwa, Carl-Alexander Graubner

Measures to the conservation, conversion and reconstruction of existing buildings become in the future an increasingly importance in the civil engineering. Sufficient capacity and usability of the building structure are crucial to the conservation of the existing buildings, especially in case of the proposed conversion. The estimated payloads according to the current regulations are often greater than those at the times where the buildings were constructed. In case where the analytical evidence cannot be provided the real load bearing - and deformation behavior can be determined by experimental tests. The load limit as well as the arrangement of the loads during the tests should reproduce the real load in the further period of use in the most unfavorable combination (Fig. 1). The transfer of the loads during the tests is path-controlled. An increasing (nonlinear) deformation of the support structure induces a decrease of the acting force.

Figure 1: Sketch of the test setup (left), loading of the ceiling (in the middle), counterweight in the basement (right)

DACON 2012 001-069 engl.indd 35 13.12.12 12:04

The test is complete when the determined load limit has been reached without damaging the frame. The test execution is also stopped when critical changes of the frame or danger due to safety are recognizable.

The Institut für Massivbau carries out such load tests for many decades now. On that score it is possible to have recourse to an enormous knowledge and empirical values. In all conducted load tests the evidence of a sufficient capacity and usability were provided. It was established that the tested elements (especially the reinforced concrete slabs) have got enormous capacity reserves compared to the static calculations. These capacity reserves are based on simplified analytical system idealizations for example none considered clamping, the effect of continuity, etc.

The ambition concerning the research is the identification of the capacity reserves of the reinforced concrete slabs. The investigation object is an existing multi-stored apartment house. First the capacity of an original ceiling should be identified. With center cuts in the reinforced concrete ceiling (preparation of a single-axle load transfer) as well as cuts in adjoining walls (reduction of the constructive clamp of the end panel) the real structural behavior of the slab should be conformed to the static system of the original structural design. With further load tests on these slab-strips their capacity will be determined. In comparison with the load capacities the capacity reserves will be identified.

All these test results provide the basis for the determination of standard values of system parameters. With these system parameters it should be possible to identify the capacity reserves of existing reinforced concrete slabs.

DACON 2012 001-069 engl.indd 36 13.12.12 12:04

ALTERNATIVE METHOD FOR EVALUATION OF ANCHOR CHANNELS UNDER FATIGUE LOADS

Andreas Heck, Karl-Heinz Lieberum, Harald Garrecht

In the course of European harmonization of construction, the approval of cast anchor channels is regulated since 2010 according to CUAP 01/06/01 (1). For this purpose, both static resistance, and fatigue resistance are determined. In particular the determination of the load cycle's dependent resistor should be done according to (1) taking place with the so-called "iterative method" by Block and Dreier. Thereafter the characterizing fatigue life curve should be made by considering "critical shifts" determined in static tests and load cycles dependent on the force amplitude. Alternatively, a method for the assessment of cast anchor channels under fatigue-relevant impacts is presented with the present statement with reference to issue 525 (2) and DIN 1045-1 (3). Assuming that, by a double logarithmic scale of the abscissa (number of cycles N) and the ordinate (force amplitude Δ F), in the area of term strength depending on the results of fatigue tests approximately a straight is formed, there should be sought an alternative for the observed stress exponent in accordance with (3) a trilinear course of the SN curve. In the exemplary illustration in Figure 1 can be seen an alternative fatigue load function for an anchor channel with load introduction via the anchor. The static part of the function is based on the resistance determined under a single section with short term load. The transition in the area of fatigue resistance is hedged through the implementation of runners- through tests. In addition to the dependent of load cycles from the force amplitude shifts are also taken into account for the final determination of the temporal fatigue resistance (see Figure 1). The critical shift that marks a significant change in stiffness in the load-cycle diagram should in any case be beyond the characteristic resistance. This change of stiffness is considered as a start of

DACON 2012 001-069 engl.indd 37 13.12.12 12:04

damage. Thus a sufficient residual capacity of the system is still guaranteed before a final rupture occurs.

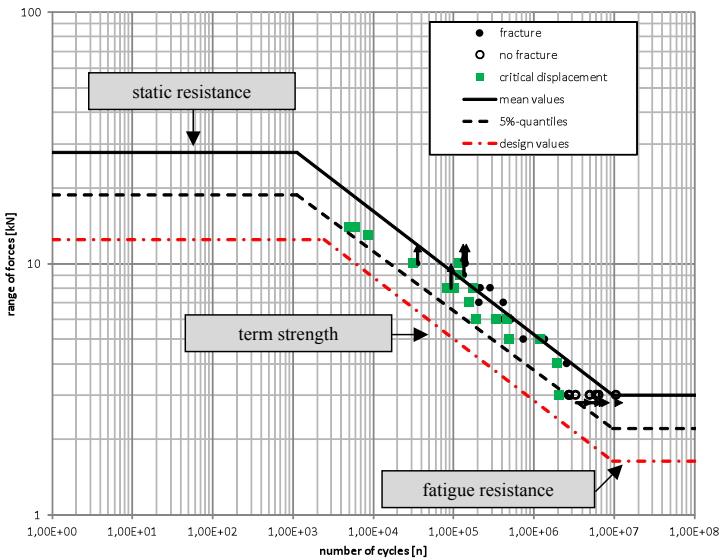


Figure 1: Fatigue load function

(1) CUAP 06.01/01 – Common Understanding of Assessment Procedure for European Technical Approval according to Article 9.2 of the construction Products Directive: Anchor channels; December 2010

(2) Deutscher Ausschuss für Stahlbetonbau, Erläuterungen zur DIN 1045-1, 2010

(3) DIN 1045-1: Tragwerke aus Beton, Stahlbeton und Spannbeton - Teil 1: Bemessung und Konstruktion; August 2008

DACON 2012 001-069 engl.indd 38 13.12.12 12:04

RELIABILITY OF INNOVATIVE UHPC-COLUMNS

Martin Heimann, Carl-Alexander Graubner

Meanwhile concrete-technological developments allow the production of ultrahigh-performed concrete (UHPC) with a compressive strength of more than 150 N/mm². Thus, the cross-sectional dimensions required for highly stressed compression members can be reduced. However, in many cases this positive development increased the trend to even more slender and therefore likelier to buckle structural systems. Hence, it is to be expected that under certain conditions the safety level of such construction elements decreases. Because of this, the reliability of slender UHPC structural members is being investigated in a research project, supported by the Deutsche Forschungsgemeinschaft (DFG) at the TU Darmstadt during the period from 2010 to 2012.

An effective Method to estimate the Reliability of slender UHPC-columns is given by the combination of calculating the bearing capacity of columns and stochastic simulations. Within this project numerical models had been developed. Furthermore a validation of these models at a series of experimental tests was done. In this context a software-tool for stochastic simulations was developed at the IfM. Based on this tool the reliability of different types of columns was determined. The investigation program focusses its calculations on conventional systems and also on innovative columns e.g. hollow columns. In addition to these calculations the sensitivities of the system- and material parameters was analysed by a sensitivity study.

In Figure 1 are given the results of a reliability analysis for a UHPC-column with different types of cross-sections. In the diagram the reliability index β is plotted in relation to the slenderness λ of the column. The axial force acts with an eccentricity of $e/h = 0.1$ on the column. (For more Details about the input parameters see (1)).

DACON 2012 001-069 engl.indd 39 13.12.12 12:04

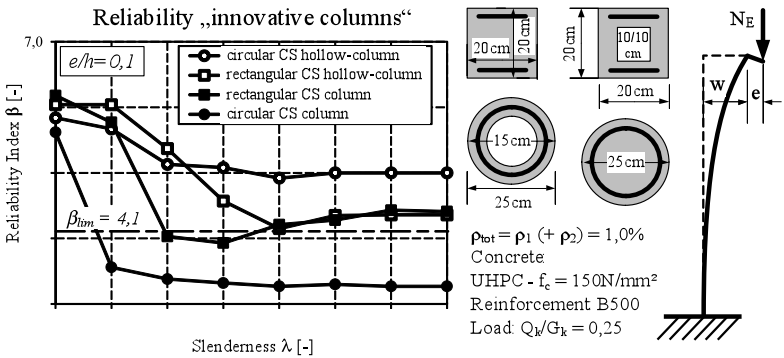


Figure 1: results of the reliability analysis

The diagram in Figure 1 shows that the columns with a solid cross-section don't achieves the target reliability index of $\beta = 4.1$ in case of a high slenderness. In contrast to that the results of the reliability analysis on columns with a hollow cross-section shows higher values than stipulated by the Eurocode. Furthermore for hollow-columns a less distinctive degradation of the reliability index in relation to the slenderness can be detected. These effects are caused by the fact.

To support the positive developments of UHPC applications, research projects should investigate the reliability UHPC-columns without reinforcement. On the basis of the results of former research projects, innovation potentials and limits of application of UHPC will be discovered. By this new casting processes like the extruder procedure for hollow columns will be realized for application. In this context new concepts for installation engineering and ventilation technology can be developed.

In particular, the authors wish to thank the Deutsche Forschungsgemeinschaft (DFG) for the support of this research project.

(1) Heimann, M.; Schmidt, H.; Tran, N. L.; Graubner, C.-A.: *Zuverlässigkeit hochbeanspruchter Druckglieder aus UHPC*, In: Beton- und Stahlbetonbau 1/2013.

DACON 2012 001-069 engl.indd 40 13.12.12 12:04

MEMBRANE COMPRESSIVE STRESSES IN MASONRY CONSTRUCTION

Michael Schmitt, Carl-Alexander Graubner

Compressive stresses, which appear parallel the wall because of horizontal loads and constraint, are mentioned as membrane compressive stresses. The analysis of basement walls subjected to lateral earth pressure with Eurocode 6 is based on these membrane stresses, also mentioned as structural arch effect. The urgent existence of fixed bearings, such as a basement or a supported slab, is the basic condition for the instruction of a pressure arch. Additional to the vertical structural arch effect and under certain condition, the horizontal structural arch effect can be considered.

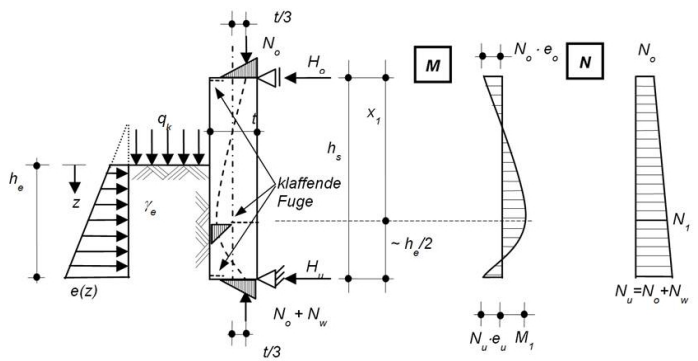


Figure1: Consideration of the structural arch effect on basement walls subjected to lateral earth pressure

In Addition to basement walls, membrane compressive stresses can appear under flexural stress and non-loadbearing interior and infill masonry walls in horizontal and vertical

DACON 2012 001-069 engl.indd 41 13.12.12 12:04

direction, which can increase the bearing load. This can only be done, if there is a constraint in-plane at the wall edges. Only the flexural strengths vertical and parallel to the bed joints are allowed for design. Based on the low strengths and the high degree of dispersion of this resistivity the consideration in design equation is difficult.

Normally non-loadbearing walls are supported by other structural elements, such as reinforced concrete columns and slabs. This kind of constraint is the reason that membrane compressive stresses can be activated in an appreciable size. Due to the activation of the membrane compressive stress condition, the horizontal bearing load was able to be raised significantly on past tests. The design standarts for the determination of the load-bearing capacity of non-loadbearing walls allow the consideration of different input parameters. An allowance of the positive membrane compressive stresses is not yet possible on the calculative way, because there are not any scientific details and analyses of the membrane compressive stresses due to horizontal loads.

The current level of research as well as the engineering standards does not represent an ecological and economic optimum for the design of non-loadbearing masonry walls. The aim of this research is to increase the load capacity of non-loadbearing masonry walls under horizontal loads and to identify the activation of membrane compressive stresses with tests and an extensive numerical analysis under this point of view and to modify the existing verification method inclusive this effect. The most important aim is the extension of the horizontal and vertical minimum distances between the supports.

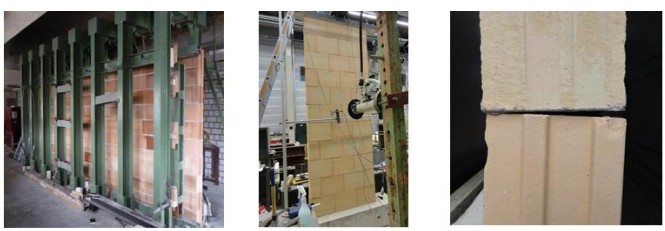


Figure2: examples for test stations (MPA Hannover; TU Darmstadt)

DACON 2012 001-069 engl.indd 42 13.12.12 12:04

EFFICIENT CONSTRUCTION LOGISTIC: PRINCIPALS AND RESEARCH APPROACH

André Tischer, Carl-Alexander Graubner

Construction logistics is commonly regarded as industry-specific expression of the logistics in construction industry. The main task of construction logistics is to plan, to control and support logistical bundled services. The goal is to identify with contractors on site for each resource an optimal supply process, thus building materials needed is in a timely manner, in the right quantity and quality at the processing site available. For the disposal chain the disposal of waste as well as the return of the storage equipment and the residual material should be productive and not obstruct the construction process.

To assess - especially under the principles of sustainable development based on ecological, economic and social aspects - already in the planning phase alternatives of logistical design for a construction project with reasonable costs and with sufficient accuracy, a suitable behavioral explanatory simulation model should be available. A reliable behaviroal description of the system of “construction logistic” is interesting as well as the simulation of the expected behavior of the system (a), *under fixed boundary conditions* which can - from logistical point of view - not be influenced, (b) *with varying factors* that vary significantly cause of specific projects and c) *for predetermined targets* that are set up by different actors with a given scope for maneuver and differentiated expectations.

Against this background, the research on "construction logistics" at the Fachgebiet Massivbau focuses on model-based studies for effective design and deployment of construction logistical resources, with particular attention to economic and environmental objectives. There firstly the effect of structure of a universal construction logistics system is set up with the help of Vester´s sensitivity analysis (1). Unknown model parameters are

DACON 2012 001-069 engl.indd 43 13.12.12 12:04

then adjusted so that the model behavior and numerically observed behavior in the real world is as closely as possible equal (empirical validity). In the next step all the interdependencies are specified as billable functional correlations, quantified and transferred into a computation-capable model. In the next step all the interdependencies are specified as billable functional correlations, quantified and transferred into a computation-capable model. The formalized model is finally used for simulation using the System Dynamics approach of Forrester (2) in order to answer the following questions:

- What are the main influencing parameters and target values for the optimal planning of logistical resources under the aspect of a sustainably managed construction process? What kind of behavior show the parameters to each other?
- Which concept for construction logistics provides - already in the early planning phase - from an economic and ecological point of view the most efficient solution for optimizing the supply and disposal of a building site?

The results of the research will be published during the next year as part of a dissertation.

(1) Vester, F.: Die Kunst vernetzt zu denken - Ideen und Werkzeuge für einen neuen Umgang mit Komplexität, 6. Aufl. München 2007.

(2) Forrester, J. W.: Industrial Dynamics. Students' Edition. Cambridge - Massachusetts: The M.I.T. Press - Massachusetts Institute of Technology, 1961.

DACON 2012 001-069 engl.indd 44 13.12.12 12:04

BENCHMARKING ON STOCHASTIC SIMULATION-METHODS

Ngoc Linh Tran, Martin Heimann, Carl-Alexander Graubner

Performing a reliability analysis of high-dimensional nonlinear problems with implicit response functions is always a big challenge. If the analysis of each sample requires much computation time, numerical methods such as Crude Monte Carlo Simulation (CMCS), adaptive importance sampling (AIS) maybe not effective enough and in many cases is not feasible. Response surface method (RSM) overcomes the disadvantages of these methods. The main idea of RSM is approximating the limit state surface of studied structure, namely response surface, to convert the problems into problems with explicit response function, which can be easily solved by popular methods. In this paper load bearing capacity presenting limit state surface of the structure is polynomial approximated as following:

$$R(x) = a_0 + \sum_{i=1}^{n} b_i \cdot \left(\frac{x_i - x_i^*}{k \cdot \sigma_i}\right) + \sum_{i=1}^{n} c_i \cdot \left(\frac{x_i - x_i^*}{k \cdot \sigma_i}\right)^2 \quad (1)$$

Here are n number of variables related to resistance of structure,

$x(x_1, x_2, \dots, x_n)$ any point of response surface, also vector of variables,

$x^*(x_1^*, x_2^*, \dots, x_n^*)$ referent point, also design point when adaption of RS is used,

σ_i standard deviation of variable i,

k factor controlling the study range, can be set with value of 3. If an adaption of response surface is used, this factor should be changed to 1 for local analysis.

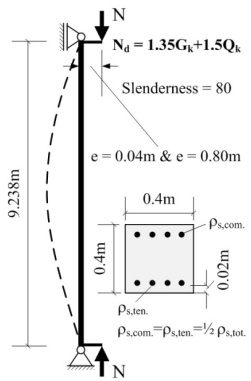
$a_0, b_i, c_i, i = 1..n$ constants, can be easily determined by solving $(2n + 1)$ equations with selection $\left(\frac{x_i - x_i^*}{k \cdot \sigma_i} = 0\right)$ and $\left(\frac{x_i - x_i^*}{k \cdot \sigma_i} = \pm 1\right)$.

Algorithm of RSM with the polynomial approximation presented above is implemented in the program RACO (**R**eliability **A**nalysis **CO**re), which is coupled with the structural analysis program STAB3D to perform reliability analysis for reinforced concrete frame structures. To illustrate the method, a reinforced concrete column with slenderness of 80 under eccentric load was studied. The column is analysed in some cases of reinforcement

DACON 2012 001-069 engl.indd 45 13.12.12 12:04

ratios and eccentricities to consider different nonlinearity situations. Detailed information of the column is given in Table 1. The reliability analysis was carried out with RSM and also the AIS method as a reference method.

Table 1: Basic variables for reliability analysis of reinforced concrete column



Variable	*Unit*	*Distribution type*	μ	σ
Length	m	D	9.2376	-
Width	m	N	0.40	0.005
Height	m	N	0.40	0.005
c_{nom}	m	N	0.02	0.005
f_c	N/mm²	LN	38	5
f_{ct}	N/mm²	LN	3	0.9
a_E	-	LN	9500	1425
f_y	N/mm²	LN	550	33
A_s	mm²	N	1600/3200	32/64
e	m	D	0.04/0.80	-
G	kN	N	G_m	$0.1G_m$
Q	kN	EI-I	Q_m	$0.4Q_m$
θ_R	-	N	1	0.1
θ_S	-	D	1	-

By controlling of maximal static error fewer than 10% the analysis shows that there is a very small difference in calculation results between two calculation methods (see Table 2). Requiring only few structural simulations, which are used for finding the limit state of structure, the response surface method gives a very efficient performance on reliability analysis. At same quality of analysis results, the calculation time required in case of using RSM is reduced about 50 times when compared with AIS method. It is also seen that the chosen polynomial approximation reflects very well the limit state surface of reinforced concrete columns. In this case, no adaptation of response surface is required.

Table 2: Comparison of numerical analysis results

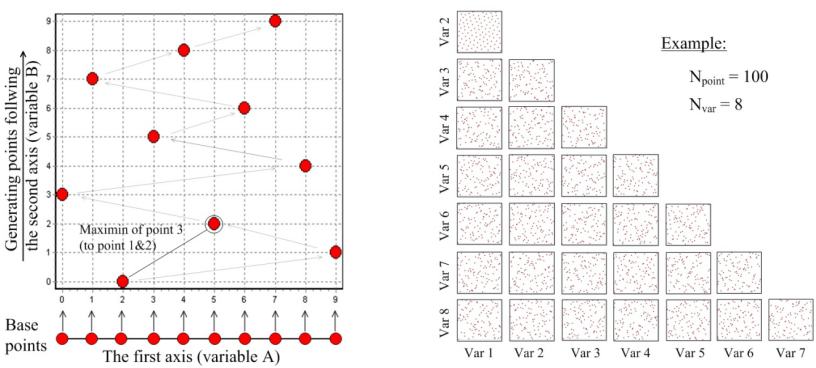
Reinf. ratio	ρ_s = 1.0%				ρ_s = 2.0%			
Eccentricity	e/h = 0.1		e/h = 2.0		e/h = 0.1		e/h = 2.0	
N_d (kN)	1830.0		182.5		2258.4		339.1	
Method	AIS	RSM	AIS	RSM	AIS	RSM	AIS	RSM
p	2.0×10^{-8}	2.0×10^{-8}	3.5×10^{-6}	3.4×10^{-6}	3.1×10^{-8}	3.0×10^{-8}	3.2×10^{-6}	2.2×10^{-6}
β	5.488	5.487	4.490	4.499	5.414	5.417	4.508	4.594
$n_{Sim.}$	15000	21	15000	21	15000	21	15000	21
$T_{cal.}$ (sec.)	**436**	**9**	**507**	**7**	**486**	**9**	**479**	**6**
Note: T_{cal} (**C**rude **M**onte-**C**arlo **S**imulation with 2.0×10^{10} samples, approximated) ≈ **21 years** Computer used for all analysis: Processor Intel® Core™ i7-2600 CPU @ 3.4GHz, 8GB RAM								

DACON 2012 001-069 engl.indd 46 13.12.12 12:04

A NEW ALGORITHM FOR LATIN HYPERCUBE SAMPLING

Ngoc Linh Tran, Carl-Alexander Graubner

Latin Hypercube Sampling (LHS) is a method for generating a distribution of suitable collections of parameter values from a multidimensional distribution, which is often used in uncertainty analysis. An optimal LHS is in general difficult to find due to much required computation time. In this article a new algorithm for fast optimal LHS is introduced. The main idea of the new algorithm is step to step generating the design points from a low dimensional space to a higher dimensional space. In every step of expanding the dimensional space, new coordinators in the new additional axis are chosen based on some criterions of point-to-point distance applying for new points to the already generated points. The process of filling the point in space is illustrated in Fig. 1a. An example illustrating for the new algorithm is presented in Fig. 1b.



a) Process of filling the points in region

b) LHS with 100 points and 8 variables

Figure 1: a) illustration of the developed algorithm and b) result of an example

DACON 2012 001-069 engl.indd 47 13.12.12 12:04

In this method the $\emptyset_p$ criterion was selected to measure a LHS (see equation (a)), which is known as maximum criterion. Minimizing $\emptyset_p$ leads to the maximization of the point-to-point distance in the design.

$$\emptyset_p = \left[\sum_{i=1}^{n_p-1}\sum_{j=i+1}^{n_p} d_{ij}^{-p}\right]^{1/p} \quad \text{(a)}$$

Here p is a positive integer, n_p is the number of points in the design, and d_{ij} is the inter-point distance between all point pairs in the design.

$$d_{ij} = d(x_i, x_j) = \left[\sum_{k=1}^{n_p} |x_{ik} - x_{jk}|^t\right]^{1/t} \quad \text{(b)}$$

To demonstrate the efficiency of the developed algorithm, a comparison to results from Viana (1) with p = 50 and t = 1 was carried out. In (1) another algorithm based on local sample design was used for generating some studied cases with number of variables n_v various from 2 to 12 (see Tab. 1).

Table 1: Comparison of ϕ_p criterion

n_v	2	2	4	4	6	6	8	8	10	10	12	12
n_p	12	120	30	300	56	560	90	900	132	1320	182	1820
$\emptyset_{p,Viana}$	2.8	9.4	1.6	3.6	1.7	3.2	1.6	2.6	1.6	3.1	1.7	2.1
$\emptyset_{p,Tran}$	1.8	3.4	1.4	2.9	1.2	2.3	1.1	1.7	1.0	1.3	0.9	1.1

The results in Tab. 1 show that the new algorithm gives in all cases smaller values of $\emptyset_p$ criterion. It states that the mesh quality of LHS generated with the new developed algorithm is better than that from (1). The main disadvantage of the new method is only the demanding much computation time in the case of a large number of design points (2000 points requires about 30 seconds for processing). The application of the new generating method is thus limited in analysis of high failure probability problems but can be well coupled with response surface method to solve low failure probability problems.

(1) F.A.C. Viana, G. Venter and V. Balabanov. *An algorithm for fast optimal Latin hypercube design of experiments*, International journal for numerical methods in engineering, Wiley InterScience, 2010.

DACON 2012 001-069 engl.indd 48 13.12.12 12:04

DETERMINATION OF RHEOLOGICAL PROPERTIES OF WATER-REDUCED FRESH CONCRETE USING A RHEOMETER

Stefan Hainer, Tilo Proske, Moien Rezvani, Carl-Alexander Graubner

The Fachgebiet Massivbau acquired a concrete-rheometer BT2 from the manufacturer Schleibinger Geräte GmbH in 2012. Using this device, rheological properties of concrete can be analysed. Conventional types of rheometer were only able to measure the rheological properties of mortar and paste. This concerns particular statements regarding the plastic viscosity. During the experiment, two paddles are conducted through the concrete, wherein the rheometer is recording the resistance and the corresponding speed. The angular velocities can be freely generated by the user depending on the research study. In Fig. 1, the rheometer and exemplary measurement results are presented.

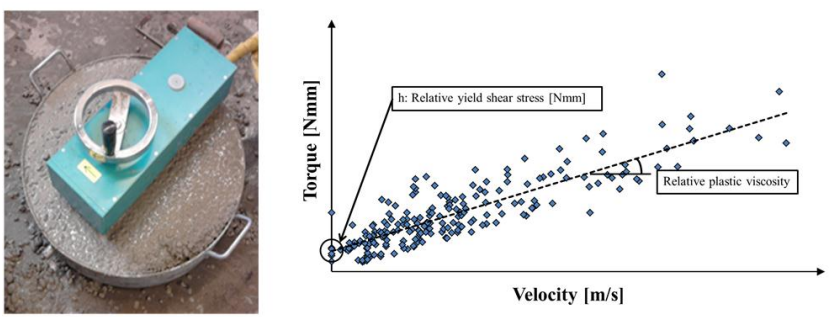


Figure 1: Concrete Rheometer BT2 (left) and Measurement Results (right)

Using the measurement results, it is possible to provide information about the specific plastic viscosity and the yield stress (= flowability). Based on these rheological parameters,

DACON 2012 001-069 engl.indd 49 13.12.12 12:04

the practical application of concretes produced in laboratory conditions can be evaluated with respect to an adequate workability on site. A significant reduction of the water content of the concrete is unavoidable in order to ensure a sufficient durability, particularly in the case of the new Eco-concretes with very low clinker content developed during the last years. The limits for the reduction of the water content are the requirements for the workability. Low water content leads to a very high plastic viscosity, which will complicate the workability on the construction site. In extensive trials, a limiting value for the BT2-related plastic viscosity of concrete was verified. If this limit is exceeded, the concrete is no longer sufficiently workable. Based on the results presented in Fig. 2, it is clearly visible that the specific plastic viscosity increases greatly with the decreasing of the water-cement ratio. For water-cement ratios less than 0.35, the mentioned limiting value is exceeded and the workability of the produced concrete is critical.

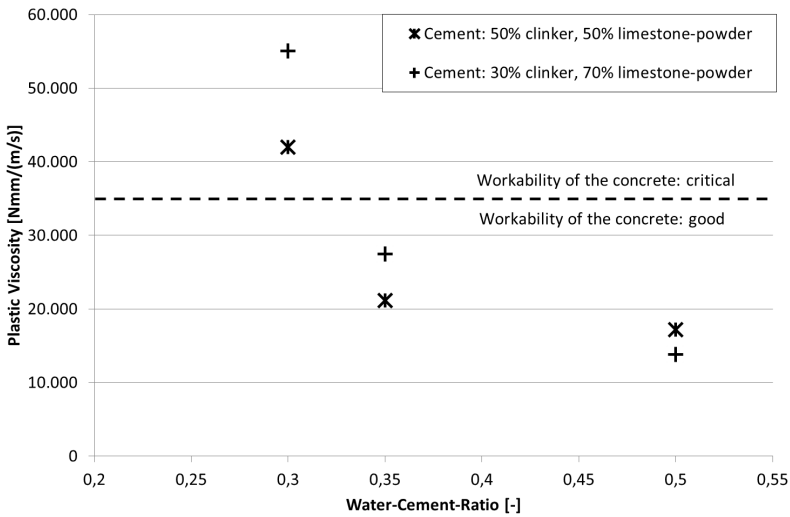


Figure 2: Experimental Results for the Workability of Clinker-Reduced Concretes with a Maximum Aggregate Size of 16 mm Using BT2

DACON 2012 001-069 engl.indd 50 13.12.12 12:04

CONCRETE MADE WITH ADVANCED CEMENTS FOR ENVIRONMENTALLY FRIENDLY CONCRETE CONSTRUCTION

Stefan Hainer, Tilo Proske, Moien Rezvani, Carl-Alexander Graubner

Within the research project “Concrete made with advanced cements for environmentally friendly concrete construction under compliance with the availability of the raw materials” in cooperation with the company Spenner Zement and the Verein Deutscher Zementwerke e.V. Novel cements were developed with a limestone content up to 70% and the application for concrete construction was investigated. The project was founded by the Deutsche Bundesstiftung Umwelt (DBU). It is not possible to produce concretes with a sufficient compressive strength and durability using these rich limestone powder cements with usual water-cement ratios. However, the application of these climate and resource efficient cements for the production of concrete structures is possible if the concrete technological boundary conditions are adjusted (reduced water content). In initial test series, cements were prepared on a laboratory scale with different limestone powder content. The results of the compressive strength tests of mortars with different water-cement ratios are shown in Fig. 1. It becomes clear that the compressive strength decreases with increasing limestone powder content. By reducing the water-cement ratio, the compressive strength can be increased significantly even at very low clinker content. Mortars and concrete made with cements containing 30% clinker and a water-cement ratio of 0.30 reach a compressive strength of 40 N/mm², although the water-clinker ratio is 1.0. This fact can be explained by the improved packing density and homogeneity of the matrix due to the addition of limestone powder.

DACON 2012 001-069 engl.indd 51 13.12.12 12:04

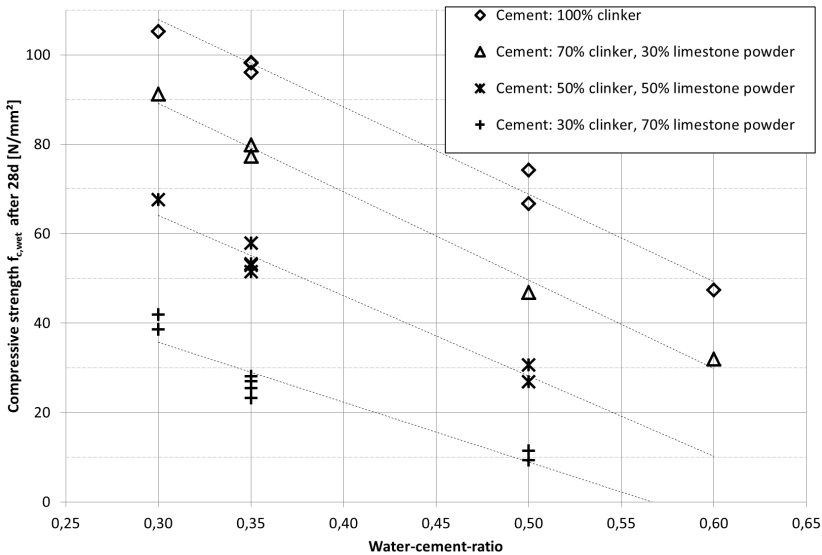


Figure 1: Results of the compressive strength tests on mortar prisms according to DIN-EN 196-1

The new developed cements have a composition outside the definitions of the cement standard EN 197-1. An application of these so-called CEM X-cements for producing concrete on site therefore requires an official approval by the government and thus more material tests on cement and concrete. In other stages of the project, concretes were made of factory-cements (containing 35, 50, 65% limestone). Currently, the determination of the required mechanical properties of hardened concrete necessary for the standards and selected material parameters for the evaluation of the durability were completed. Furthermore, load capacity tests have been performed on reinforced concrete beams to investigate varying failure mechanisms. In addition the investigated concretes will be produced industrially in a ready mix concrete plant.

DACON 2012 001-069 engl.indd 52 13.12.12 12:04

INFLUENCE OF AGGREGATES ON THE RHEOLOGICAL PROPERTIES OF LOW WATER CONCRETE MADE OF CLINKER REDUCED CEMENT

Moien Rezvani, Stefan Hainer, Tilo Proske, Carl-Alexander Graubner

As part of this study, fresh concrete properties regarding workability (table flow, demand of superplasticizer) and rheology were investigated. Eleven different concrete compositions using cement with a reduced clinker level (50% of Portland cement clinker, 50% limestone powder) were casted with a constant water-cement ratio of 0.35. Specifically, the following variations of the raw materials were made: (1) Variation of the particle size distribution in the range of U16 and B16 at constant paste content, (2) variation of the maximum particle size at a constant paste volume and grading curve, (3) Variation of the paste volume with equal aggregates. For the reference mixture, a grading curve AB16 with increased sand content and a paste volume of 290 kg/m³ was used.

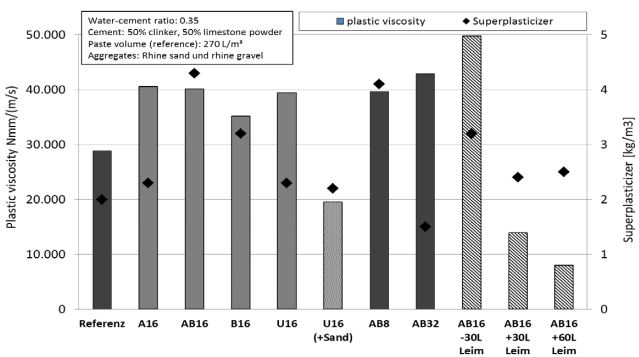


Figure1: Plastic viscosity and superplasticizer demand of the investigated concrete mixes

DACON 2012 001-069 engl.indd 53 13.12.12 12:04

The objective of this test series was to reduce the plastic viscosity and the superplasticizer demand by optimizing the aggregates and the paste volume at a constant table flow diameter of 50-55 cm.

The relative plastic viscosity increases with a change of the grading curve to one of the standard grading curves. A significantly lower plastic viscosity was measured in the mixture with the particle size distribution U16 and an increased sand content. With a change in the maximum particle size diameter and a reduction of the paste volume, the plastic viscosity increased. Although the "perceived toughness" of the concrete with a maximum particle size of 32 mm was lower than the reference mixture, the measurement of the concrete rheometer was contrary. A reason for this measurement is that the paddles of the rheometer will push the aggregateswith largerparticle diametersmore often than aggregates with smaller particle sizes. To increase the paste volume at a constant composition means raising the cement content.

The result of the investigation was that a change of the grading curve could not lead to any significant reduction in the plastic viscosity. The grading curve with the particle size distribution AB16 and an increased sand content can be maintained for further concrete mixes. Increasing the paste volume is no approach because an associated higher cement demand will not equalize the lower plastic viscosity.

DACON 2012 001-069 engl.indd 54 13.12.12 12:04

DEVELOPING AN ULTRA HIGH PERFOMANCE CONCRETE FOR EXTREME FILIGREE PRECAST CONCRETE ELEMENTS

Frank Röser, Andreas Heck, Harald Garrecht

Referring to the Renewable Energy Act the amount of regenerative energy in Germany is supposed to double its amount until the year 2050, which means it will be at this point approximately half of the entire amount of needed energy. Using hydraulic power these days isn't as popular in Germany as in other European countries. Due to the fact both rivers and oceans could be used for generating energy in Germany waterpower plants probably are going to increase their amount significant over the next decades.

The constant approach flow stresses this kind of underwater building units. Furthermore the surface eventually will be full of microorganism, what will cause material damages and a declined degree of efficiency. Nowadays industrial enterprises mostly use very expensive stainless steel and treat them additionally with anti fouling coating to prevent those kinds of damages. The coatings are highly toxic and consequentially affect the hormonal system of marine animals. A long-lasting, cheap and ecological alternative hasn't been thought of.

The Chair of Building Materials, Building Physics and Building Chemistry was searching for a different solution in the course of an AiF financed project. In a technical cooperation it was supposed to show that cement bounded materials can be a substitute for the expensive stainless steel even if the building units need to be very filigree.

The geometry and the expected influences of the building units caused fastidious and various requirements for the concrete consistency and the hardened concrete.

DACON 2012 001-069 engl.indd 55 13.12.12 12:04

Computational simulations made it very clear: the concrete needed to be steel- and fibre-reinforced, which made it even more difficult to find the convenient concrete-mixture.

The filigree measurements and the double curved profile furthermore caused an elaborated fastening hardware. The thickness of the precast element was not allowed to be thicker than 4 cm and the installation of a joining ring needed to be force-fit to guarantee the assembling on the underwater construction was possible. Threaded sheaths were put into the fresh concrete and their rough structure caused an extremely good connection with the fibre reinforced high performance concrete. Actually it is not possible to use those kinds of sheaths for such filigree elements because the products general constructional authorization says it needs to be at least 12 cm from the edging. In experiments it was possible to proof that the high performance material was able to achieve such a high bond so even 2 cm distance to the edging was enough.

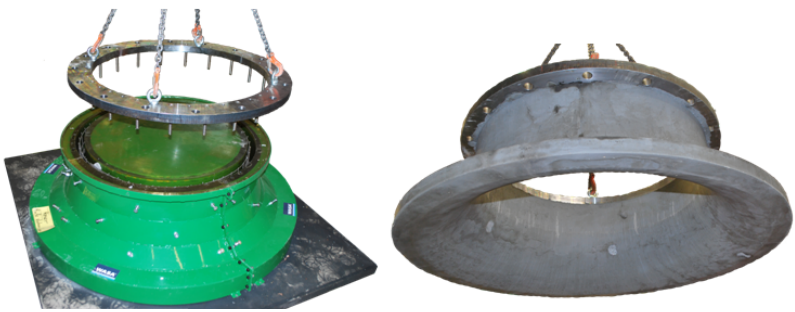


Figure 1: Installation of the joining ring and the stripped prototype

As you can see in Figure 1 a prototype could be realized. These results promise thrilling developments in the future.

DACON 2012 001-069 engl.indd 56 13.12.12 12:04

DEVELOPMENT OF NEW TECHNOLOGY OF LIGHTWEIGHT GLASS CERAMIC MATERIALS FROM PRIMARY AND RECYCLING RAW MATERIALS

Svetlana Volland, Vladimir Vereshchagin, Olga Kazmina

The search for new efficient building materials with low density and sufficient strength is necessary for an optimization of the heat insulating properties of building constructions. A promising solution is the development of porous materials under use of in the regionally available primary and recycled raw materials.

The focus of the joint international project (financed by the Federal Ministry of Education and Research) is on the development of the physical-chemical bases of the development of new warm isolation nanostructure materials (foam glass analog), in particular on the investigation of the law of the forming of the phase composition, the microstructure and the mechanical properties as well as on the assessment of the environmental friendliness by using of these new materials. The project continues the research which has been found that the formation of a nanodimensional crystalline phase in the amorphous matrix leads to a strength increase of foam materials in silicate systems. Investigations with regard to the durability and ecological safety of the nanomaterials in the course of her use represent topically priority research subjects in the majority of the EU – states.

The objective of the research project agrees with the scope of the Federal Government‘s strategy to the internationalization of science and research - directives for the support in the scientific-technical cooperation with Russia in the thematic main focuses Environmental technologies and sustainability research.

DACON 2012 001-069 engl.indd 57 13.12.12 12:04

During of the realization of the project has been planned to ascertain up to unknown dependence between the physical-mechanical characteristics of the foam materials and their durability. A better knowledge of these laws will contribute to the improvement of the production technology of light glass ceramic materials, to accelerate market launch and to make therefore an essential contribution to the solution of the problem of the global energy conservation.

The developed technology will allow the introduction of a new generation of heat insulating materials with improved characteristics by using of different sources of raw materials, including recycling materials, with relatively low energy consumption.

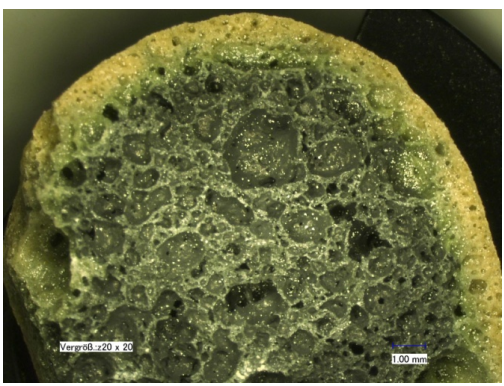


Figure 1: Lightweight granulated Material from sand sludge

As an example of an alternative raw material sand sludge can be mentioned. According to the Federal Institute for Geosciences and Natural Resources in Germany approx. 15 million t. per year of sand sludge are produced of which most remain unused. The investigations resulted (Fig. 1) that the sand sludge can be used for the production of the lightweight granular materials.

DACON 2012 001-069 engl.indd 58 13.12.12 12:04

MONITORING AND ENERGETIC REFURBISHMENT BY THE EXAMPLE OF A HISTORIC STRICKBAU IN APPENZELL

Elena Alexandrakis, Andreas Heck, Christian Renner, Simone Reeb, Harald Garrecht

The European project of 3ENCULT unites the issues between historic buildings and energy efficiency. Buildings such as the old Strickbau in Switzerland can only endure if maintained as a living space. “Strickbau” buildings are prevalent in most alpine regions and consist of layered wooden beams, connected at the corners for stability and typically extending somewhat from the core block.

To enable the pleasant habitation of historic buildings, it is necessary to carry out the best possible energetic refurbishment without harming the historical substance. The Chair of Building Materials, Building Physics and Building Chemistry of the TU Darmstadt operated with two solutions. Firstly, it is important to work with previously existing materials in the building, if possible, and to preserve historical materials. Secondly, it is significant to provide surveillance possibilities by monitoring the procedure. The possibility of monitoring temperatures and humidity in each room and in all layers of the attached refurbishment in comparison to the existing outdoor climate, allow better assessment of risks. The selected substance-preserving construction can be monitored by long term, in order to document the success of the procedure or to allow possibility of intervention, if needed. In addition, other methods such as the Blower Door and infrared measurements can demonstrate the pre-improvement and post-improvement of the condition.

The aim and result is the best balance between the three major concerns of comfort, energy and conservation.

DACON 2012 001-069 engl.indd 59 13.12.12 12:04

A wooden frame construction was placed on the surface of the floor and ceiling, including the climate membrane and the compriband underneath the structure. Furthermore, an energetic refurbishment of the windows was executed. For this purpose, acrylic glass was placed in front of the existing window and in the wooden construction as shown in Figure 2 on the left side. Eventually, the climate membrane and the windows were sealed with an appropriate tape to avoid high airflows.

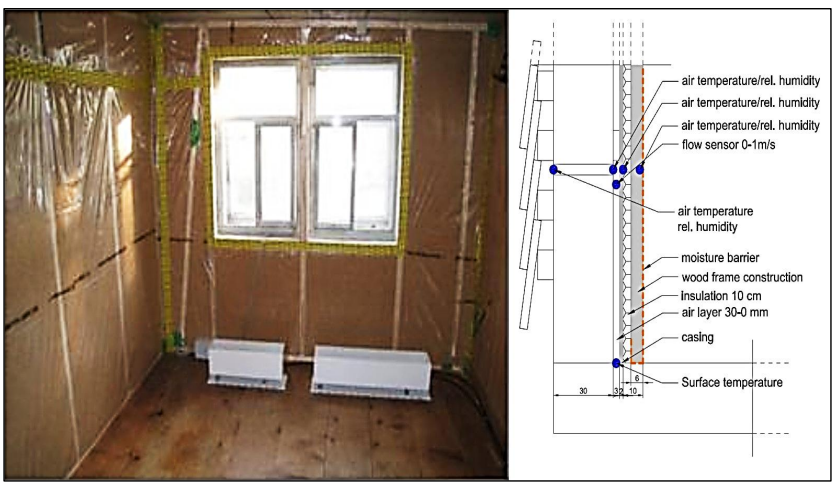


Figure 2: left: one refurbished room; right: vertical cut through the outer wall

There are two different types of sensors displayed in Figure 2, the sensors measuring the surface temperature and the sensors measuring temperature and air humidity. Figure 2 shows where the installed sensors are located inside the construction to allow better surveillance possibility. To generate living conditions, humidifiers and heaters were installed in the refurbished rooms in order to assess whether this method is applicable for other “Strickbauten” instead of a demolition as it is usual in Appenzell.

DACON 2012 001-069 engl.indd 60 13.12.12 12:04

NON-INVESTMENT-RELATED MEASURES OF OPTIMIZATION FOR ENERGY EFFICIENT BUILDING OPERATIONS

Christian Siegel

Facing the goal of reducing the energy expenditure of buildings and of the technical installations in buildings, the energy conservation regulations (EnEV), which are state regulations, play a central role in evaluating cladding and technical installations of buildings. EnEV claims contiguous to individual measures (i.e. energetic inspection of air condition (§12 EnEV) or other retrofitting obligations (§10 EnEV)) also the maintenance of energetic qualities as well as operating and maintenance of technical installations that lower the energy requirements of buildings always regarding continuous increase of energy efficiency during building operations respectively building utilization. Therefore the claims of EnEV inherently contain the conservation of the status quo and furthermore the implementation of several individual measures for optimizing the energy expenditure of buildings. In professional practice the state regulations of EnEV along with economical and ecological motivations eventuate in an increased demand for energy management services. That manifests itself in operating contracts that oblige the facility management to increase the energy efficiency not only by various individual measures but also in respect of a continuous improvement process. Regardless of whether the energy management services are determined in contracts or not measures of optimization have to be identified and subsequently implemented. This implies detailed information on level and structure of energy expenditure that facility management is able to refer to.

The challenge is now to develop a catalogue of small- to non-investment-related measures of optimization. The stated goal is to provide standardized, universally valid solution

DACON 2012 001-069 engl.indd 61 13.12.12 12:04

approaches in the form of a catalogue, that enable the actor in energy management to identify and implement energetic measures of optimization providing that they are aware of the structure of the energy expenditure of the building. Rather than being based on quantitative analyses of the expenditure of buildings this approach is based on a qualitative assessment conducted by experts of the energy business. The energy efficiency measures initially display options of acting or reacting. The catalogue facilitates systematic access to these options. The measures are selected regarding the valuation if an increase of energy efficiency is expected or not. The following image illustrates the structure of the catalogue in its function as a system of expert assessment. The catalogue divides technical installations in buildings in four sub-systems for lighting engineering, refrigeration engineering, heating engineering as well as ventilation and air-conditioning engineering. In addition the catalogue functions as a building management system and hence complies with the outstanding importance of managing technical installations in buildings to increase the energy efficiency during building operations.

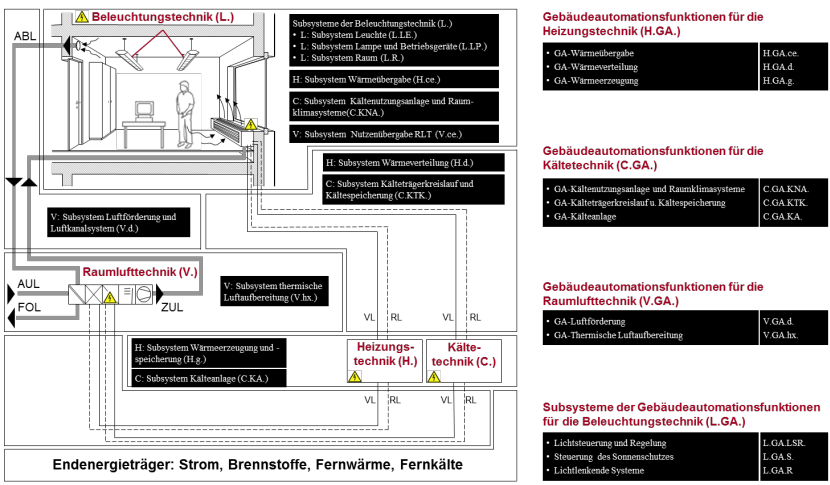


Image 1: Structure of technical installations in buildings and the building management system in the catalogue of measures.

DACON 2012 001-069 engl.indd 62 13.12.12 12:04

SUSTAINABILITY ASSESSMENT OF HOUSES

Torsten Mielecke

The special significance of the building and real estate industry for sustainable development has been recognized for a considerable time. This has been reflected in the development of different analysis and evaluation system for the sustainability performance of buildings. In the past few years in Germany, various tools for assessment of buildings in terms of sustainability were developed. In particular, the public presence of DGNB system "Deutschen Gesellschaft für Nachhaltiges Bauen e.V." (DGNB) and the „Bewertungssystem Nachhaltiges Bauen für Bundesgebäude" (BNB) have achieved the BMVBS. Earlier these systems were only focused on commercial buildings, such as Office buildings, educational buildings, and industrial buildings. Hence an essential part of the building environment has been excluded. Consequently the small residential buildings and especially the single-family homes could not be analyzed with any of the sustainability ratings named above. Just in autumn of 2012 a system version for the new small residential buildings was introduced by the DGNB e.V. In the first application of this system showed that this system which is derived from the office building system is an elaborating process. The processing period of at least four to six weeks must be assumed. In that case this system is too costly for the average owner of a single-family house. The DGNB system aims in the current configuration to prefer prefabricated house manufacturers or developers that prefabricate a building type several times and thus the costs of evaluation can be spread on several buildings. According to a representative survey of the Federal Ministry for the Environment, about 50% of the populations are willing to pay up to 10% more for environmentally friendly products (1). By using this approach, a sustainability assessment and optimization would cost a maximal amount of 2,000 to 3,000 €.

DACON 2012 001-069 engl.indd 63 13.12.12 12:04

This is the result of a LBS study which is based on conclusion that an average terraced house in Germany costs € 210,000 (2). For the sustainability assessment means this result that the rating system is held so simple in its systematic that it can be used without complex calculations and evidence guides. At the same time the system must capture the essential aspects of sustainability, regardless of the proven construction experience of the client. The main aspects of sustainability are divided into environmental, economic and social-functional qualities of a property. Looking at the different qualities in details, at least the following criteria should be considered in single-family homes:

- Environmental quality: energy consumption, pollutants in the building / healthy living, fresh water consumption, land consumption
- Economical quality: life-cycle costs, user information / monitoring, site inspection, maintenance schedule for building services
- Social-functional quality: safety, acoustic protection, preparation of age-appropriate housing, adaptability of the floor plans.

This approach is consistently developed at the IfM and in cooperation with the LCEE GmbH transferred in an evaluation system.

(1) Borgstedt, Silke; Reusswig, Fritz (2010): Umweltbewusstsein in Deutschland 2010. Ergebnisse einer repräsentativen Bevölkerungsumfrage. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Berlin 2010.
(2) LBS (Hrsg.) (2012): Markt für Wohnimmobilien 2012. Pressemeldung vom 24.06.2012, Berlin 2012.

DACON 2012 001-069 engl.indd 64 13.12.12 12:04

SUSTAINABILITY IN BUILDINGS' OPERATION

Sebastian Pohl, Carl-Alexander Graubner

Due to its enormous resource extraction and equally huge input of substances into the environment the construction and real estate industry is considered to be a key sector for a resilient development. Especially the operation of buildings stands for massive impacts or vice versa considerable potentials concerning sustainability.

So far these potentials are only inadequately activated because the relevant players, i.e. facility management service providers, have no methodology to operationalize the holistic strategic sustainability approach for the operation of buildings. Although sustainability rating systems such as BNB/ DGNB address the entire life cycle of buildings and hence the use and operating phase as well, the systems in fact still have a prognostic approach looking at the life cycle timeline and do only model prerequisites of a sustainable buildings' operation. In addition they are lacking the required clear direction for the steps to be taken.

In cooperation with a leading German facility management supplier the Department of Concrete and Masonry Structures developed a criteria based guideline for a sustainable operation of buildings within the framework of a one-year research project and as the first step towards a certification methodology (see fig. 1). On the one hand the complexity of the topics facility management and sustainability required a clear delimitation by identifying and fixing adequate system boundaries and on the other hand a practical definition of sustainability in buildings' operation.

Designing the guideline a set of protection objectives and action targets had to be deduced from the sustainability definition and split up into selective and facility management

DACON 2012 001-069 engl.indd 65 13.12.12 12:04

specific criteria (operationalization). The identification of possible relevant elements of an according catalogue of criteria followed a comprehensive analysis of existing national (BNB, DGNB) and international certification methodologies (LEED, BREEAM) respectively the relevant system versions or usage profiles.

An additional comparative observation involving the entire range of facility services delivered the required completion control of the derived portfolio of possible guideline-criteria as the basis of the catalogue of criteria.

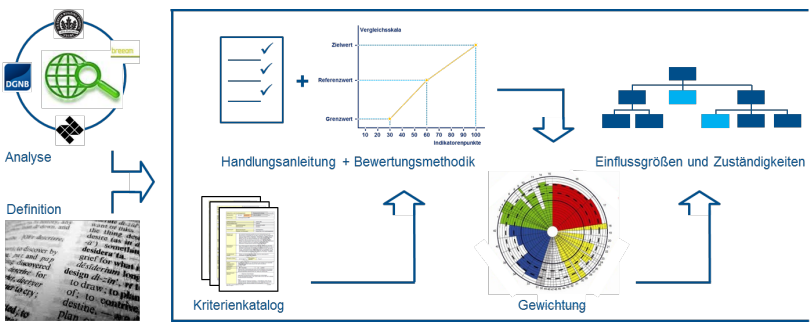


Figure 1: Scope and methodology of the project Sustainability in Buildings‘ operation

Each criterion of this catalogue was filled with assessment methods and levels, whose clear direction for the steps to be taken gives the criteria the character of an operational guideline. Together with the structural order of all criteria in a weighting matrix the developed guideline represents the substantial elements of a certification methodology.

But its completion requires further conceptual measures in the future. A certification methodology has always to be tested and checked intensively by implementing a phase of initial application. Based on the results and key findings of this pilot phase the finalization and market rollout of the system can be realized.

DACON 2012 001-069 engl.indd 66 13.12.12 12:04

PENTECOSTAL EXCURSION TO KRAKOW, WROCLAW AND PRAGUE FROM 28/05/2012 TO 06/02/2012

Jaroslav Kohoutek, Carl-Alexander Graubner

A group of 42 students, professors and scientific employees of the Institute of Concrete and Masonry Structures of the TU Darmstadt and the Institutes of Concrete and Masonry Structures and Steel Structures of the TU Kaiserslautern set out on Whit Monday by plane to this year's big trip to Poland and the Czech Republic. First stop was the 111 m high wooden radio tower of Gliwice. Thereupon we went straight on towards Opole inside the cement plant Górazdze of the Heidelberg Cement GmbH. Here we got a factory tour in English and could closely inspect the rotary kilns for clinker production.

Abbildung 1: Group picture in front of the cement plant Górazdze

First highlight on Tuesday was the UEFA European Championship stadium of Wroclaw. In this 42,000-seat stadium we were given an informative tour by two UEFA employees. Then we went to the Centennial Hall. This was built in 1911 and inherited the title of the largest dome in the world from the Pantheon in Rome.

DACON 2012 001-069 engl.indd 67 13.12.12 12:04

The tour led us through the beautiful city of Görlitz to Prague, where we first visited a subway construction site on Wednesday. On this site were various tunneling techniques used - the NATM (New Austrian Tunneling Method), the tunneling method using the tunnel boring machine and the open tunnel forming. We were able to visit a tunnel boring machine, as well as excavators and other excavation equipment. Visibly impressed and with many stories from the lives of the construction workers we went on to the bridge construction site "New Troy Bridge Prague". At the time of the visit the assembly of the arches was performed. In the evening, we took part of a guided tour of Prague Castle.

On Thursday we left early in the morning towards Krakow. First stop was a stress ribbon bridge in Brno-Bystrc, here we got a little lecture by a student about the construction of stress ribbon bridges. We then drove on to Ostrava, to visit the steel mill of the company ArcelorMittal. Our tour started with a visit of the factory premises, where we were given an explanation of the iron production steps. Then we visited the rolling mill, with an impressive length of one kilometer. In the evening we then visited the construction site of the Jagiellonian University in Krakow.

On Friday first two sites were on the program. At the construction site Novum we visited the construction of 400 new apartments, at the construction site Auchan in Bronowice a large shopping center. Then we visited the old town of Krakow with the marketplace and the Cloth Hall and also the Krakow castle. Crowning the day's events was the visit of the salt mines and UNESCO World Heritage in Wieliczka. Here we could visit the largest underground chapel in the world. This trip was made possible not least by the generous support of the Darmstadt students by the “Freunde des Instituts für Massivbau”, for which we would like to thank you here again quite cordially.

DACON 2012 001-069 engl.indd 68 13.12.12 12:04

DACON 2012 001-069 engl.indd 69 13.12.12 12:04