Review of Construction Mechanics, Statics and Dynamics for the academic year 2021 (1.10.2020 - 30.09.2021)

TEACHING AND RESEARCH FOCAL POINTS

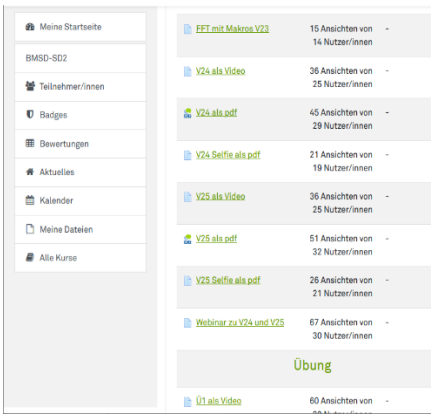
The chairs of Construction Mechanics and Statics and Dynamics have officially founded the *Institute of Construction Mechanics, Statics and Dynamics* (BMSD) in the academic year 2021, which was unanimously approved by the Faculty Council in its 423rd meeting. The merger will ensure

- consistency in teaching,
- visibility in research and
- the efficiency in operation

The close cooperation has been in preparation since the academic year 2020.
The bundling of forces was particularly helpful for the development of digital teaching. Thus, in the academic year 2021, all scheduled lectures, exercises and tutorials for the study of civil engineering could be carried out digitally without any problems.

The expanded media technology and the experience from the previous summer semester 2020 served as a solid basis. The combination of webinars, videos and written work materials have created learning opportunities that are well received by the students, which can be tracked via the Moodle platform, see image below.

In the event of a return to face-to-face operation, the digital formats represent added value, provided they continue to be maintained and improved at the current intensity.



Statistics on the number of users at the end of the lecture period in the subject SD2

The medium-term goal of our digital teaching is to promote individual learning behaviour. This is possible by offering different formats with equivalent learning content.
The first effects can be seen, for example, in the user statistics in the picture above.
There, webinars that have already been followed live by numerous students are subsequently accessed by about the same number of people. The same applies to the selection of lecture materials, which are accessed in a ratio of 3:2 as full text or self-supplementary text (selfie).

In both cases, it can be assumed that students pursue only one of the two redundant variants, depending on their personal inclination.

In addition, there is the retrieval of lecture-accompanying working materials, such as the VBA programme for Fast Fourier Transformation (FFT). Here, however, it is also easy to see from the statistics that such less exam-relevant materials are only used by a smaller group of participants. The anonymous selection option implies that interested students are encouraged without overburdening the overall course.

Professor Ingo Münch gave his inaugural lecture on 18 January 2021 under the topic *Building with Trees - From Vision to Concrete Research Activities*. The event also had to be held digitally, but made it possible for numerous colleagues from distant universities to attend.

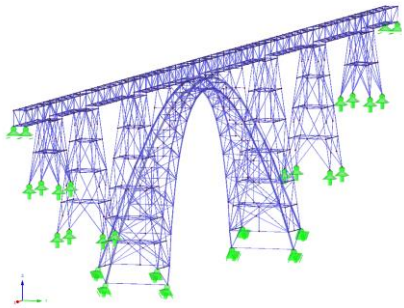
Inaugural lecture as part of the lecture series *Come.Stay.Go*

As a substitute for a student excursion in spring, picture and film recordings as well as the very elaborate numerical model of the Müngsten Bridge were created as digital teaching materials *and* demonstrated within the lecture *Computer-Oriented Statics and Dynamics*.

Interview with Jens Kalameya on the history, statics and ongoing renovation work on the Müngsten Bridge

The action was supported by the ongoing funding measure of the *OER content* project "Digital learning environment - structural analysis - as a holistic concept", as well as Dr Jens Kalameya from the *engineering office PSP, who* accompanied the concept and was available for the interview. We would also like to thank *Deutsche Bahn* for permission to film.
The Müngsten Bridge has spanned the valley of the Wupper between Remscheid and Solingen at a height of up to 107 metres since 1897 and is still the highest railway bridge in Germany.

The statically indeterminate arch with a 170-metre span went through various structural systems during construction to allow for the free cantilever.



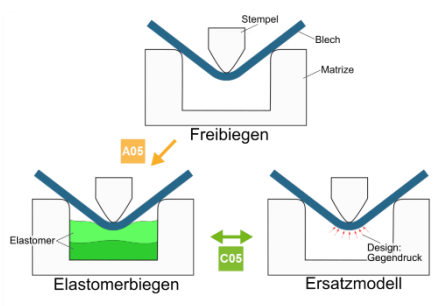
Numerical model of the Müngsten Bridge with 802 knots and 2276 rods

In cooperation with the model construction workshop, a model is currently being made which will be used in lectures to demonstrate the static systems used in the construction of the bridge, among other things.

Interim status of the model construction work on the Müngsten Bridge in September 2021

The TU Dortmund University library has also succeeded in acquiring an impressive book copy on the statics of the bridge from 1904. This shows how the calculation methods of mechanics and statics were established about 130 years ago. It also shows where the advantages of further development, especially through numerical methods, lie to this day.

The teaching of numerical mechanics in the Master's programme includes lectures on optimisation and material modelling. One aspect here is the description and control of
of damage following sub-project C05 of TRR 188.
For this purpose, numerical optimisation was applied to the forming process of free bending at the Chair of Structural Mechanics. In cooperation with the IUL of the Faculty of Mechanical Engineering, their experience from the extended process of elastomer bending was used to set up the optimisation problem for load optimisation.
Here, the elastomer cushion was replaced by external loads in the outer area of the forming process. For the contact calculation of the simulation, the software Abaqus was used, which had to be considered in the optimisation routine. In this way, optimised external loads could be generated by means of numerical optimisation.



Optimisation of elastomer bending by means of external optimum loads

Scientific meetings and conferences also took place exclusively digitally in the past year. This was also the case at the third seminar and general meeting of the "GAMM Student Chapter at TU Dortmund University" on 26 November 2020. The aim of this association is to promote interdisciplinary cooperation in applied mathematics and mechanics between master's students and doctoral students at TU Dortmund University.

The annual general meeting of GAMM (Society for Applied Mathematics and Mechanics, 15-19 March 2021), was also attended by the scientific staff online, as this is an important platform for scientific exchange between the chairs.

In the summer semester of 2021, the subject Stability of Structures was offered for the first time as an elective course for students in the Master's degree programme in Civil Engineering and was attended by a small group of listeners. The concept of a stable structure can also be extended to systems that have kinematics and behave in a distinctly dynamic way, such as the tree house in the following illustration. Here, too, film recordings were made to explain the topic of influence lines using a real supporting structure.

Kinematic but stable structure used to explain lines of influence

The student excursion on 15.09.2021 again led to the botanical experimental plant in Kamen, which is inspected and maintained by the Institute.
Under the guidance of Martin Zeller, the students were able to learn and practise "tree surgery", e.g. to deliberately fuse together crossing shoots of flanking planting.
A former student of architecture also took part in the excursion, which we are now taking as an opportunity to inform former students about our activities and invite them in the future.
The flanking planting developed so positively in the rainy summer of 2021 that we would like to begin the partial removal of the steel supports as early as next year, which is a primary goal of the present construction botanical experiment.

Welding of two tree shafts to form a cross brace under the "Growing Footbridge" in the botanical trial field in Kamen

In cooperation with the *Forestry Training Centre for Forest Work and Forestry Technology NRW,* a number of almost 70-year-old copper beech trees (Fagus Sylvatica) were repeatedly taken from the forest in Arnsberg and destructively tested for their load-bearing capacity under bending stress within one week at the Institute for Building Research. The new differential test cylinder with a stroke of 1000 mm and a maximum load of 350 kN, which was designed by *Walter + Bai* according to our requirements, was used for the first time. At this point, we would like to thank Christoph Rempe and all the other employees of the Institute for Building Research for their great commitment during the commissioning of the cylinder as well as during the execution of the test.

Bending test on the freshly cut shaft of a copper beech with the new long-stroke cylinder

The experiments serve to research strength values as well as failure mechanisms of green wood, e.g. in order to safeguard the construction of trees through deterministic models. On the one hand, this should minimise the risk and, on the other hand, make the construction more scalable. The associated construction technology and building biology find a variety of tasks as a further field of research in Tree Engineering.
Since 2017, the sub-project C05 "Sensitivity and Optimisation of Damage in Forming Processes" is being worked on at the Chair of Structural Mechanics. This project is part of TRR 188, which deals with the understanding and control of damage in forming processes. After a successful first four-year funding period, funding for a further four years for the second funding period was secured during the inspection in 2020. For this second funding period, TRR 188 focuses on the performance of components produced by forming technology.
The influence of temperature will therefore also be taken into account in the individual sub-projects. Sub-project C05 in particular is expanding the underlying material description in the modelling. Furthermore, the already developed optimisation using Abaqus will be continued in order to be able to consider the complex forming processes of the TRR 188. In addition, the optimisation on the microscale will be taken into account.

Linking of sub-project C05 in the 2nd funding period of TRR 188

Under the title *Organic Tiny Houses,* research has been conducted on the development of small housing modules since July 2021. Within the consortium, the Institute's working group takes on technical and planning tasks with a clear emphasis on sustainability. This includes, among other things, the saving of resources during construction as well as the preservation of material cycles. The focus is on ecological and contemporary construction methods as well as compliance with the highest standards in thermal insulation, structural design and load-bearing safety. All work objectives are supported and evaluated by the construction of prototypes.

In May, our long-time and valued staff member Sigrid Middeldorf retired. We thank her for her many years of service and wish her all the best.

Mirjana Vujanic, Sabine Potrafke and Sigrid Middeldorf at their farewell ceremony

List of compulsory and elective courses

Winter semester 2020/21
Stereostatics
Basics of statics and dynamics
Linear elasticity theory
Linear Finite Element Method
Computer-oriented higher mechanics
Non-linear finite element method
Tree Engineering in Practice
Engineering with ANSYS
Special areas of structural optimisation
Summer semester 2021
Elastostatics
Computer-oriented statics and dynamics
Software in structural mechanics
Tree Engineering
Nonlinear material mechanics
Structural optimisation
Enhanced Simulation with ANSYS
Stability of the supporting structures

Promotions
Dr Mohammad Amin Esmail Molod
Strengthening reinforced concrete column-beam joints with modular shape memory alloy plate optimised through probabilistic damage prediction

Dr Navina Waschinsky
Structural optimisation of diffusion-driven degradation processes

Dr.-Ing. Jan Liedmann
Elastic-plastic design sensitivities based on variational analysis and applications in optimal specimen design

Publications

Sky, A., Polindara, C., Muench, I., Birk, C.: Assembly of sparse matrices via atomics, SIAM Journal of Scientific Computing, submitted 2021.

Zeller, M., Muench, I.: Fastening of structures in trees with tree anchors and double strapping, Bautechnik, submitted 2021.

Sky, A., Neunteufel, M., Münch, I., Schöberl, J., Neff, P.: A hybrid H1 x H(curl) finite element formulation for a relaxed micromorphic continuum model of antiplane shear. Journal for Computational Mechanics, 2021. https://doi.org/10.1007/s00466-021-02002-8

Wulf, J. B., Muench, I.: Topology evolution of composite structures based on a phase field model. Proc. Appl. Math. Mech. 20(1), 2020. https://doi.org/10.1002/pamm.202000163

Sky, A., Muench, I., Neff, P.: A finite element formulation for a simplified, relaxed micromorphic continuum model. Proc. Appl. Math. Mech. 20(1), 2020. https://doi.org/10.1002/pamm.202000336

Ghasemi, S. A., Muench, I., Liedmann, J., Barthold, F.-J.: Numerical approach for a continuum theory with higher stress gradients. Proc. Appl. Math. Mech. 20(1), 2020. https://doi.org/10.1002/pamm.202000264

Molinari, A., Witte, R., Neelisetty, K. K., Gorji, S., Kübel, C., Münch, I., Wöhler, F., Hahn, L., Hengsbach, S., Bade, K., Hahn, H., Kruk, R.: Configurable Resistive Response in BaTiO3 Ferroelectric Memristors via Electron Beam Radiation. Advanced Materials 32, 2020. https://doi.org/10.1002/adma.201907541

Münch, I., Wagner, W., Naumann, J.: Isogeometrische Analyse zur Evolution von Verbundystemen mit der Phasenfeldmethode, in: Bischoff, M., von Scheven, M., Oesterle, B. (eds.) Berichte der Fachtagung Baustatik - Baupraxis 14, 2020.

Liedmann, J., Barthold, F.-J.: Shape Optimization of the X0-specimen; theory, numerical simulation and experimental verification. Comp. mech., (2020).

Liedmann, J., Barthold, F.-J.: Variational sensitivity analysis of elastoplastic structures applied to optimal shape of specimens. Struct. Multidisc. Optim., (2020).

Guhr, F., Sprave, L., Barthold, F.-J., Menzel, A.: Computational shape optimisation for a gradient-enhanced continuum damage model. Comp. Mech. 65, (2020).

Fields of research

Continuum mechanics
Numerical methods and FEM formulations
Structural optimisation (topology, shape and material optimisation)
Inverse problems
Variational sensitivity analysis
Control of damage during forming processes
Analysis and optimisation of multi-scale problems
Micromorphic continua
Phase field simulation
Tree Engineering

Research projects

Combined shape and cross-section optimisation of fibre composite structures based on singular value decomposition of the sensitivities (DFG)

SFB/Transregio 188 "Damage Controlled Forming Processes", TP C05: "Sensitivity and Optimisation" (DFG)

Digital learning environment in structural engineering as a holistic concept (funding line "OER-Content.nrw" for the production of digital teaching and learning offers for the state portal DH-NRW)

Organic Tiny Houses (Special Programme Environmental Economy NRW)

List of employees

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Mirjana Vujanic
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M.Sc. Seyed Ali Ghasemi
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Dr.-Ing. Jan Liedmann
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B.Sc. Lydia Puttkamer
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Otto Baxter Horn