

Institute for Building Mechanics, Statics and Dynamics

TEACHING AND RESEARCH FOCAL POINTS

The chairs Construction Mechanics as well as Statics and Dynamics guarantee continuous teaching in the area of mathematically sound basic subjects. In addition, in-depth, practice-oriented as well as research-oriented courses are offered, which individualise the profile of graduates and prepare them for the wide range of tasks in civil engineering.

Among other things, this requires an understanding of how to solve boundary value problems, which is why a basic mathematics course for civil engineering was initiated and prepared in cooperation with various chairs. This course (Higher Mathematics 3, Civil Engineering) is compulsory for all students of civil engineering for the first time in winter semester 2022/23 and is intended to help improve the learning requirements for several subjects in the Bachelor's and Master's degree programmes. A "blended learning" concept is used for this purpose, which has also been used in the parallel course "Statics and Dynamics 1" since winter semester 2021. Among other things, motivation through practical applications in civil engineering is to be used to illustrate technical terms and to

continue to apply mathematical methodology in a results-oriented manner.

For the subject of structural analysis, the creation of digital formats to supplement lectures as "Open Educational Resources" (OER content) has been implemented since 2020. The first of two stages will be completed in 2022 and firmly integrated into the subject "Fundamentals of Structural Analysis". It should be emphasised that these digital materials deliberately supplement the classroom lectures and do not completely replace them, as is necessary in the pandemic semesters.

Fig. 1 shows how so-called "teasers", both experts and laypersons, are interviewed to motivate and discuss a structural engineering topic against the background of a supporting structure. The consortium formed for this purpose (RWTH Aachen University, Cologne University of Applied Sciences and Arts, University of Duisburg-Essen, Ruhr-West University of Applied Sciences and Arts, TU Dortmund University) will continue to produce such materials under the consortium leadership of TU Dortmund University for the subject of dynamics until the end of 2024. We are expressly grateful for this funding from the state of NRW.

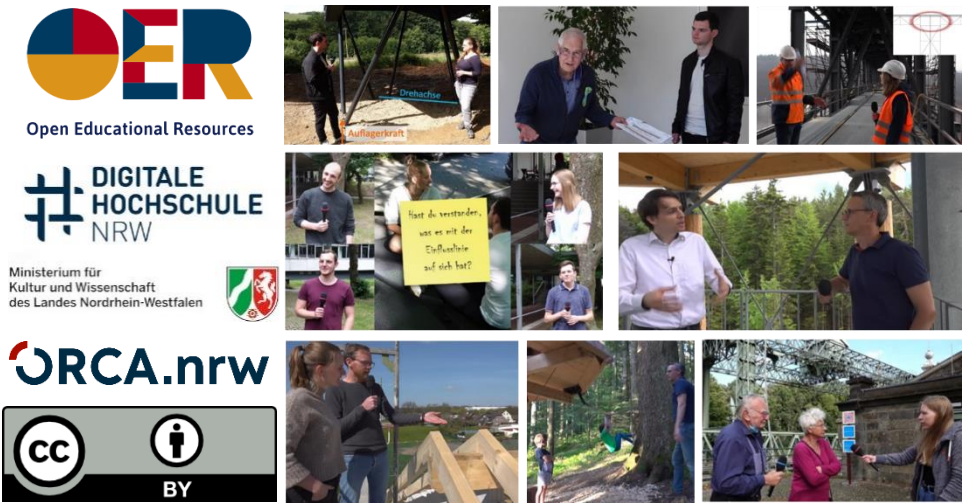


Fig. 1: Interviews on structural analysis with experts and laypersons against the background of different supporting structures. The content is available to the public under CC-BY-SA licence via the ORCA server of the state of NRW.

The academic teaching year 2021/22 was marked on the one hand by the ongoing pandemic, but also by the return to classroom lectures and a major excursion in spring 2022 by the Chair of Structural Analysis and Dynamics in cooperation with the Chair of Solid Structures.



Fig. 2: Spring excursion with architecture and civil engineering students

Twenty-six students took part in the tour of very innovative but also very traditional buildings. Via the Jüberturm in Hemer and the Wartburg in Eisenach, the programme led to Leipzig, where we were given guided tours of the Auwaldstation and the Z8 wooden high-rise. A visit to the water games in

Bergpark Wilhelmshöhe in Kassel rounded off the programme, which was entirely devoted to the theme of sustainability. For more than 300 years, the water features have only used positional energy by storing rainwater above the installation. This means that neither pumps nor other forms of energy are required for operation. The 52-metre-high final water fountain in the lowest basin is hard to believe, but it demonstrates the skills of the master builders over 300 years ago.

The Laboratory for Statics and Dynamics was able to set up the prestressed cable nets and membranes for the first time in spring 2022 in the course of the TU Dortmund Summer Festival and offer an associated course on this.



Fig. 3: Rope nets and measurement technology during the course on dynamic loading

Afterwards, the installation was released to all visitors of the summer festival, who could then test the dynamic balance of this pre-stressed construction above the refectory on Campus North. A safety concept was therefore drawn up in advance with the occupational safety department and ensured, among other things, by a safety net under the construction.

In cooperation with the chair "Materials in Civil Engineering" and under the guidance of the lecturer Dr.-Ing. Daniel Algernon, a total of 15 students in five teams dealt with questions on non-destructive building diagnostics in the summer semester, which were presented in a final colloquium on

24.06.2022 through the presentation of posters.



Fig. 4: Entire installation of rope nets and membranes during the TU Summer Festival.

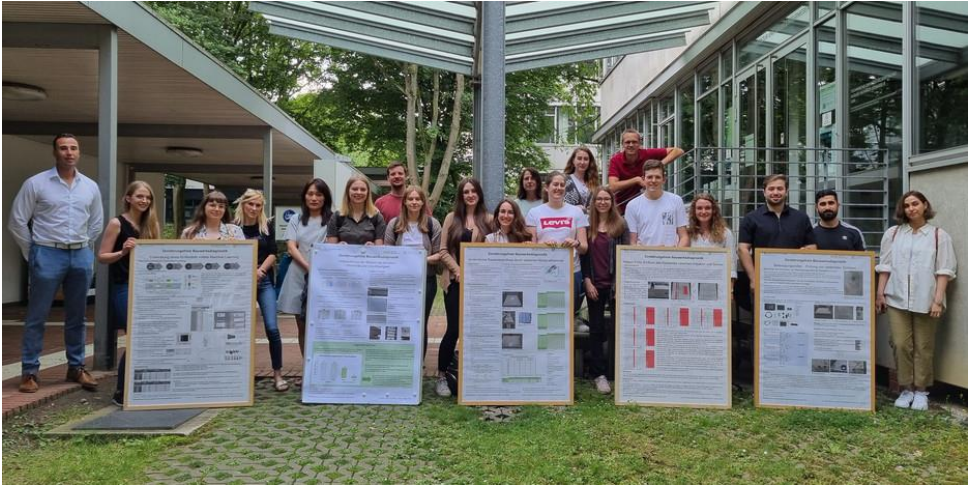


Fig. 4: Final colloquium in the subject of non-destructive building diagnostics in front of GB II

Another final colloquium in the subject "Organic Building" took place on 27.07.2022 in the Rombergpark Botanical Garden. Five student designs including their constructive execution were presented to the public and evaluated by the teaching team. The students of the faculty developed ideas and made models for this as part of a semester

project. Existing natural materials, the terrain formation and the tree population were integrated in order to do justice to the aspects of sustainable construction and minimisation of ground encroachment. To the surprise of the students, the designs and ideas were rewarded with cash prizes by the Botanical Garden.

Fig. 5: Presentation of sustainable footbridge designs in the Rombergpark Botanical Garden



On 31 March 2022, Professor Davide Bigoni, member of the Department of Solid State and Structural Mechanics at the University of Trento (Italy), gave a lecture at the Institute on "Flutter, Hopf bifurcation and Ziegler paradox in structures and elastic media". Professor Bigoni is an expert in material instabilities, bifurcation theory, shear bands and fracture mechanics and was recently awarded the ERC grant "Beyond hyperelasticity: a virgin land of extreme materials" (2022-2027), the second ERC grant in his career.

The Chair of Continuum Mechanics is developing a new sound barrier structure for acoustic applications (880-2750 Hz) using metamaterials. The project is part of the ongoing ERC grant META-LEGO and the samples are fabricated in collaboration with the

Model Workshop Chair. The samples have a wide frequency band gap in their dispersion relation. In the next step, they will be assembled by the Chair of Construction Materials and given to the "System Dynamics Laboratory" (LTDS) at the École Centrale de Lyon to carry out the experiments.

With the "International Conference on Nonlinear Solid Mechanics" (ICoNSoM) in Alghero, the "European Solid Mechanics Conference" (ESMC) in Galway and the GAMM annual conference in Aachen, three internationally renowned conferences were attended. In addition, the development of a new international Master's programme in Continuum Mechanics is being prepared in cooperation with 2 other European universities.

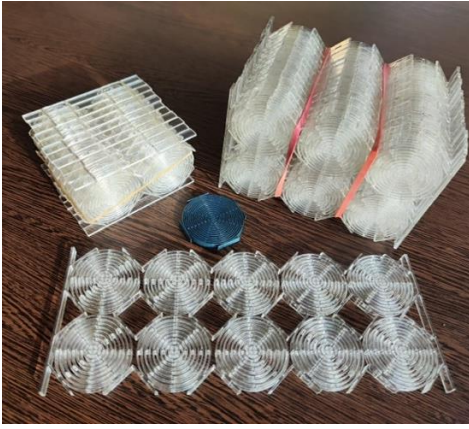


Fig. 6: Acoustic metamaterials made of Plexiglas based on a labyrinthine unit cell

The team of the Chair of Statics and Dynamics continued to participate in the research colloquium Baustatik - Baupraxis, which is held every three years by a research association. All university chairs of statics in Germany and Austria belong to this association. Here, staff members have the opportunity to present interim results of their dissertations and to discuss them with their colleagues and professors. This year, the audience decided on the best presentation by means of a voting system. We are pleased that the Institute was able to participate with a total of two presentations by Jan Wulf and Simon Loske and that Mr. Simon Loske received the first prize of 300 euros.



Fig. 7: Presentation of the award certificate to Dipl.-Ing. Simon Loske by the chairman of the Forschungsvereinigung Baustatik-Baupraxis e.V., Prof. Dr.-Ing. Sven Klinkel at the Steinfeld monastery.

The GAMM junior research group has been in existence at TU Dortmund University since 2019. This is a research group consisting of the Institute of Mechanical Engineering Mechanics, the Institute of Structural Mechanics, Statics & Dynamics and various chairs of mathematics. The aim of the junior research group is an interdisciplinary exchange of the various research topics in applied mathematics and mechanics. After three successful years at TU Dortmund University, an application for the continuation of the GAMM junior research group had to be submitted at the end of 2021. This was also approved at the beginning of 2022, guaranteeing continued existence for the next three years.

In addition to the extension of the term, Prof. Angela Madeo's group also joined the junior research group, which now comprises 7 chairs and institutes and thus 52 members at TU Dortmund University. Along with this, Prof. Madeo presented her research topics and her team to the existing group members in a lecture on 22 April 2022. Afterwards, the new members had the opportunity to exchange ideas at a barbecue. Within the framework of the junior research group, there were two further lectures by external guests during the course of the year. On the topic of neural networks, Dr Knut Andreas Meyer gave a lecture entitled "Knowledge Augmented Neural Network

Plasticity Modeling" on 24.06.2022; on 16.09.2022, Chiara Hergl presented her research results on "Electromechanical Coupling in Electroactive Polymers - a Visual Analysis of a Third-Order Tensor Field". In addition to external lectures, an internal seminar was also offered by Prof. Ben Schweizer on 14.07.2022 to facilitate the exchange between mechanics and mathematics and to illustrate the possibly different ways of looking at things.

In addition to the professional exchange, social contact was also promoted. Thus, after two years, the social activities that had been restricted by the covid pandemic were restarted. This began with a friendly football match on 02.06.2022 at TU Dortmund University and was continued with bouldering in the Boulderwelt Dortmund on 06.10.2022. In the future, other activities and interesting lectures will also follow. In addition to the lectures, a doctoral hour has also been offered every semester since 2022. The purpose of this is to give interested students the opportunity to find out from staff currently working on their doctorate at various institutes what the everyday work of a doctoral student is like and to ask general questions about the topic of doctoral studies. The first doctoral hour took place on 21.4.2022 and led to a lively exchange between doctoral students and students.

PUBLICATIONS

- Sky, A., Neunteufel, M., Münch, I., Schöberl, J., Neff, P.: A hybrid $H^1 \times H(\text{curl})$ finite element formulation for a relaxed micromorphic continuum model of antiplane shear. *Computational Mechanics* 68, 1-24, 2021. <https://doi.org/10.1007/s00466-021-02002-8>
- Sky, A., Muench, I., Neff, P.: On $[H^1]^3 \times [H(\text{curl})]^3$ and $H(\text{sym curl})$ finite elements for matrix-valued curl problems. *Journal of Engineering Mathematics* 136(5), 2022. <https://doi.org/10.1007/s10665-022-10238-3>
- Sky, A., Neunteufel, M., Muench, I., Schöberl, J., Neff, P.: Primal and mixed finite element formulations for the relaxed micromorphic model. *Computer Methods in Applied Mechanics and Engineering* 399, 115298, 2022. <https://doi.org/10.1016/j.cma.2022.115298>
- Zeller, M., Münch, I.: Fastening of structures in trees with tree anchors and double strapping. *Bautechnik* 99(S1), 13-22, 2022. <https://doi.org/10.1002/bate.202100078>
- Rizzi, G., Neff, P., Madeo, A.: Metamaterial shields for inner protection and outer tuning through a relaxed micromorphic approach. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*.
- Rizzi, G., Tallarico, D., Neff, P., Madeo, A.: Towards the conception of complex engineering meta-structures: Relaxed-micromorphic modelling of low-frequency mechanical diodes/high-frequency screens. *Wave Motion*.
- Demore, F., Rizzi, G., Collet, M., Neff, P., Madeo, A.: Unfolding engineering metamaterials design: Relaxed micromorphic modeling of large-scale acoustic meta-structures. *Journal of the Mechanics and Physics of Solids*
- Rizzi, G., Valerio d'Agostino, M., Neff, P., Madeo, A.: Boundary and interface conditions in the relaxed micromorphic model: Exploring finite-size metastructures for elastic wave control. *Mathematics and Mechanics of Solids*.
- Rizzi, G., Khan, H., Ghiba, I.-D., Madeo, A., Neff, P.: Analytical solution of the uniaxial extension problem for the relaxed micromorphic continuum and other generalized continua (including full derivations). *Archive of Applied Mechanics*

SUBMITTED PUBLICATIONS

- Sky, A., Polindara, C., Muench, I., Birk, C.: Assembly of sparse matrices via atomics. Submitted to *SIAM Journal of scientific computing*
- Sky, A., Muench, I., Neff, P.: A quadratic element for the relaxed micromorphic model. In preparation for *Proc. Appl. Math. Mech.*
- Wulf, J. B., Muench, I.: Growth of green wood based on a phase field model. In preparation for *Proc. Appl. Math. Mech.*
- Loske, S., Muench, I.: Experiment and Modelling of the Load Capacity of Green Wood. In preparation for *Proc. Appl. Math. Mech.*
- Guhr, F., Barthold, F.-J.: Geometric and material sensitivities for elasto-plasticity including non-local damage regularisation. In preparation for *Proc. Appl. Math. Mech.*
- Voss, J., Rizzi, G., Neff, P., Madeo, A.: Modeling a labyrinthine acoustic metamaterial through an inertia-augmented relaxed micromorphic approach. Submitted to *Mathematics and Mechanics of Solids*.

DISSERTATIONS

- Kampschulte, R.: Stability investigations and parameter studies for slender columns with bracing by cables. Master thesis, September 2022
- Puttkamer, L.: Holistic approach to statically integrated planning of residential modules made of logs. Master thesis, January 2022
- Waldecker, M.: State line of bending stress under wind action in tree stands. Bachelor thesis, November 2021
- Blume, S.: Programming and comparison of different finite element methods: standard method, mixed FEM and least squares FEM for membrane equation. Bachelor thesis, September 2021

LECTURES

- Klinkel S., Münch, I., Birk, C.: Digitale Lernumgebung -Baustatik - als ganzheitliches Konzept. Symposium Baustatik-Baupraxis, 27.-30.09.2022, Kloster Steinfeld
- Wulf, J., Münch, I.: Simulation of the growth of green wood with a phase field model. Symposium Baustatik-Baupraxis, 27-30.09.2022, Kloster Steinfeld
- Loske, S., Münch, I.: Foundation of free-hanging residential structures over vital copper beeches. Symposium Baustatik-Baupraxis, 27-30.09.2022, Kloster Steinfeld
- Algernon, D., Orlowsky, J., Münch, I.: Nondestructive Structural Assessment - Understanding the Toolset and its Application for Diagnostics-Based Engineering. International Symposium on Nondestructive Testing in Civil Engineering, 16-18.09.2022, Zurich, Switzerland.
- Münch, I., Puttkamer, L., Hielscher, L.: Adaptive Learning Environment in Dynamics as OER. OER Symposium Engineering Sciences, 01.09.2022, online
- Wulf, J. B., Muench, I.: Growth of green wood based on a phase field model. GAMM Annual Meeting, 15-19.08.2022, Aachen, Germany
- Loske, S., Muench, I.: Experiment and Modelling of the Load Capacity of Green Wood. GAMM Annual Conference, 15-19.08.2022, Aachen, Germany
- Sky, A., Rizzi, G., Muench, I., Madeo, A., Neff, P.: Numerics for the relaxed micromorphic model. GAMM Annual Meeting, 15-19.08.2022, Aachen, Germany

Sky, A., Muench, I., Neff, P.: A quadratic element for the relaxed micromorphic model. The European Solid Mechanics Conference, 04-08.07.2022, Galway, Ireland

Guhr, F., Barthold, F.-J.: Geometric and material sensitivities for elasto-plasticity including non-local damage regularisation. GAMM Annual Meeting, 15-19.08.2022, Aachen, Germany

Guhr, F., Barthold, F.-J.: Numerical Damage Optimisation For Rod Extrusion Processes Utilising Commercial Simulation Software, GACM, 21-23.9.2022, Essen, Germany

Ghasemi, S.A., Liedmann, J., Barthold, F.-J.: Variational shape sensitivity analysis of dynamic structures applied to a damage material using IGA, GAMM Annual Conference, 15-19.08.2022, Aachen, Germany.

Ghasemi, S.A., Liedmann, J., Barthold, F.-J.: Shape Sensitivity Analysis Of Dynamic Structures Using IGA, GACM, 21-23.9.2022, Essen, Germany

Wohlgemuth, F., Barthold, F.-J.: A Modular XFEM Approach Used For Elastoplastic Materials, GACM, 21-23.9.2022, Essen, Germany

Rizzi, G., Voss, J., Perez Ramirez, L., Neff, P., Madeo, A.: Exploring metamaterials' structures through the relaxed micromorphic model. GAMM Annual Meeting, 15-19.08.2022, Aachen, Germany

Rizzi, G., Neff, P., Madeo, A.: Exploring metamaterials' structures through the relaxed micromorphic model. The European Solid Mechanics Conference, 04-08.07.2022, Galway, Ireland

Rizzi, G., Voss, J., Collet, M., Demore, F., Neff, P., Madeo, A.: Finite-size metamaterial modeled as a relaxed micromorphic continuum for acoustic control applications. International Conference on Nonlinear Solid Mechanics, 13-16.06.2022, Alghero, Italy

Voss, J., Rizzi, G., Demetriou, P., Neff, P., Madeo, A.: Wave propagation in an acoustic metamaterial modeled as a relaxed micromorphic continuum. GAMM Annual Meeting, 15-19.08.2022, Aachen, Germany

Voss, J., Rizzi, G., Neff, P., Madeo, A.: Wave propagation in an acoustic metamaterial modeled as a relaxed micromorphic continuum. The European Solid Mechanics Conference, 04-08.07.2022, Galway, Ireland

Voss, J., Rizzi, G., Demetriou, P., Neff, P., Madeo, A.: Wave propagation in an acoustic metamaterial modeled as a relaxed micromorphic continuum. International Conference on Nonlinear Solid Mechanics, 13-16.06.2022, Alghero, Italy

EMPLOYEES:INSIDE

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Prof. Dr.-Ing. I. Münch

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M.Sc. Felix Wohlgemuth
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Dr Jendrik Voss
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M.Sc. Simon Loske
B.Sc. Kira Johanna Peper
M.Sc. Adam Sky
M.Sc. Jan Bernd Wulf

Lecturer

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Dr.-Ing. Daniel Algenon

Student assistants

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Ariana-Lucia Hargesheimer
Nina Kerwien
Sophie Katharina Schliefer
Nepomuk Pinkernell
Johannes Sundheim

LECTURES

WS 2021/22

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

SS 2022

Elastostatics
Computer-oriented statics and dynamics
Software in Structural Mechanics (WPF)
Organic Building (WPF)
Nonlinear material mechanics
Structural Optimisation (WPF)
Non-destructive building diagnostics (WPF)

RESEARCH PROJECTS

European Research Council (ERC) Grant: META-LEGO

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)

Adaptive learning environment in dynamics as OER - Alfdyn (funding line "OER-Content.nrw" for the production of digital teaching and learning offers for the state portal DH-NRW)

