University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Fatigue

Steel Structures

Karl Drebenstedt

Georgios Skarmoutsos

Re-evaluation and extension of the fatigue detail catalogue in Eurocode 3

Many parts of our modern infrastructure, for example bridge constructions, crane runway constructions, mast constructions and wind turbines are subjected to fatigue stresses during their life cycle. The fatigue strength of structures is standardized in Eurocode 3 Part 1-9. The given fatigue classes within this standard are based on experimental data. However, this database is partly outdated and incomplete. The project team has built an online database of thousands of fatigue tests. With help of this database, parameters can be identified, which are influencing the fatigue life.

The project conducted experimental investigations. This includes the German version of the construction details cover plate end which is a common welding detail especially in bridge construction. The project was realised by three research facilities: RWTH Aachen, Institute of Steel Construction, Karlsruhe Institute of Technology and University of Stuttgart, Institute of Structural Design.

Duration: 2016-2019

Project funding: AiF - DASt/ FOSTA

Contact:
Karl Drebenstedt, M.Sc.

Fatigue design of tension rods with end threads

The standards referring to the fatigue strength of tension rods with end threads are currently not sufficiently clear enough. For tension members, DIN EN 1993-1-11 is available. For tension rods the fatigue detail, category 105 could be used without considering the size effect. As an alternative, EN 1993-1-9 applies. In this case, tension rods are categorised in the fatigue class 50 for bolts. Moreover, in EN 1993-1-9 the size effect is taken into consideration through a reduction factor, applicable to diameters bigger than 30mm. For the design engineer the question of “which fatigue detail category is correct? “ arises.

Within the framework of this project, the influence of the size effect up to M100 of the hot-dip galvanizing and of the thread’s manufacturing technique (cut or rolled threads) on the fatigue strength of tension rods with end threads have been investigated. With the help of numeric models, notch stresses for the different diameters were determined and subsequently verified by using optical measuring systems. Furthermore, extensive Finite Element Model analyses were carried out, so that the influence of the size effect, the tolerances and the imperfections were examined. The research project was realised in cooperation with TU Braunschweig.

Duration: 2017-2020

Project funding: AiF - DASt

Contact:
Dipl.-Eng. Georgios Skarmoutsos

Arc brazing for joining of attachments on cyclic loaded structures

Fatigue strength of cyclic highly stressed structures are often a significant determinant factor for dimensioning and economic efficiency. Welded secondary steel elements often limit the fatigue strength of cyclic highly stressed steel structures due to the negative notch effect.

By brazing instead of welding these attachments the metallurgical notch effect can be reduced due to lower heat input. As part of the research project about 150 fatigue tests were carried out. Moreover, there were numerical investigation and development of calculation models for the use of arc brazing in common steel construction practice. The project was realised by two research facilities: Fraunhofer Research Institution for Large Structures in Production Engineering IGP and University of Stuttgart, Institute of Structural Design.

Duration: 2018-2020

Project funding: AiF - FOSTA

Contact:
Karl Drebenstedt, M.Sc.

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Institute of Structural Design
Steel, Timber and Composite Constructions
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Fatigue

Steel Structures

Mathias Euler

Gloria Hofmann

Lisa-Marie Gölz

Detail catalogue for economically optimised steel structures

The superior objective of this project is the systematic re-evaluation of essential parameters of fatigue strength according to EC3-1-9 with regard to construction details of steel and composite bridge, crane and crane runway construction as well as mast and chimney construction. This offers the possibility of designing the detail catalogue in a more advantageous, realistic and possibly more economical way.

For this purpose, the existing DASt database will be expanded. Part of this extension are data of different existing experimental results, among others from Deutsche Bahn AG, as well as the results of new experiments, that are realised within the context of this project. The aim of the investigations is to study the fatigue influence of geometry of butt welds and longitudinal attachments in order to optimise and simplify the detail categories. Furthermore, the limiting values of manufacturing tolerances for selected details, such as the cross joint, will be determined. Another goal is the improvement of detail categories for high production quality. This project is being carried out in coopera-tion with RWTH Aachen, Institute of Steel Construction and Chair of Steel and Lightweight Metal Construction and the Karlsruhe Institute of Technology, Research Center for Steel, Timber and Masonry.

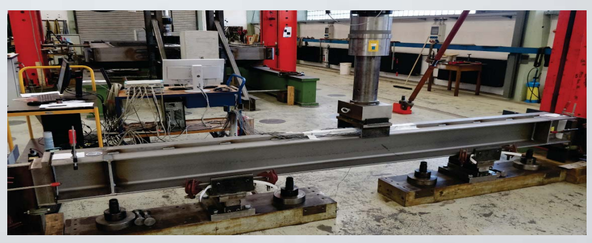
Duration: 2020-2023

Project funding: AiF - DASt

Contact:
Gloria Hofmann, M.Sc.

Fatigue strength of interrupted rail welds

A common way for fastening rails to crane runways are interrupted rail welds. By avoiding continuous rail welds, the production time and material input are reduced on one hand, on the other hand the welding distortion of the beam and therefore the adjustment effort is reduced. At the moment, however, their calculation and design is not regulated by the current steel construction standard (DIN EN 1993-6). As crane runway girders are subjected to cyclic loads, fatigue checks must also be carried out for the construction details of the rail fastening in accordance with DIN EN 1993-6 in combination with DIN EN 1993-1-9.



In order to support the practice in the design of rail welds, three urgent questions are to be clarified. Does the contact between rail and flange reduce the stress on the rail welds? In which notch case may the existing multiaxial stress state be classified, in the context of a nominal stress check for each stress case ($\sigma_{\perp}$, $\sigma_{\parallel}$, $\tau_{\parallel}$), according to DIN EN 1993-1-9? How do the stress condition interact in contrast to the continuous rails welds? This project is carried out in cooperation with the Materials Testing Institute at the University of Stuttgart.

Duration: 2019-2021

Project funding: AiF - DASt

Contact:
Prof. Dr.-Ing. Mathias Euler
Gloria Hofmann, M.Sc.

HFMI-treatment of ultrahigh-strength structural steels

Fatigue assessment is of major importance for dynamically loaded steel structures. Increased operating loads and lightweight construction demands increase the requirements of steels considering the material strength used. Standards and guidelines specify fatigue classes for fatigue assessment that are independent of material strength, so there is no benefit regarding the use of high-strength steels in fatigue loaded structures. By using HFMI-treatment, the fatigue strength of welded joints can be increased and the potential of high-strength steels can be utilized. Therefore, the DASt-guideline 026 which regulates the fatigue assessment of constructional details made of steel grades reaching from steel grade S235 to S700 was developed. An extension for steels up to a steel grade of S960 is pending and geometric imperfections exceeding quality level B of ISO 5817 are not covered yet.

The objective of the project is to extend the DASt-guideline 026 and to investigate the influence of geometric imperfections on the fatigue strength of HFMI-treated welds. Therefore, investigations are carried out on constructional details with and without imperfections. The project is carried out jointly with the KIT Karlsruhe Research Center for Steel, Timber and Masonry, dept. for Steel and Light Weight Structures and the Fraunhofer IGP in Rostock.

Duration: 2021-2023

Project funding: AiF - FOSTA

Contact:
Lisa-Marie Gölz, M.Sc.

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Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Welding

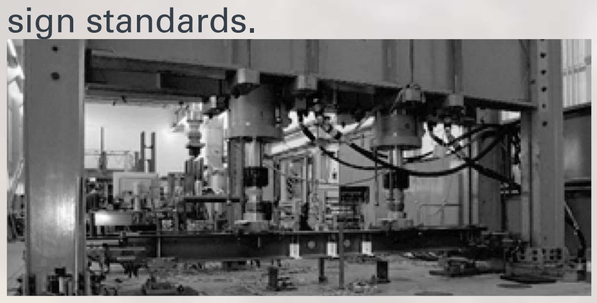
Steel Structures

Stephanie Breunig

Konrad Kudla

Application of HFMI-treatment on high strength steels

The improvement of the fatigue resistance by the application of High Frequency Mechanical Impact (HFMI) treatments was confirmed within several research projects. Since for high strength steels having higher yield strengths these improvements are even strengthened, those benefits of the HFMI treatment on S690 should be taken into account for bridges in the European fatigue design standards.



Within the European research project OPTIBri, where the optimal use of high strength steels for bridges was further developed, there were tests on small specimen series for the welded detail of the transverse stiffener with HFMI out of S690 by project partners. In comparison to the real bridge girder situation, the small scale tests did not consider the scale effects. So within a beam test series of 7 HFMI treated S690 welded girders being performed at the Institute of Structural Design, the effect of a welded structure where shrinkage is restrained and higher residual stresses from the welding procedure occur, was quantified. In addition to already existing HFMI treated beam tests series of S690, the stress ratio was R = 0,1 and the reduction through the scale effect on HFMI treated transverse stiffeners was investigated.The investigations were conducted jointly under the coordination of the University of Liège with the partners University of Coimbra, Belgian Welding Institute, GRID and INDUSTEEL.

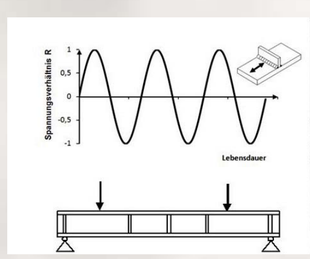
Duration: 2014-2017

Project funding: RFCS

Contact:
Dr.-Ing. Stephanie Breunig

Development of a DASt-Guideline for the application of HFMI

In recent years, investigations by different research institutions on the quantification of fatigue improvement on welds by the application of high frequency mechanical impact treatment had been carried out. Those investigations resulted in different design approaches. Nevertheless, there were still some open questions, which had to be clarified before developing one uniform design approach considering all investigations. For example, the mean stress influence was not completely quantified yet. Besides the influence of the scale effect, by now being considered with a reduction of the fatigue strength of 20 %, which is rather conservative, the effectivity of post-weld treatment of a preloaded weld was investigated as well as the influence of a multi-level loading. These effects were quantified with the help of numerical models and experimental tests. Application limits and boundary conditions for the HFMI treatment could be identified. With the knowledge gained, a design concept was developed based on existing approaches for application to three essential notch details, taking into account the relevant influences and boundary conditions. The proposal was transposed into a DASt-Guideline and thus made available in practice.



The project was a cooperation with the Karlsruhe Institute of Technology, Research Center for Steel, Timber and Masonry, dept. for Steel and Light Weight Structures.

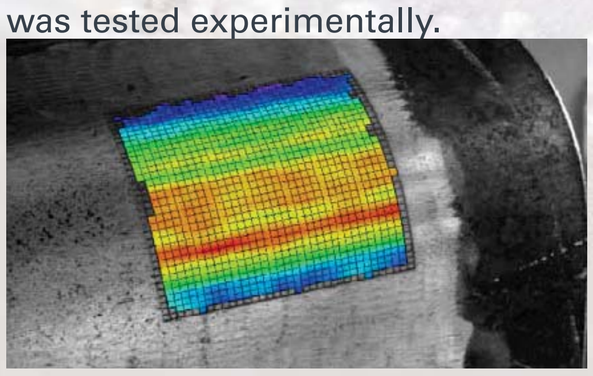
Duration: 2013-2017

Project funding: AiF - DASt

Contact:
Dr.-Ing. Stephanie Breunig

Welding of cold-formed elements

In steel and plant construction, it is standard practice to produce steel profiles by cold forming. One of the most frequent joining methods in steel construction is the arc welding. Thus, it is inevitable to weld cold-formed elements in the area of cold forming. By this research project, the existing rules for welding in cold-formed areas relating to currently available steels were checked. The behaviour of cold-formed and welded parts at low temperatures was tested experimentally.



The evaluation of 20 brittle fracture investigations and results from the literature show only slight coincidences of the standard transition temperature shift according to DIN EN 1993-1-10 by $\Delta T_{\varepsilon cf}$. The range of alloy components and manufacturing methods permissible according to currently valid delivery standards is too broad, which has a negative effect, especially in steel bridge construction, due to the restricted reference temperature according to DIN EN 1993-1-10 to -50 °C. Based on the results of this research project, a new standard-compliant concept for material selection was developed, in which the most important influences of cold forming and welding can be taken into account through a practical engineering concept. Positive properties of e. g. fine grain steels can hereby be determined and form the basis of economic design.

Duration: 2010-2014

Project funding: AiF - DASt

Contact:
Dr.-Ing. Konrad Kudla

www.uni-stuttgart.de/ke

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Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Post-Weld Treatment

Steel Structures

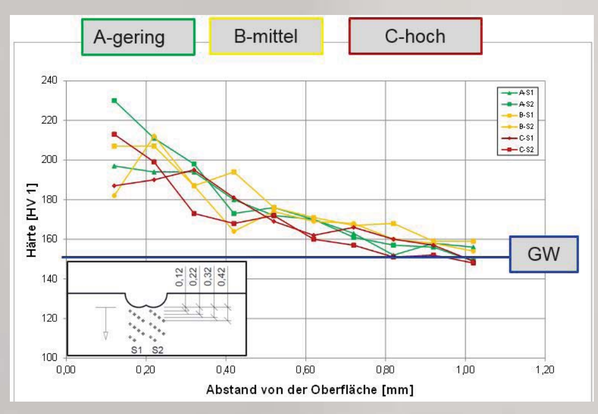
Stephanie Breunig

Konrad Kudla

Lisa-Marie Gölz

Development of a simple quality assurance test for HFMI

The effectiveness of increasing fatigue strength by high frequency mechanical impact (HFMI) treatments could be verified on several welded construction details. In addition to recognized rules for the fatigue design of treated welds, the qualification of users as well as the qualification and quality assurance of the equipment is necessary for a reliable application.



HFMI treatment produce plastic deformations on fillet welds and residual compressive stresses in the surface layer, which are to be regarded as the main cause of the increase in fatigue strength. The verification of the process reliability can be carried out in addition to cost-intensive residual stress measurements in form of a simple visual assessment of the HFMI treated component. It was the objective of this study to develop a simple, practice-friendly quality assurance test that can be applied under construction site conditions, so that the process safety of the HFMI treatment techniques can be ensured. First approaches were examined within this short study and checked for their relevance and validity. The project was a cooperation with the Karlsruhe Institute of Technology, Research Center for Steel, Timber and Masonry, dept. for Steel and Light Weight Structures.

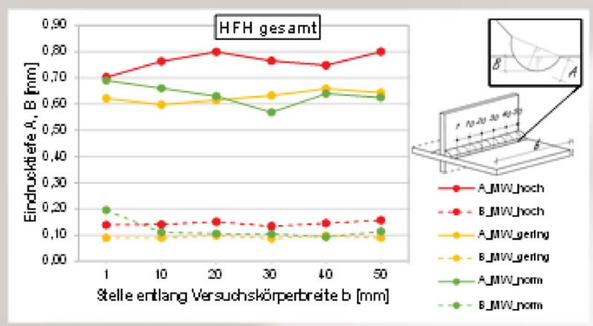
Duration: 2010-2015

Project funding: FOSTA

Contact:
Dr.-Ing. Stephanie Breunig

Quality assurance by varying HFMI-treatment

The effectiveness of post-weld treatment by high-frequency mechanical impact (HFMI) treatment was already shown on several notch details for normal and high-strength steels. A design concept for post-weld treatment with HFMI is given by the German DASt-guideline 026. For the component-specific application on the weld toe, further studies on quality assurance were carried out at as part of the BAW research project.



The objectives of the project were: a) Identification of the influence on the fatigue strength with varying post-weld treatment intensity on the transverse stiffener, b) residual stress and hardness measurements on the HFMI-treated weld toe and evaluation of the correlation and c) derivation of a quality assurance test by means of hardness measurements and / or visual inspection, if necessary with definition of hardness limit values or hardness ranges for HFMI-treated weld toes. As a conclusion at the end it was shown that the intensity of the post-weld treatment has no influence on the fatigue strength and that a careful visual inspection is sufficient to detect remaining notches.

Duration: 2017-2018

Project funding: BAW

Contact:
Dr.-Ing. Stephanie Breunig
Lisa-Marie Gölz, M.Sc.

HFMI-treatment in hydraulic engineering

In recent years, welded joints of high strength steel (350 MPa) post-weld treated by high-frequency hammering have been investigated in several test series concerning the increase of fatigue strength. Up to now, only few test results of post-weld treated welded joints of mild steel S235 were available. This research project was supposed to investigate the influence of post-weld treatment on water locks usually made of S235. It was assumed that the remaining service life of these structures can be extended by reducing the geometric notch effect. In order to determine the fatigue category of the post-weld treated constructional members, large-scale tests on specimens with fillet welds were planned. Through the tests the fatigue resistance of the as-welded state before loading, of post-weld treatment at the end of the assumed service life and of post-weld treatment after retrofitting were determined.

The project was a cooperation with the Karlsruhe Institute of Technology, Research Center for Steel, Timber and Masonry, dept. for Steel and Light Weight Structures.

Durationt: 2009-2013

Project funding: BAW

Contact:
Dr.-Ing. Stephanie Breunig

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Welded Connections High-Strength Steel

Steel Structures

Jennifer Spiegler

Christina Schmidt-Rasche

Andreas Kleiner

SAFEBRICTILE

In SAFEBRICTILE a consistent procedure for safety assessment of the various failure modes relevant for steel structures has been developed, covering ductile, semi-ductile and brittle modes, respectively driven by plasticity, stability and fracture. Especially for joining High-Strength Steel (HSS) and Mild Carbon Steel (MCS) elements the present design rules, e.g. in EN 1993-1-8 lead to comparatively thick fillet and partial penetration welds. The code rules for mixed connections are insufficient due to the fact that the recent rules and safety margins are developed traditionally for standard steels and then transferred to high-strength steels. The existing data which have formed the basis for Eurocode draw a dependency on the material strength f_u and not on f_y as some more traditional design rules assume.

One of the main outcomes of former research projects was that in all cases brittle facture occurred determined obviously by the tensile strength f_u of the base material but also of the filler metal. This is presumed to be also the case for mixed connections which are not yet covered in EN 1993-1-8 or EN 1993-1-12. On basis of these knowledge, further investigations on mixed connections were initiated to set up a data base for the statistical evaluation of brittle failure modes. The research project was in cooperation with 5 partners under coordination of University of Coimbra.

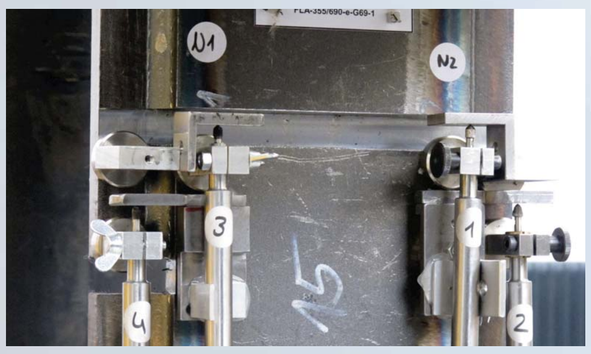
Duration: 2013-2016

Project funding: RFCS

Contact:
Jennifer Spiegler, M.Sc.

Mixed Connections

In practice, mixed connections occur as standard situation, since the choice of steel is usually adapted to the utilization as for example a Mild Carbon Steel (MCS) S355 is connected to a High-Strength Steel (HSS) S690. In order to be able to check the applicability of the design resistance function, which has already been developed for fillet welds of High-Strength Steel with the same base metal for mixed connections, a comprehensive investigation of the load carrying capacity of such connections was required. On the basis of the evaluation of the experimental results of fillet welds from Mild Carbon and High-Strength Steel using different weld material strengths as well as of the results of the statistical evaluation, the applicability could already be confirmed within the research project „mixed connections".



The results were condensed into recommendations, which on one hand include the constructional and welding production of mixed connections for the practice and on the other hand reflect design rules that had been transmitted as a proposal of code rules to the CEN committees.

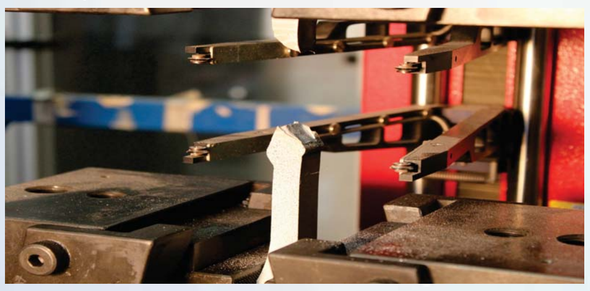
Duration: 2014-2017

Project funding: AiF - FOSTA

Contact:
Jennifer Spiegler, M.Sc.

HighButtWeld

According to EN 1993-1-8, the load carrying capacity of „partial penetration" butt welds must be determined as for fillet welds with deep penetration. For fillet welds, an adapted design model could be developed on the basis of already conducted research. The adaptation for welded butt welds on the other hand had not been done yet. According to EN 1993-1-8, full penetration butt welds must only be verified in the connected member. However, the strength of the used filler metal must be equal to or higher than of the base metal. For normal strength steels, this is ensured in any case because the strength of each filler metal is higher than that of the base metal. For high-strength steels, it only applies to a limited extent. The strengths of the filler metal are often only just above the base metal. At the experiments the failure was often occurring in the heat affected zone, not in the base metal.



Hereby, the determination of the design load of welded butt welds of higher-strength steels according to EN 1993-1-8 would not be on the safe side. As part of the research project "HighButtWeld", experimental investigations on the load carrying capacity of welded butt welds of high-strength steels were realised to develop an adapted and more economical design resistance function. The research project was a cooperation with TU Ilmenau and SLV Halle.

Duration: 2017-2020

Project funding: AiF - DVS

Contact:
Jennifer Spiegler, M.Sc.

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

High-Strength Steels

Steel Structures

Wigand Knecht

Mareike von Arnim

Efficient design of high-strength hollow section K-joints

Lattice girders made of hollow sections are among the most common systems in steel building construction. The use of high-strength steels enables resource efficiency construction methods with lower material input and high load-bearing capacities. The design rules for welded joints with hollow sections have been validated semi-empirically by tests on normal-strength steels and are based on the assumption that local stress peaks are reduced by plastic load redistribution. The question arises whether the local stress peaks have to be considered for high-strength steels, since their high yield strength and limited ductility allow only limited plasticity.

The research project is intended to derive efficient design rules for hollow section K-Joints, which refer to the individual failure modes, if necessary with an adaptation of the reduction factors for high-strength steels. Recommendations will be developed which serve as a basis for practical application and the normative rules in the building code. In order to achieve this goal, large-scale joint tests will be carried out and innovative damage-mechanical numerical models will be used. The project is realised by two institutes: RWTH Aachen University, Institute of Steel Construction and the University of Stuttgart, Institute of Structural Design.

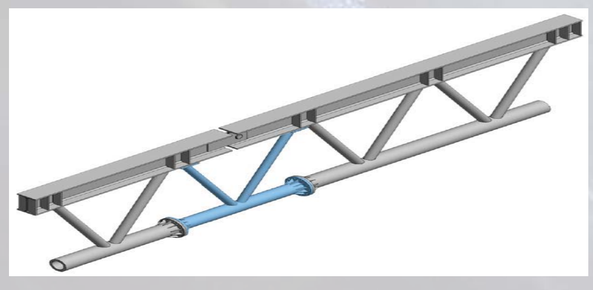
Duration: 2020-2023

Project funding: AiF - FOSTA

Contact:
Wigand Knecht, M.Sc.

High-strength steels in hollow section trusses – HighTRUSS

Circular or rectangular hollow sections are economical profiles for the execution of slender, wide-spanning trusses. In particular, the use of hollow sections made of high-strength steels can lead to economical lightweight structures. The design of hollow sections joints made of high-strength steels is currently being redefined in the revision of Eurocodes 3 in Parts 1-8. Due to the lack of test results, it is intended to meet the safety requirement by means of high reduction factors C_f, which will severely limit the economic use of high-strength steels.



The objective of the project is to extend differentiated and verified information on reduction factors and practical recommendations for the consideration of secondary bending moments. These are intended to provide the basis for the formulation of rules in the corresponding National Annex to the future German edition of prEN 1993-1-8. In order to achieve this goal, large-scale tests on truss girders and X-joints as well as numerical investigations will be carried out. The project is being carried out jointly by Hochschule München University (co-ordinator), Karlsruhe Institute of Technology, University of Stuttgart, Engineering company KoRoh (CCTH) and Feldmann + Weynand, steel construction companies Prebeck and Wegscheid.

Duration: 2021-2023

Project funding: BMWi - WIPANO

Contact:
Wigand Knecht, M.Sc.

Design concepts for mixed connections in steel structures

In order to endorse the economical and future-oriented use of high-strength steels, efficient design concepts for welded connections of high-strength steels must be developed, which is the aim of this research project. This concerns both butt welds, that may fail prematurely due to the formation of a soft zone in the heat affected zone, and fillet welds, where the improved extended design concept may currently only be used up to S700.

For the design of butt welds in steel construction, the design concepts in Eurocode 3 are inadequate: up to now, the design of a butt weld has been based on the cross-section design for the member with the lower steel grade. For butt welds in mixed connections from normal and high strength steels, there is currently no consistent design concept in the European standards, although mixed connections are essential for the application of higher-strength steels. The improved concept extended for fillet welds on higher-strength steels, which considers the filler metal, is only valid for steels up to S700, since there are no experimental investigations on fillet welds up to S960. On the basis of experimental and numerical studies, design concepts will be developed for the draft standards prEN 1993-1-8 and prEN 1993-1-12. The project is being carried out jointly with the TU Ilmenau (Production Engineering) and the Fraunhofer IGP in Rostock.

Duration: 2020-2022

Project funding: AiF - FOSTA

Contact:
Mareike von Arnim, M.Sc.

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Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Connections

Steel Structures

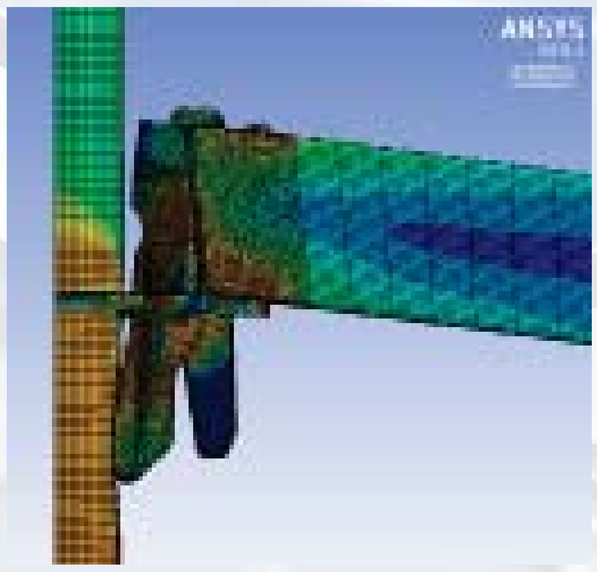
Mareike
von Arnim

Georgios
Skarmoutsos

Gloria
Hofmann

Numerical investigations on the UH Plus beam-column joint

The joint of the UH Plus beam to the column is frequently used for PERI scaffolds of the PERI UP Flex group. For this reason, a finite element (FE) model has been developed with ANSYS, detailed numerical investigations and parameter studies may be carried out on the scaffold joint. The model has been validated with some test results. As changes in dimensions and geometry can quickly be implemented and thus their influence on the structure can easily be investigated in FE simulations, this FE model allows to contribute to an economic development process for an optimised beam-column joint.



With the developed FE model, parameter investigations are carried out for different material properties and steel grades with different yield strengths in particular. Furthermore, the influence of geometrical variations due to tolerances during manufacturing, such as thickness changes, are investigated. The research is carried out together with PERI GmbH Weißenhorn.

Duration: since 2020

Project funding: Peri GmbH

Contact:
Mareike von Arnim, M.Sc.

FAILNOMORE

Structural robustness and mitigation of progressive collapse is a specific safety consideration, which requires particular care from all professionals involved in the construction industry, including architects, designers, constructors, control officers, and insurance managers. During the past decade, RFCS has funded a significant number of research projects related to the structural response of steel and composite buildings in view of robustness. In the frame of these projects, technical aspects related to global (structure) and local (members, compartments, ...) behaviour have been widely investigated for various exceptional loading situations (impact, fire, earthquake, ...). Besides that, EU has financially supported a COST action (TU0601) entitled „robsutness of structures“ which was devoted to the risk assessment and scenario definition aspects.

As an outcome of the FAILNOMORE project, based on the results of already completed research projects, the end-user will be provided with practical and user-friendly design guidelines in view of improved robustness. Example calculations will show the application of these design rules. These will enable a safe yet economic design of steel and composite structures exposed to the threat of possible catastrophic events. This project is being carried out jointly with the University Liège, Coimbra, Trento, Timisoara, Prag, Rzeszów, Delft, Catalunya, INSA Rennes, ECCS, Feldmann + Weynand GmbH and ArcelorMittal Belval & Differdanga S.A..

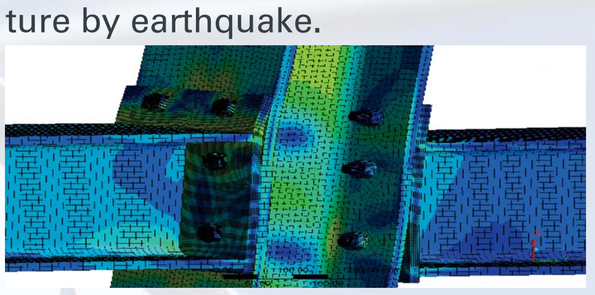
Duration: 2020-2022

Project funding: RFCS

Contact:
Dipl.-Eng. Georgios Skarmoutsos
Gloria Hofmann, M.Sc.

Prequalified beam-to-column joints in areas of moderate seismicity

Key aspects for the design of seismic resistant steel and composite steel-concrete structures are the utilization of the steel material ductility as well as the selection of the appropriate structural system. These will allow for effective redistribution of the internal forces and dissipation of the energy induced to the structure by earthquake.



Aims of the project are (i) the development of prequalified, dissipative, partial-strength bolted beam-to-column joints for steel and composite structures and for use primarily in Moment Resisting Frames and (ii) the preparation, on the basis of the performance-based-design concept, of design guidelines for certain structural systems regarding the allowable deformations and their energy dissipation capacity. Additionally, when referring to low-to-moderate seismicity areas, criteria for the assessment of the need for energy dissipation in the structure will be developed. These investigations involve numerical studies as well as cyclic joint tests and static reference tests. The project aims to selectively adopt already known, valuable principles of seismic design and develop new ones, applicable for areas of up to medium seismicity. This project is being carried out jointly with the RWTH Aachen, Center for Wind and Earthquake Engineering.

Duration: 2020-2023

Project funding: AiF - FOSTA

Contact:
Dipl.-Eng.
Georgios Skarmoutsos

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Stability

Steel Structures

Alexander Enders

Fabian Jörg

Vahid Pourostad

Stability of rolled sections s.t. axial force, bending and torsion

Double symmetric steel sections, especially rolled sections, are the most important type of members used for steel and hall constructions, due to their high load bearing capacity and their flexibility resulting from a large product line-up. Nowadays, they are used for columns and trusses, as well as for purlins and runway beams. As a result of their slenderness, the sections are often sensitive to buckling and are also confronted with various external influences and combinations of different internal forces.

This can be illustrated quite well by the example of a runway beam subjected to dual-axis bending stresses with torsion, due to the horizontal loading at the top flange. During acceleration and brake-application of the crane, additional axial forces in the girders occur. Currently, several design requirements exist to prove buckling resistance, however, these are often too complicated for practical application. Also, the cross section verifications based on large test results according to the theory of second order, or the equivalent member method in Eurocode 3 do not include all internal forces. Within the frame of this research project and based on large scale tests, extended dimensioning rules based on Eurocode 3 Part 1-1 Section 6.3.3 allowing practical calculations for interactions of axial force, bending moments and torsion were developed.

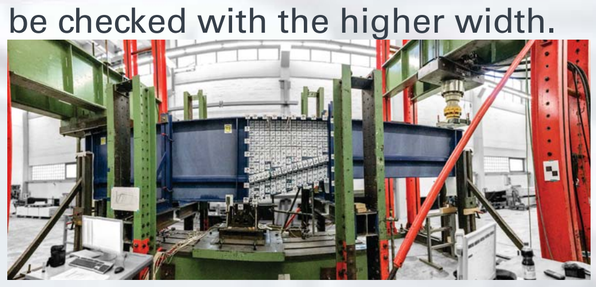
Duration: 2016-2019

Project funding: AiF - DASt

Contact:
Fabian Jörg, M.Sc.

Buckling behaviour of nonrectangular panels

Nonrectangular steel panels are used more frequently in the design of new bridges, due to architectural and/or structural demands. In order to save material and consequently to decrease the impact on the environment, they are used at large spans. The girders are curved in elevation, with maximum depth at an intermediate support and minimum depth at the mid span. Steel bridges built up of slender panels which tend to buckle may be designed based on EN 1993-1-5, which offers among others the effective width method. As a consequence of the optimized shape of new bridges also nonrectangular panels are used, most commonly as web panels of girders with a lower flange curved in the longitudinal direction. However, for an application of the effective width method only rectangular panels with parallel flanges are taken into account. This may also be applied for α up to 10° according to the existing rules. However, in case of the larger angles, the stability of panels has to be checked with the higher width.



Within the framework of a European Research Project OUTBURST (Optimization of Steel Plated Bridges in Shape and Strength) experimental as well as numerical investigations on the buckling behaviour of stiffened and unstiffened nonrectangular panels were conducted. Based on the investigations an appropriate design approach according to EN 1993-1-5 was developed and proposed. The outcomes of this project have led to more economic and safe design for nonrectangular panels. The project was in cooperation with University of Coimbra, Ljubliana and Lisboa, AKTIN, ABES, MCE, GRID.

Duration: 2016-2019

Project funding: RFCS

Contact:
Vahid Pourostad, M.Sc.

Combined steel sheet pile walls

In the construction of large quay walls in deep sea ports, combined steel sheet pile walls; consisting of I-shaped king piles and Z-shaped intermediate piles; are frequently used to compensate for high topographical changes. In order to provide a more economical design of combined steel sheet pile walls, regarding stability, the soil bedding of the steel profiles in non-cohesive soils was investigated experimentally and numerically in the project „Development of efficient design principles for king piles of combined steel piling walls (P 813)". Additionally, effects such as the partial, longitudinal welding of double king piles were taken into account and design rules based on the Eurocode 3 Part 1-1 were derived.

In cooperation with theTUHH the design rules for stability will be extended to include cohesive soils in the current successor project „Optimized design of combined steel sheet piles for the loading process and the final state." Positive constructional effects, such as a thicker head and base weld of the double king piles, can be taken into account for a more economical design. Furthermore, interaction relationships will be developed for the king piles under global stress and local flange bending.

Duration: 2018-2021

Project funding: AiF - FOSTA

Contact:
Alexander Enders, M.Eng.

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Stability

Steel Structures

Fabian Jörg

Alexander Enders

Simplified lateral-torsional buckling method for welded members

The verification of the compression flange as an equivalent compression member represents a clear and easy model for the check of lateral-torsional buckling in practice. This traditional type of verification as given in EN 1993-1-1, para. 6.3.2.4 needed to be adapted for modern beam design considering the point of load introduction as well as mono-symmetric sections. For bridges, the existing verification method is conservative regarding the plateau length of the reduction function and the choice of buckling curve d for welded sections. Also, regarding fire design of beams subjected to lateral-torsional buckling, this simplifies approach of an equivalent compression flange is possible, depending on adequately chosen material parameters.

In fact, in most cases the residual stresses of welded sections are more critical than of rolles sections. However, regarding welded sections scientific findings of residual stresses caused by the welding of the sections were lacking.Within the project, residual stresses were measured for the same girder sections, which were tested for lateral torsional buckling. Furthermore, in case of fire these residual stresses may be neglected because of their minor influences on the buckling behaviour. Therefore, the aim of the project, carried out in collaboration with the Chair of Steel, Light- and Composite Structures of the Ruhr-University of Bochum, was to identify the influence of residual stresses on the member resistance of steel girders, vulnerable to lateral torsional buckling in cold and fire conditions.

Duration: 2017-2020

Project funding: AiF – DASt

Contact:
Fabian Jörg, M.Sc.

Boundary and system influence on the stability behaviour

The use of slender steel members promotes the competitiveness of steel structures in structural engineering. However, it requires an efficient design, in particular for the structural stability behaviour such as lateral torsional buckling. Typical joints between main and secondary beams often deviate from the idealisations (fork bearing), on which normal design methods, in particular assuming simply supported members, are based. Depending on the type of joint, the torsional stiffness varies and a significant difference in the structural behaviour between idealised and real structural behaviour may exist. Additional effort is needed to realise the assumed idealistic boundary conditions in practice. And finally, at the system level, continuous girders or frames are more common than simply supported beams.

The project addresses these open questions of realistic boundary conditions and system effect, which may lead to uncertainties in design. Lateral torsional buckling tests will examine typical joints and connection details and their „clamping effects“ as well as indeterminate structural systems, so that subsequent systematic numerical investigations can lead to supplementary rules. Therefore, the aim of the research project, carried out in collaboration with the Chair of steel, light- and composite structures of the Ruhr-Universität Bochum, is to extend the application range of the simplified design methods and to adapt the design to realistic conditions for the practice.

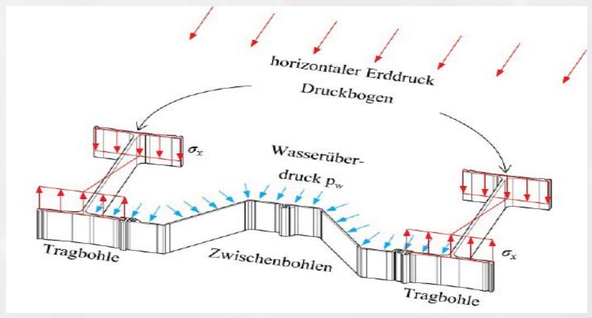
Duration: 2020-2022

Project funding: AiF – FOSTA

Contact:
Fabian Jörg, M.Sc.

3D-Load bearing behaviour of combined steel sheet pile walls

Combined steel sheet pile walls are mainly used for quay wall constructions as a retaining element. They are typically designed as 2D systems. There is only little information on the 3-dimensional load bearing behavior of combined walls. On one hand, there are no approaches on how to determine the influence of the horizontal arching effect and how the load distributes on the steel members. On the other hand, a vertical arching bow occurs due to the depth-dependent increase in earth and water pressure. The inclusion of both, vertical and horizontal arching effects is not taken into account.



Thus, the aim is to determine the load distribution regarding the geotechnical modelling and to investigate the three-dimensional load bearing behaviour of combined walls, which are loaded with earth and water pressure, in order to improve the design rules and guidelines. For this purpose, small compression with beam tests and larger piling tests are planned using the geotechnical determined load sequence. The project is carried out together with the TU Hamburg, Institute of Geotechnical Engineering and Construction Management.

Duration: 2021-2023

Project funding: AiF - FOSTA

Contact:
Alexander Enders, M.Eng.

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Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Bridge Constructions

Steel Structures

Mathias Euler

Stephanie Breunig

Simon Bove

Holistic evaluation of steel and composite railway bridges

Compared to concrete bridges, for the majority of small and medium spans, steel and composite bridges are not competitive in regard of construction costs. Further criteria considering the whole life cycle of bridges may provide more opportunities for steel and composite bridges. Since for bridges no such evaluation system considering the sustainable criteria existed, this project concentrated on systematic investigations on influencing factors. The dominant aim of this project was the holistic assessment of steel and composite railway bridges. The aspects of economic, ecological and functional quality were regarded during the entire life cycle of railway bridges. Important details were focused in view of durability and fatigue design. Since the improvement of fatigue-critical details has major consequences for the lifetime and the maintenance costs of the construction, investigations supported by specific test series were realised.

The project was a cooperation with the Karlsruhe Institute of Technology (KIT), the Technical University Munich (TUM), the Department of Life Cycle Engineering of the Chair of Building Physics and the German railway network operator DB Netz AG.

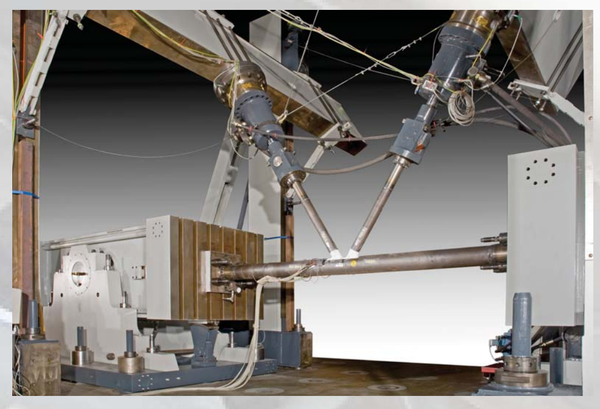
Duration: 2013-2016

Project funding: AiF - FOSTA

Contact:
Dr.-Ing. Stephanie Breunig

Fatigue of thick-walled CHS-joints under considering the weld quality

Welded trusses made of circular hollow sections are widely used in structural and mechanical engineering as well as in plant construction. In the last few decades, the use of thick-walled circular hollow section joints, whose chord diameter to wall thickness ratios $\gamma = d_0/(2\,t_0)$ reach values of $\gamma < 12$ and for which there are still no accepted standardization rules, increased. The closed cross-sectional shape of hollow sections leads to a one-sided welding process. This may cause weld irregularities at the weld roots of hollow-section joints, such as weld root openings or incomplete fusions at the crown-toe. Sometimes hollow section joints have been questioned because a reliable detection of internal weld irregularities by non-destructive testing (NDT) is nearly impossible.



To counteract this, the research project FOSTA P1163 focused on such irregularities in welds, their influence on the fatigue strength and their non-destructive detection. In addition, the transferability of the results from the predecessor project to large scale structures (chord diameter $d_0 = 660$ mm) and the effects of the weld design on the fatigue strength were quantified. In order to open the way for standardization, a DASt-guideline was drafted. The project was realised by the University of Stuttgart, Munich University of Applied Sciences and the Ultrasonic Research Center in Halle.

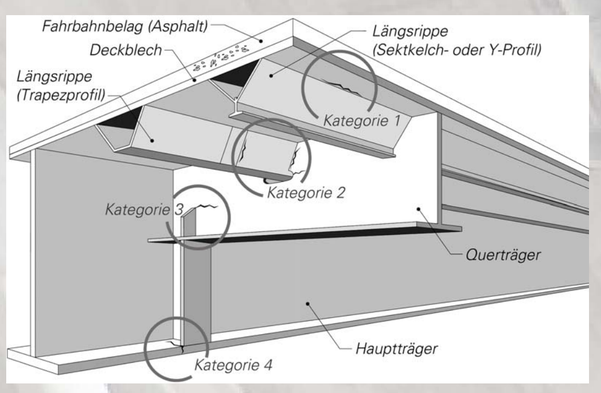
Duration: 2016-2019

Project funding: AiF - FOSTA

Contact:
Simon Bove, M.Sc.
Prof. Dr.-Ing. Mathias Euler

Refurbishment of orthotropic steel bridge decks by bolted solutions

Usually, orthotropic steel bridge decks consist of a deck plate, longitudinal stiffeners, transverse and main girders. Originally, a fatigue design of these road bridges was not mandatory, in contrast to the design rules for railway bridges and the requirements of today's standardization. The unexpectedly rapid increase in heavy traffic in recent years and the associated dynamic traffic loads have led to many fatigue cracks, especially on welded joints.



Besides other damages, damages of the category 2 (cracks in the connecting area of cross girder and longitudinal stiffeners) are most common. In practice, these cracks are usually repaired by grinding and rewelding, but often not with the desired effect. In the context of this research project, an innovative refurbishment technique was investigated, which focused on the use of a bolted solution by means of mechanical fasteners and powerful blind rivets. The fatigue tests on blind rivets also now allow the extension of the scope of application to other cyclically loaded connections of hollow sections. First pilot applications on bridges, which have to be renovated, confirm the advantages of the solution.

Duration: 2015-2019

Project funding: AiF - DASt

Contact:
Simon Bove, M.Sc.

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Bridge Constructions & Standardisation

Steel Structures

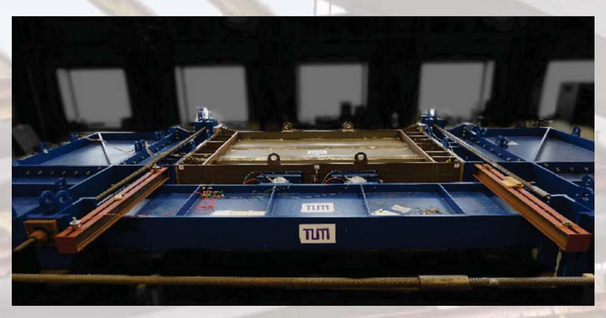
Vahid Pourostad

Lisa-Marie Gölz

Christina Schmidt-Rasche

Longitudinally stiffened panels subjected to multi-axial stresses

Bridges may be built using the incremental launching method, which mostly determines the dimensions of the cross section of bridges. When the bridge is launched, it is of particular importance that the panel above the launching support in the web as well as in the bottom panel are subjected to multi-axial compressive stress states. Theoretical and experimental investigations of steel panels under multiaxial loading are very limited.



In this research project, the following topics were investigated numerically and experimentally. For the global verification EN 1993-1-5 does not contain explicit rules, in particular for the consideration of the influences from column-like behaviour in a stiffened panel subjected to biaxial compression stresses. The favourable effects of the torsional stiffness of the longitudinal stiffeners should be neglected according to the current rules. Due to the lack of investigations, it has been pointed out in literatures that the longitudinal stiffeners must be verified according to the II. Order Theory. Furthermore, the influences of imperfections occurring with different launching systems, namely rockers and hydraulic bearing systems, were investigated. The conclusions from this joint project with TU Munich will be implemented into EN 1993-1-5.

Duration: 2018-2021

Project funding: AiF - DASt

Contact:
Vahid Pourostad, M.Sc.

Practice-oriented design of tubular bracings

The project focuses on the practice-oriented design of fatigue-loaded tubular bracings in steel and composite bridge design. The bracings are usually used in bridge design with box girders as circular hollow sections with a welded connection between the slitted tubular element and the gusset plate. Various design variants are currently used in German bridge construction with different fatigue relevant notches. Those are not regulated by the standards EN 1993-2 or EN 1993-1-9. Therefore, the development of general rules is urgently needed to provide a more economical approach to the design and construction of steel and composite bridges.

By means of experimental investigations and numerical analyses, previously implemented and modified solutions were evaluated with regard to their fatigue behaviour and optimized in accordance with manufacturing requirements. Within the scope of this project for structural engineers and construction companies, a recommendation for three different notch details for the detail catalogue in prEN1993-1-9 was prepared and a proposal for supplementing and adapting the German design aids for steel and steel composite bridges RE-ING published by the Federal Highway Research Institute was made.

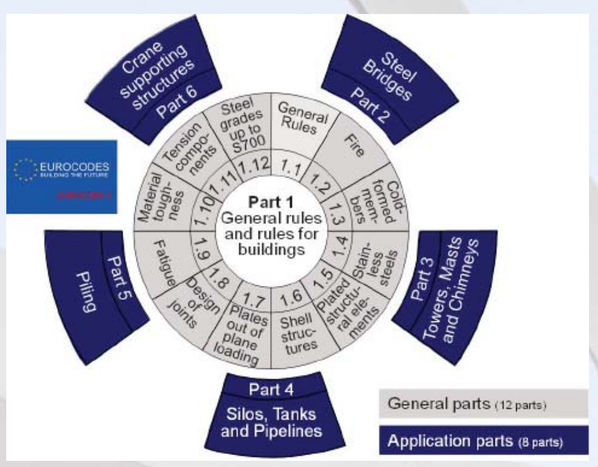
Duration: 2019-2021

Project funding: AiF - DASt

Contact:
Lisa-Marie Gölz, M.Sc.

Steel structures standardisation

The standard EN 1993 „Steel Structures“, with its general and application codes consisting of a total of 20 parts, represents a very large set of rules that is important for building practice. The 2nd Generation of Eurocodes is being developed at the moment.



The evolution, revision and improvement of EN 1993 at the European level is supervised in scientific and technical terms in the technical committee CEN/TC 250/SC 3 “Steel Structures“ chaired by Prof. Kuhlmann. This includes the feedback with the review of the Eurocodes taking place at national level and guidance of the results of the different project teams of Mandate M/515 and the European working groups. The 13 project teams work in the frame of Mandate M/515. They create the drafts for the technical evolution of Eurocode 3. The work in 22 Working Groups of SC3 (nominated experts of different mirror committees) includes the general revision and improvement of the code. Prof. Kuhlmann represents SC3 in the higher level committees of TC250 in order to achieve the best possible harmonization and coordination with the other Eurocodes.

Contact:
Dr.-Ing. Christina Schmidt-Rasche

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Bridge Constructions & Joints

Composite Structures

Maximilian Ziwes

Lena Stempniewski

Steel-to-concrete joints with superimposed loads

Bearing of bridges or foundations of columns are typical situations, where high forces have to be transferred from the steel via anchor plates into a localized concentrated area of concrete. The advantages of composite structures can only be utilized, if these connection between steel and concrete meet economical and technical demands such as easy erection. Especially for these cases the bearing capacity of the joints determined by the design standard tends to be very conservative due to a possible concrete edge failure. Furthermore, the beneficial impact of existing reinforcement or superimposed loads on the load-bearing behaviour is usually not considered.

In reality, the bearing capacity of the anchor plate is increased by a superimposed load due to the compression of the concrete and additional shear capacity based on the friction between steel plate and concrete. Within this research project a practical design concept for steel-to-concrete joints with superimposed loads is developed considering edge influences, effects due to friction, mortar bedding and existing and supplementary reinforcement. Experimental and numerical investigations on anchor plates with headed studs have been conducted and used to verify the design model which is derived from a component model.

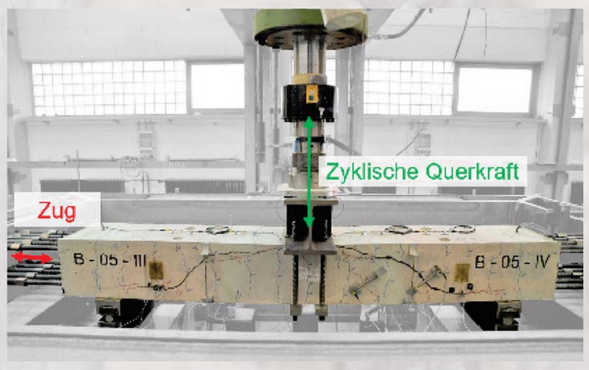
Duration: 2019-2021

Project funding: AiF - DASt

Contact:
Maximilian Ziwes, M.Sc.

Fatigue strength for new cross sections of large composite bridges

For large composite bridges, cross-sections with transverse cantilever beams and longitudinally spanning, non-prestressed concrete deck plates are frequently used. The use of semi-prefabricated concrete slabs allows a short construction time. The concrete slab spans in the longitudinal direction of the bridge, resulting in tensile stresses in the concrete slab above the support. This leads to cracked concrete cross-sections. Transversal forces resulting from traffic such as the wheel load of a lorry need to be transmitted through this cracked concrete. Currently, in design the crack width is limited to 0.15 mm.



In this research project, on one hand the load transfer of the transverse forces over the cracked concrete is clarified, on the other hand the welded connection of the cantilever to the steel web is experimentally investigated with regard to fatigue. In addition, a monitoring system on three bridges will provide information about the actual stresses in the concrete slab and the connection of the cantilever beam. The research project is carried out in collaboration with the consulting office of Prof. Dr.-Ing. Ulrike Kuhlmann, TU Berlin (Prof. Dr.-Ing Karsten Geißler), GMG Ingenieurgesellschaft, Dresden and TU Munich (Prof. Dr.-Ing Oliver Fischer).

Duration: 2019-2021

Project funding: BMVI

Contact:
Lena Stempniewski, M.Sc.

Reinforced concrete bridge decks under multi-stage cyclic loading

For highway bridges, numerous large bridges with spans in the range of 50-60 m and above will have to be replaced in the coming years. For this span range, for the superstructures steel concrete composite construction has established as an economical construction method. Recently, precast concrete elements have increasingly been used for building the concrete bridge deck. A transversely oriented steel structure is then required to support the precast elements, e.g. by arranging inclined struts with a tension band and secondary longitudinal girders or steel cantilever girders to support the precast elements. As a supplement to the BMVI project, multi-stage cyclic tests will be carried out on reinforced concrete decks in order to clarify the application of the damage hypothesis for fatigue loading. In addition, investigations in order to optimize the top flange welded connection for fatigue and a supplementary structural monitoring are planned.

The research project is carried out in collaboration with the consulting office of Prof. Dr.-Ing. Ulrike Kuhlmann, TU Berlin (Prof. Dr.-Ing Karsten Geißler) and GMG Ingenieurgesellschaft, Dresden.

Duration: 2020-2022

Project funding: BASt

Contact:
Lena Stempniewski, M.Sc.

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Connections

Composite Structures

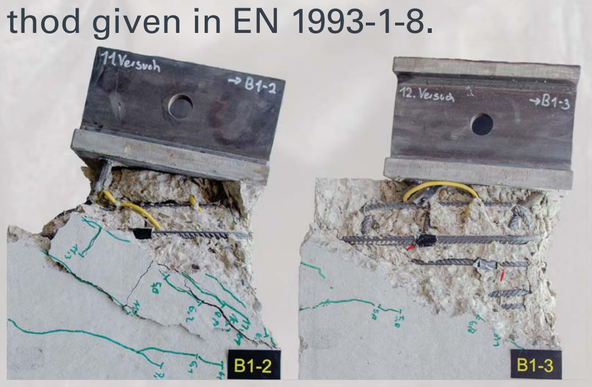
Jakob Ruopp

Lena Stempniewski

Steel-to-concrete joints with concentrated loading

In practice, large forces often have to be transferred in a localized concentrated area of concrete structures by steel-to-concrete joints. Typical applications are columns, strip foundations, anchor plates at the top of columns or the bearing points of bridges, which can be loaded by large horizontal forces.

At the anchor plates close to the edge, concrete failure mechanisms are decisive, as failure modes such as concrete edge failure may occur. The shear capacity of these joints according to current standards is generally too low. As consequence, complicated solutions for this detail are designed in order to transfer high loading into the concrete structure. Within this research project, appropriate design models for steel-to-concrete joints under concentrated loading according to DIN EN 1992-4 were developed. In addition, high strength materials were considered within the project to increase the load carrying capacity of these joints. Based on tests and numerical calculations an analytical design model considering also additional reinforcement has been derived based on the component method given in EN 1993-1-8.



Duration: 2016-2018

Project funding: AiF - DASt

Contact:
Dr.-Ing. Jakob Ruopp

Horizontally lying studs under tension loads

Prefabricated composite girders with horizontally lying studs are an economical solution for bridge constructions without interrupting the traffic. For the application range of smaller and medium bridge spans T-beam cross-sections with horizontally lying studs connecting a prefabricated concrete slab can be used. This design concept represents an innovative design for composite girders as the upper flange of the steel girder can be saved by welding the studs on the steel web and the prefabricated slab serves as scaffolding for the cast-in-situ concrete. In this case the compression forces in the upper flange are carried mainly by the concrete cross-section.

The capacity of headed studs in edge position is limited by splitting forces in the concrete flange due to combined shear and tensile forces in the direction of the concrete flange thickness. A design model for the tensional resistance according to DIN EN 1992-4 has been developed based on experimental and numerical studies that takes into account the amount of reinforcement in the concrete slab. Higher load-carrying capacity of the composite girder can be reached by increasing the reinforcement ratio and the thickness of the concrete plate by applying the new design approach. The project contained testing of the edge situation of the horizontally lying studs and the development of a concept for designing the horizontally lying studs not only for shear but also for tension.

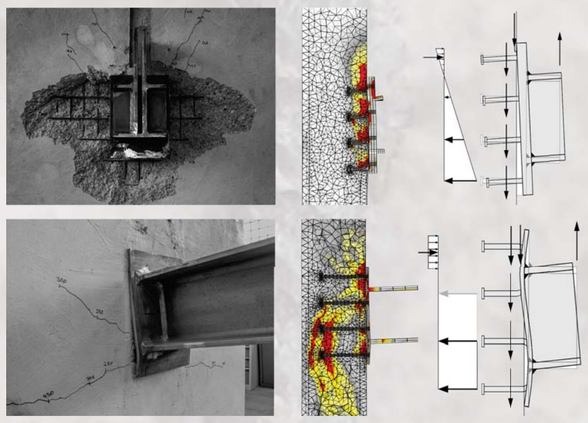
Duration: 2017-2018

Project funding: BASt

Contact:
Dr.-Ing. Jakob Ruopp
Lena Stempniewski, M.Sc.

Large anchor plates

Especially in industry and plant engineering, high flexibility in the area of connections between steel and concrete is required. According to current standards, the maximum number of fasteners is limited to a distribution of 3x3 anchors on an anchor plate. The objective of the DASt/AiF research project was the development of new calculation approaches for large anchor plates with more than nine headed studs.



In collaboration with the University of Kaiserslautern, the load-bearing behaviour of large anchor plates was investigated by extensive test series. Tests under normal forces were carried out at the University of Kaiserslautern and tests under shear forces at the University of Stuttgart. Within these experiments, parameters such as embedment depth of the headed studs, thickness of the anchor plate and eccentricity of the shear loading were varied. Further influence parameters were investigated by means of numerical studies. A new calculation approach for large anchor plates was developed based on the component method. This approach was verified by experimental and numerical investigations and can be used for anchor plates with more than nine headed studs.

Duration: 2013-2016

Project funding: AiF - DASt

Contact:
Dr.-Ing. Jakob Ruopp

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Composite Beams & Shear Connections

Composite Structures

Johannes Schorr

Florian Eggert

Innovative shear connector systems

Within the frame of two industrial research projects, innovative ductile shear connectors have been tested and approved successfully in cooperation with ArcelorMittal Europe – Long Products, Luxembourg and Hilti AG, Liechtenstein. The CoSFB system (Composite Slim-Floor Beam) by ArcelorMittal is suitable for composite flooring systems. The steel beam is fully or partially embedded in the concrete chord. The composite action is not realized by headed studs but by innovative concrete dowels. A common reinforcement bar is positioned in a hole in the web of the beam. CoSFB concrete dowels show excellent performance with regard to bearing capacity and ductility and were approved in Germany in summer 2014. The CoSFB concrete dowel system was honoured with the "Ingenieurpreis des Deutschen Stahlbaus 2015".

The X-HVB system of Hilti is particularly suitable for the modification of existing steel structures to composite structures. The shear connectors are fixed by powder-actuated fasteners on the upper flange of the steel beam. The powder-actuated fasteners also ensure the ductility of the system. In the past, a German approval was received for this system. Within an extension of the product range to very small shear connectors (height 40mm) for very low top concrete layers a European approval has been strived for – supported by additional test series.

Duration and project funding:
ArcelorMittal 2009-2014
Hilti AG 2015-2016

Contact:
Johannes Schorr, M.Sc.

Composite beams with low degrees of shear connetion (DISCCO)

Within the framework of a European project coordinated by SCI, London, composite slabs with additional steel sheeting spanning transversally to the supporting beam were investigated (DISCCO). Under certain conditions, current rules of Eurocode 4 dealing with the minimum degree of shear connection lead to an uneconomic dimensioning – especially when using modern types of profiled sheeting. When using modern types of profiled sheeting, numerous tests showed that the real failure load of headed studs were clearly lower compared with the prediction of the equations in Eurocode 4.

To investigate the real behaviour of composite beams with low degree of shear connection, a comprehensive study was carried out. This study confirmed that composite beams with degree of shear connection clearly lower than the current limit of 40% can also be calculated according to the current rules of Eurocode 4 (ULS and SLS). The new knowledge on the reduced bearing capacity of composite slabs with additional steel sheeting spanning transverse to the supporting beam has to be taken into account. The findings of these tests as well as results of further numerical investigations lead to new rules concerning the minimum degree of shear connection and the bearing capacity of headed studs when using profiled compsite slabs. This project was a cooperation with the University of Bradford and Luxemburg , SCI Steel Construction Institute and ArcelorMittal.

Duration: 2012-2015

Project funding: RFCS

Contact:
Johannes Schorr, M.Sc.
Dr.-Ing. Florian Eggert

Application rules for slim-floor beams

Within this European research project, involving six partners coordinated by the Institute of Structural Design, new application rules for slim-floor solutions were developed. Currently, the design approach is ruled by national applications or manufacturer specific slim-floor solutions. The development of integral rules simplifies and generalizes the application rules. The aim was to increase the competitiveness of steel in buildings by developing an integral and holistic approach for the application of flooring systems with steel slim floor beams. By use of new and optimized shear connector systems, the application of the slim floor system has been optimized.

The developed design rules base both on experimental and numerical results. In this context, existing design rules of the Eurocodes have been revised for their application to slim-floor beams, such as the 6 mm ductility criterion of shear connectors required for partial shear connection. These rules were developed for composite beams in the early 1990s. In addition to the design rules, recommendations and guidelines for practical application of slim floor systems have been developed. This project was a cooperation with the University of Bradford and Trento, SCI Steel Construction Institute, ArcelorMittal and Lindab.

Duration: 2015-2018

Project funding: RFCS

Contact:
Johannes Schorr, M.Sc.

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University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Timber-Concrete-Composite Structures

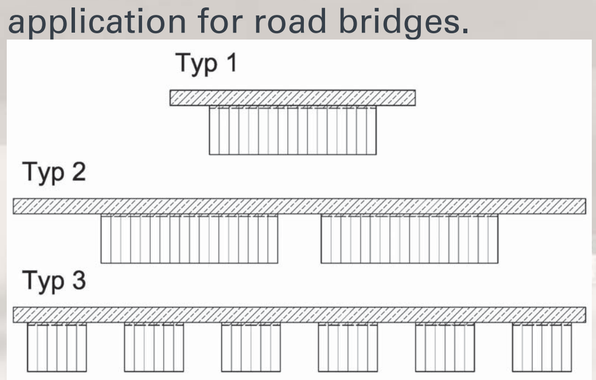
Timber Structures

Simon Mönch

Katrin Kudla

Simplified fatigue verification of timber elements in TCC road bridges

Timber-concrete-composite (TCC) structures are an economical and sustainable alternative solution for road bridges with span lengths up to 30 m compared to pure timber or pure concrete bridges. Around 50 % of all road bridges in Germany have spans between 5 and 30m, which shows the market potential. Through the combination of timber and concrete, higher stiffness and higher strength are achieved in comparison to timber bridges. The fatigue verifications play an important role for an application for road bridges.



As a first step, the fatigue behaviour of a notched connection, which is very easy to construct, was investigated. In the next step, the fatigue verification for typical TCC road bridges was improved and simplified. Three different types of bridge cross-sections with various span lengths, service lives between 80 and 140 years and two different fatigue load models were investigated. Particular attention was paid to the fatigue verification of the notch, which has to transfer high longitudinal shear forces. The results show that for most of the TCC road bridges fatigue verifications of the timber members are not decisive in comparison to the strength verifications. Even a high traffic volume and long service lives of 100 years or more may be realized with regard to fatigue.

Duration: 2012-2014

Project funding: AiF - iVTH

Contact:
Simon Mönch, M.Sc.
Dr.-Ing. Katrin Kudla

Fatigue behaviour of notched connections for TCC-beams

The main objective of the project is to analyse the fatigue behaviour of timber-concrete-composite beams (TCCBeams) with notched connections. Firstly, the transferability of accepted methods and procedures in design of steel and steel-concrete-composite constructions was reviewed. An appropriate fatigue verification will be derived in order to allow for the practical application of this connection in road bridges and other types of constructions with relevant fatigue loading. This project is carried out in close collaboration with the TU Braunschweig (Prof. Sieder). At the TU Braunschweig, fundamental investigations of the fatigue properties of self-drilling full threaded screws are carried out. The verification process, which originally was derived for steel- and steel-concrete-composite beams is studied. This design process is based on S-N-curves and the linear damage accumulation hypothesis by Palmgren and Miner.

It is checked if this process is also applicable for notched connections in TCC-beams or whether additional limitations are necessary. Therefore, preliminary studies are conducted to identify possible effects of sequential arrangements in variable amplitude spectrum and the remaining bearing capacity after a cyclic testing for a number of cycles without fracture. The conducted investigations on the fatigue behaviour of notched connections within this research project should enable a safe and efficient use of this kind of connections.

Duration: 2018-2021

Project funding: DFG

Contact:
Simon Mönch, M.Sc.

TCC-floors for industrial buildings

Timber constructions become more and more important for multi-storey and industrial buildings. But for this field of application requirements regarding fire protection, sound insulation and loading become more stringent. For this reason, timber-concrete-composite floors are chosen more and more frequently. This type of floors withstands the stringent requirements and has a very high cost-benefit ratio. Some advantages of TCC-floors are high strength, excellent physical properties, small overall thickness and optimal utilization of specific material properties. Floors with long span lengths for high concentrated and distributed loads are possible.

Within the research project, a new type of TCC floor, suitable for high loads, was developed. The notched connection between timber and concrete was investigated in particular. It was improved to match the new requirements. Experimental push-out and beam tests were performed in order to determine strength and stiffness of the chosen connection of the whole floor. Thus, a design model and a calculation method were proposed for the new TCC-floor system. This project was a cooperation with PIRMIN JUNG Deutschland GmbH.

Duration: 2014-2017

Project funding: AiF-ZIM

Contact:
Simon Mönch, M.Sc.

www.uni-stuttgart.de/ke

University of Stuttgart
Institute of Structural Design
Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Joints

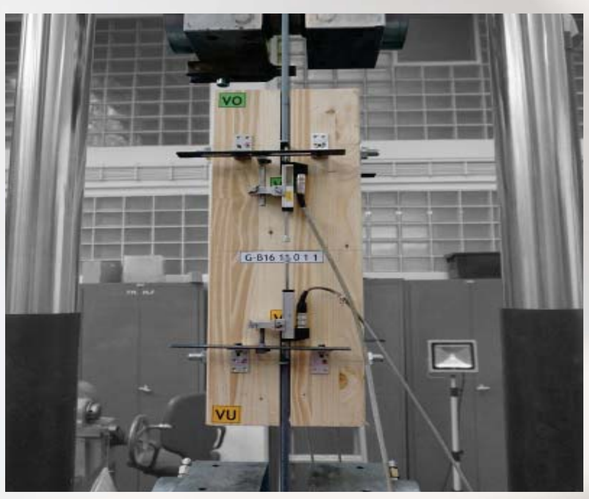
Timber Structures

Julius
Gauß

Lea
Buchholz

Efficient steel-timber dowel connections

Forming joints with high-performance and easy-to-create connections is the key to the economic optimization of timber structures. While the load-bearing capacity is already covered correctly by the standard, the determination of the connection stiffness is not satisfactory. In addition to a redistribution of internal forces in the system, with an accurate prediction of the load-displacement behaviour, e.g. with the component method, also the expected failure mechanism of the connection can be predicted.



The aim of the cooperation research project with the University of Applied Sciences Biberach is to investigate and quantify the load-displacement behaviour of dowel connections as accurately as possible. Among other things, the effects of a change of the number of dowels in the grain direction, of the load-to-grain angle or of the slenderness of the fastener or the influence of reinforcing measures on the stiffness have been examined.

Duration: 2019-2021

Project funding: AiF – iVTH

Contact:
Julius Gauß, M.Sc.

Innovative timber joints

High-performance wooden structures require the selective influencing of the deformation behaviour of the joints. Innovative timber joints are made up of different „components“ that can be put together according to the desired properties of the joints. The component method is appropriate for the optimisation of timber joints and for the determination of the connection stiffness, which is required above all in today‘s common use of computer-based methods for the calculation of internal forces and verification in the design. However, the values for the connection stiffness of dowel connections in softwood stored in the current Eurocode 5 are incomplete. For hardwoods, no systematic investigations of the deformation behaviour exist yet.

The aim of the project is to significantly increase the data base on connection deformation through experimental investigations on approx. 165 connections in hard- and softwoods. By processing and making available the research results for practice and standardisation, as well as developing guidelines for an economical and safe application of stiffness in timber construction, the design of even demanding engineering load-bearing structures can be simplified.

Duration: 2021-2022

Project funding: Holzbau-Offensive

Contact:
Lea Buchholz, M.Sc.

IntCDC - FE-based design of timber structures

RP-7 is part of the Cluster of Excellence IntCDC at the University of Stuttgart. The aim is to develop an integrated approach for the design verification of new construction products and processes on the basis of experimental and numerical investigations (abbr. IATN) which respects or further develops the basic rules in Eurocodes for timber construction is the aim of RP7. The idea behind IATN is an integrated design approach, whereby extensive experimental investigations can be replaced by numerically simulated tests.

For the development of IATN, the Institute of Structural Design is experimentally investigating the embedment properties of dowels in hard- and softwood. Influences of defects, the load-to-grain angle and the diameter of the fastener are also systematically recorded. The experimentally obtained embedment properties serve as input values for numerical models of dowel connections. These are verified and validated by connection tests, which have been and are being conducted in two further research projects. Finally, comprehensive parameter studies can determine the model uncertainty and thus the prediction accuracy.

Duration: 2019-2022

Project funding: DFG

Contact:
Julius Gauß, M.Sc.
Lea Buchholz, M.Sc.

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University of Stuttgart
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Steel, Timber and Composite Constructions
Prof. Dr.-Ing. Ulrike Kuhlmann

Stability & Standardisation

Timber Structures

Janusch Töpler

Optimization of the effective length method M-N-interaction

Due to in-plane flexible buckling and lateral torsional buckling of long-spanning timber beams, stability failure often occurs in these members. According to current investigations, for a combined loading of compression and bending the equivalent length method according to EN 1995-1-1 is partly far on the safe side, which makes an economic and competitive design of such timber members considerably more difficult.

The aim of the research project is therefore, to create the data base for analytical and numerical investigations by means of experiments, on the basis of which the combined equivalent length method of in-plane buckling/lateral torsional buckling can be economically optimised and the moment-normal force interaction relationship for members at risk of lateral torsional buckling can be revised. Within the scope of the test programme, the influence of slenderness and the ratio of moment to normal force on the load-bearing behaviour of timber beams are to be investigated. Based on this analytical and numerical investigations will be conducted. The revised verification should enable planners as well as small and medium-sized timber construction companies to plan and erect more economical and competitive timber structures.

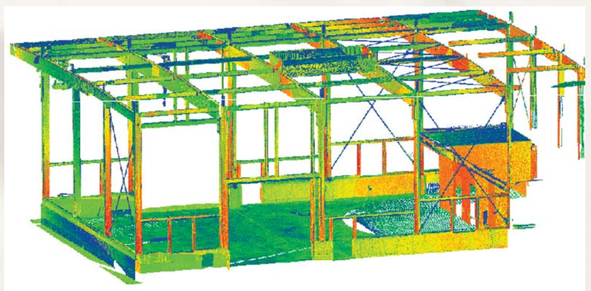
Duration: 2021-2022

Project funding: AiF – iVTH

Contact:
Janusch Töpler, M.Sc.

Imperfection measurements on timber members

With the increasing use of long-span structures made of glulam and innovative hardwood products, increasingly slender load-bearing structures with higher imperfection sensitivity are being designed in timber construction. An extensive measurement programme in cooperation with the Institute for Photogrammetry (IfP) of the University of Stuttgart on real members will create a database with geometric imperfections of hardwood elements (especially LVL) and elements (especially glulam) made of softwood that are subject to bending stresses. Together with assumptions on structural imperfections, the measured geometric imperfections serve as input values for systematic FE-calculations for the determination of the load-bearing capacity of imperfection-sensitive timber members. The comparison of the „numerically“ determined equivalent imperfections with the approaches of the Eurocode allows an evaluation of the existing verification methods and the derivation of recommendations for improved approaches.



Finally, recommendations for the equivalent imperfections of imperfection-sensitive timber members, are to be given, which allow an economic design at a uniform safety level.

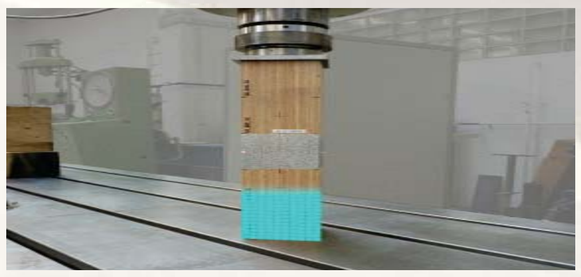
Duration: 2020-2021

Project funding: DIBt

Contact:
Janusch Töpler, M.Sc.

IntCDC – FE-based design of timber structures

RP-7 is part of the Cluster of Excellence IntCDC at the University of Stuttgart. The aim is to develop an integrated approach for the design verification of new construction products and processes on the basis of experimental and numerical investigations (in short: IATN), which respects the basic rules of the Eurocodes or further develops them into a guideline for FE-based design in timber construction.



The idea behind IATN is an integrated design approach, whereby extensive experimental investigations can be replaced by numerically simulated tests. Experiments are however needed for the validation of numerical models, which then allow within parameter investigations to produce “fictive test results” which can be dealt with as proposed in Eurocode 0 Annex D. Within the development of IATN case studies on e.g. slender beech LVL (laminated veneer lumber) columns will be conducted. Within the scope of the case study on slender beech LVL columns, the load-bearing behaviour of such columns prone to in-plane buckling is investigated experimentally at different slenderness ratios. Based on further material tests on hardwood LVL, a FE model is developed, validated and used for parameter studies to determine the buckling curve for beech LVL columns.

Duration: 2019-2022

Project funding: DFG

Contact:
Janusch Töpler, M.Sc.

www.uni-stuttgart.de/ke