ETH zürich

ibk Institute of Structural Engineering
Chair of Steel and Composite Structure

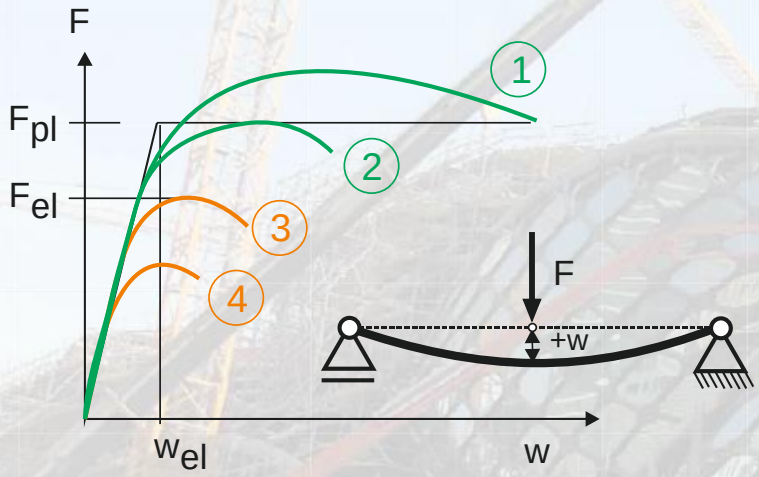
Process-quality based Performance Assessment for Metal Structures

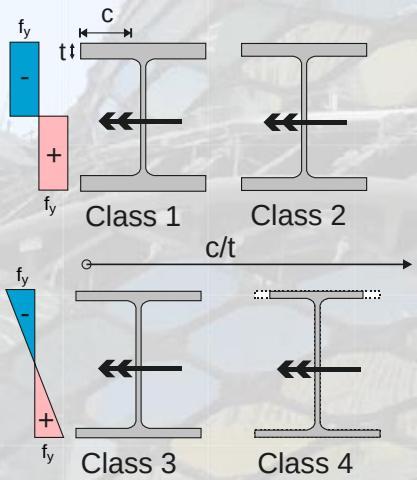
Prof. Dr. Andreas Taras

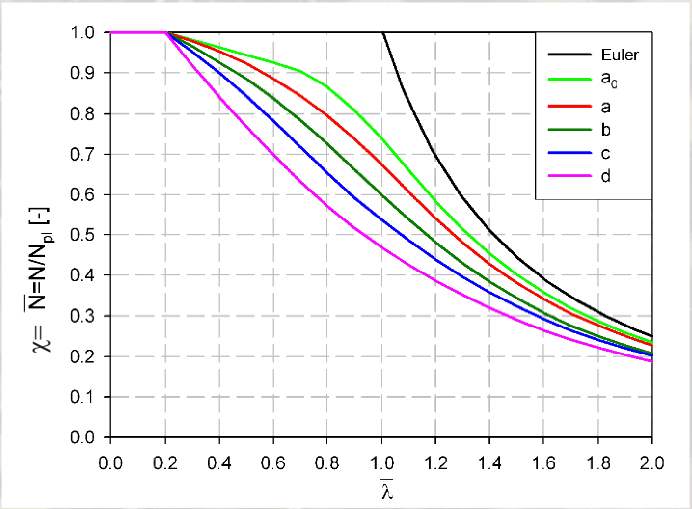
D-BAUG, IBK, Steel and Composite Structures

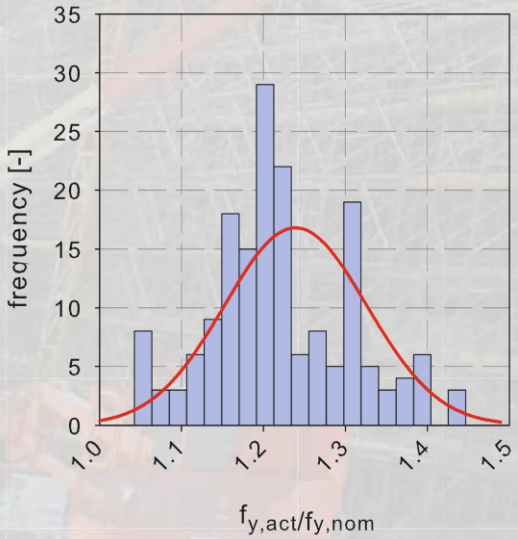
Steel Structures – Infrastructure, Energy, Architecture

Traditional Metal Structures Design and Performance Assessment









a. Deformation capacity is represented by rough classification system that leads to discontinuities of predictions

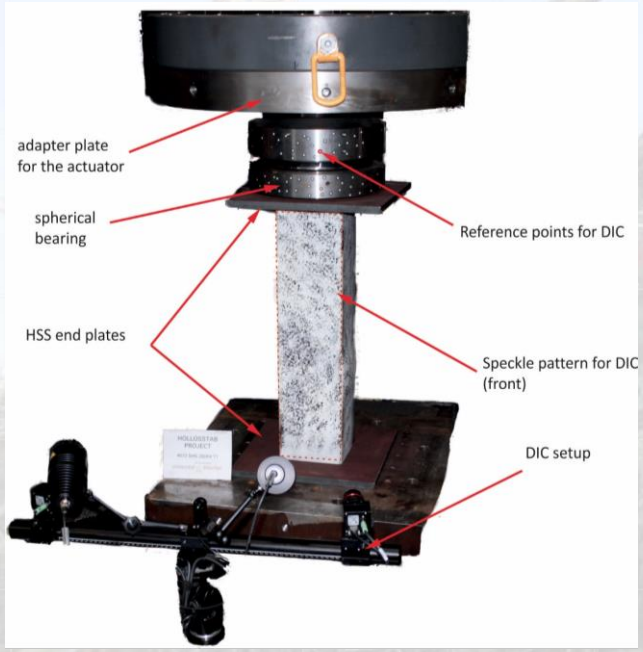
b. Strength is estimated through highly idealized stress distributions

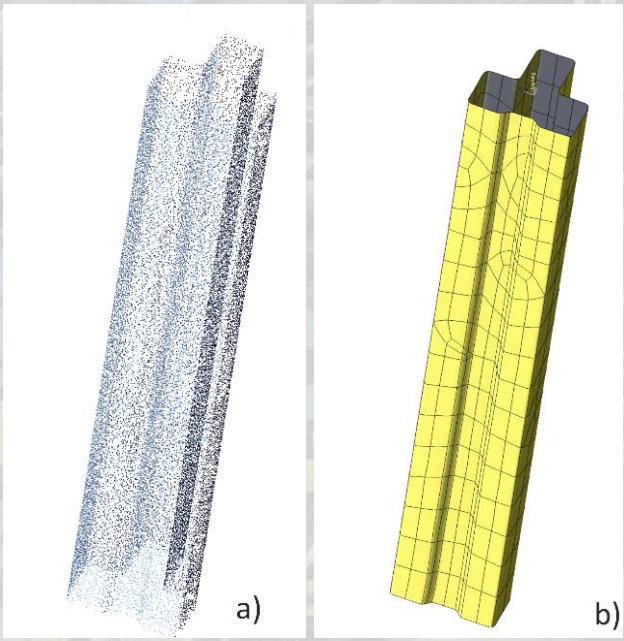
c. Instability in compression is covered by calibrated “buckling curves“ = resistance functions, f (geometry, material, modelling...)

d. All resistance functions are based on extremely low fractiles of production / material parameters (guaranteed values)

➡ *Average underestimation of strength in the range of 50%*

Large scale:
Compressive behaviour of high-strength-steel thin-walled tubes

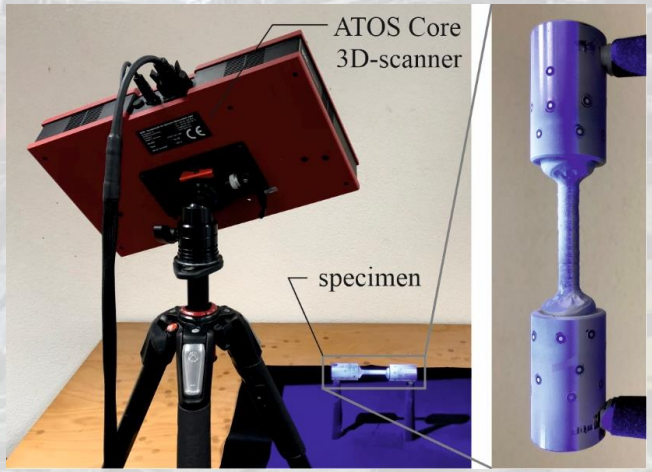


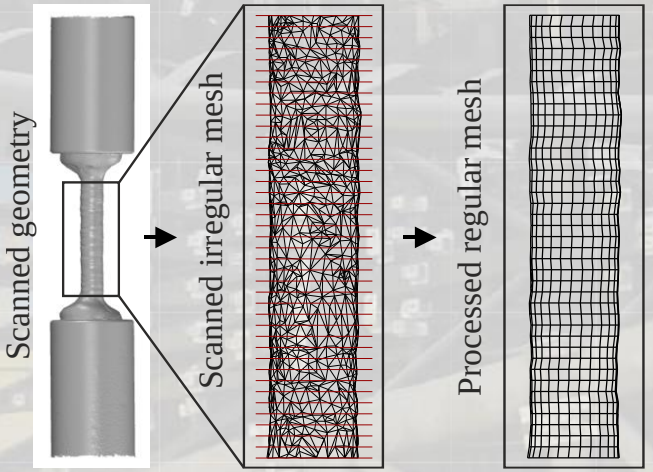


- DIC: measurements of initial shape and 3D displacement field during loading
- Reverse engineering: construction of FEM models with as-built geometries from point clouds
- Standard destructive and non-destructive material characterization tests on samples

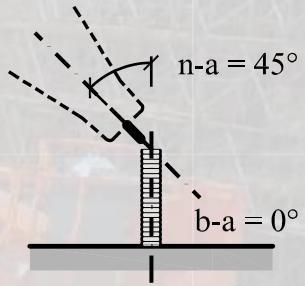
Small scale:
Wire and arc additively manufactured (WAAM) steel bars
(cooperation with Gramazio Kohler Research Group, D-ARCH)

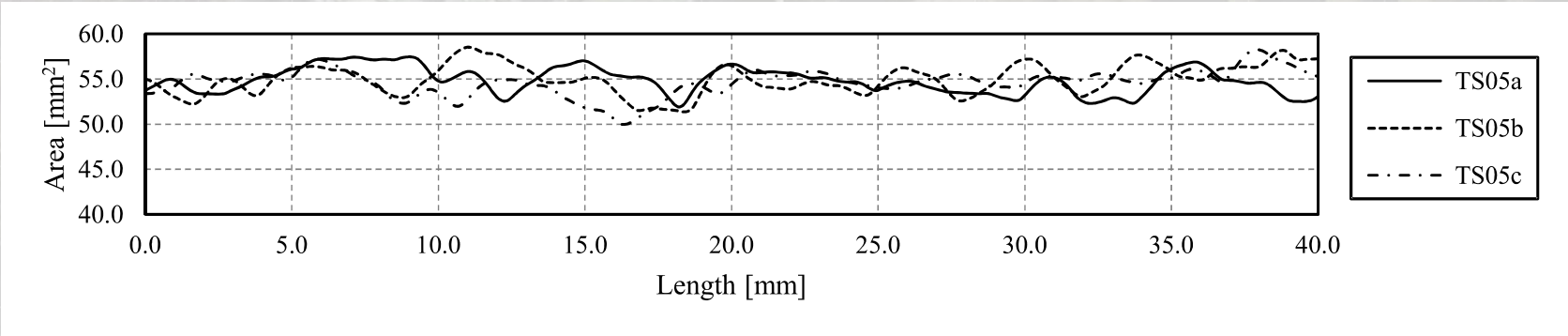
- *same steps as previously shown ...*



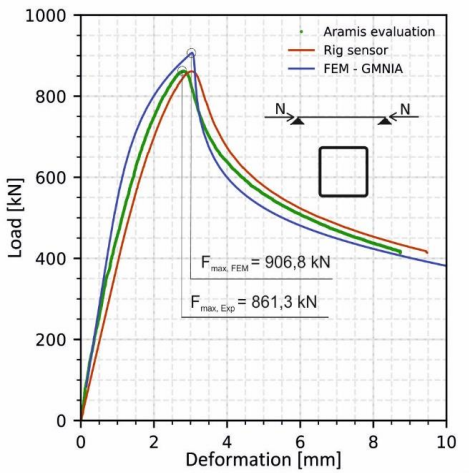


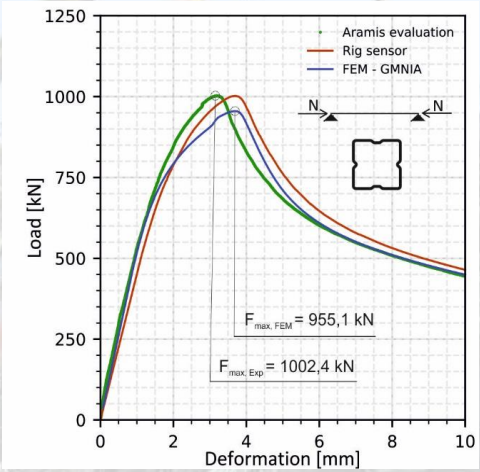
Geometry evaluation of the WAAM steel bars and mesh processing for finite element simulations

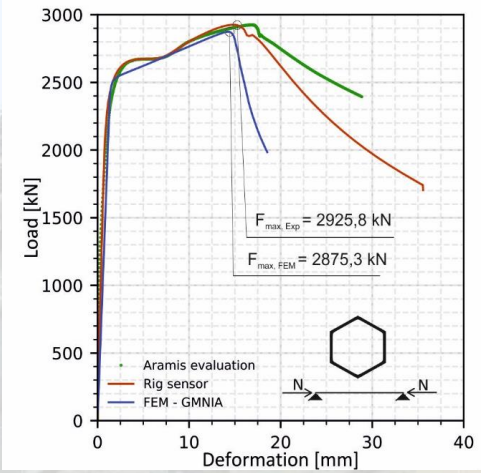




Prediction accuracy of simulation models:

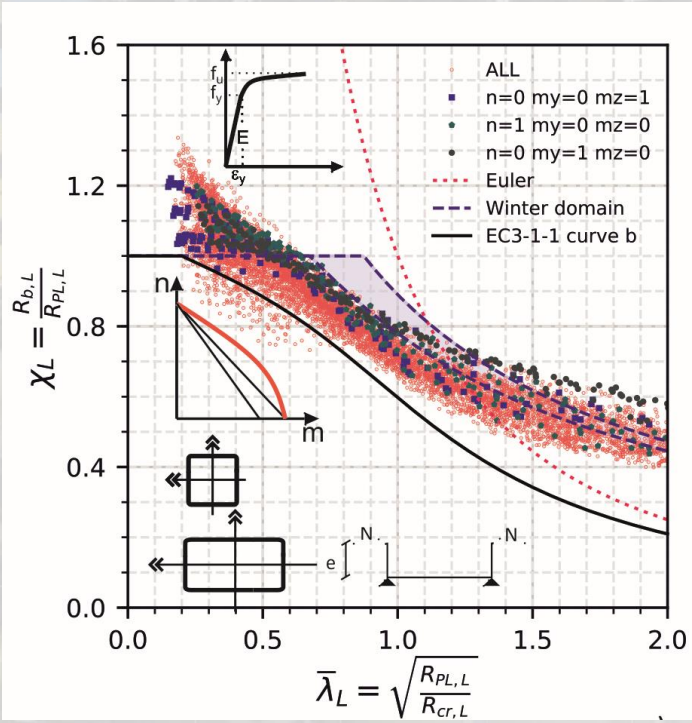




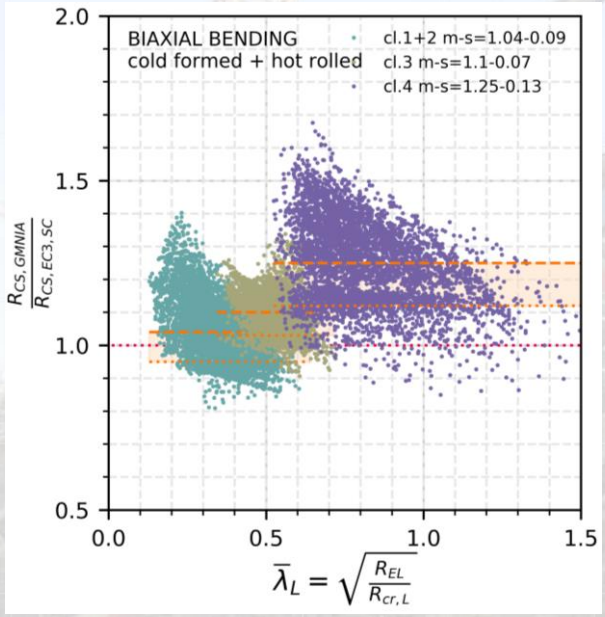


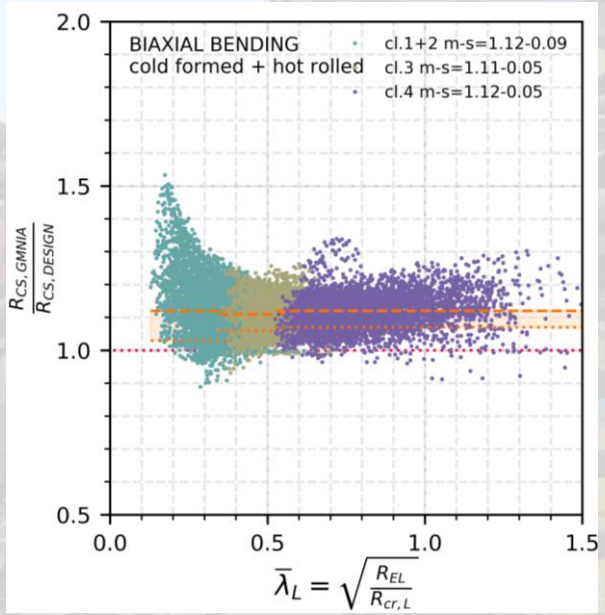
Statistics for $N_{u,Exp}$ / $N_{u,SIM}$	
Mean value (n=180)	99%
CoV	3,5%

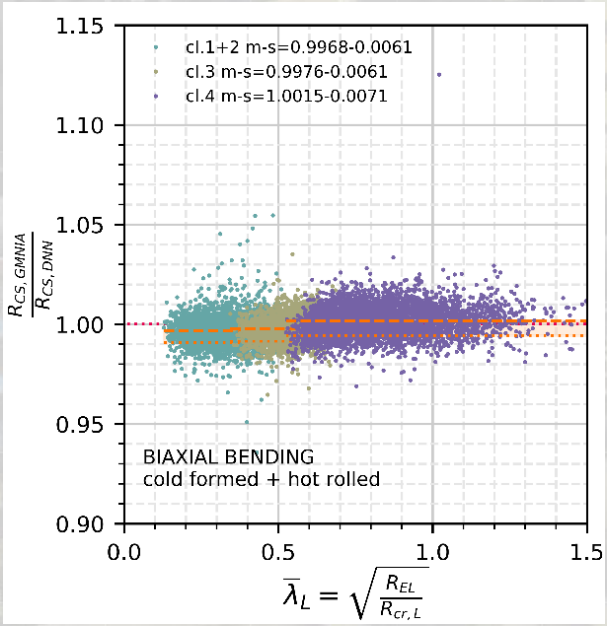
- Simulation accuracy for ductility- and instability-dominated failure modes is very high
- Validated models are thus used for the creation of very large data sets of numerical tests
- The latter are based on quality-control data on basic variables from production (material, geometry) and Monte Carlo sampling techniques



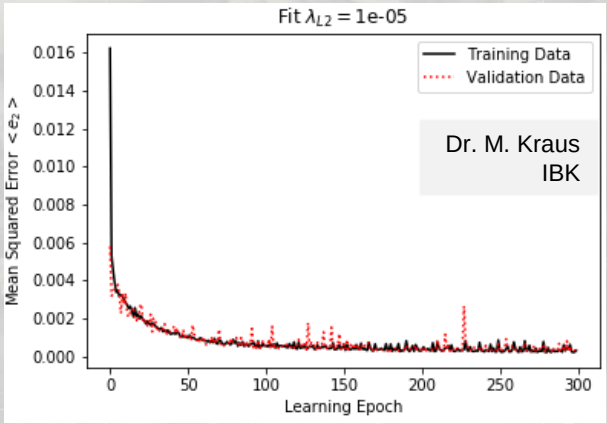
Development of Prediction Models: by Human and Artificial Intelligence



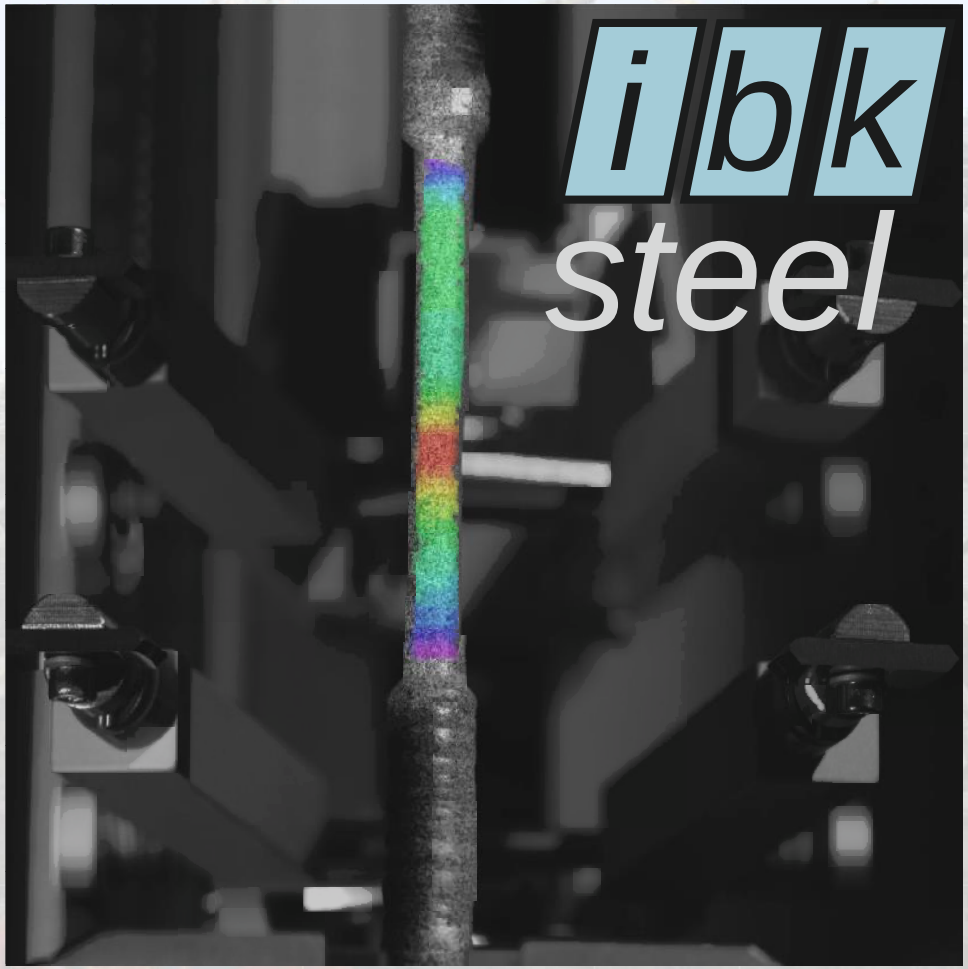




- With these data sets, significant improvements in prediction model accuracy and economy can already be achieved with conventional, „human-developed“ resistance functions
- Accuracy can further massively be increased with AI techniques (here: Deep Neural Networks)



Conclusions:
What we could do with your production data



For individual, bespoke construction products:

- Vastly reduce or altogether eliminate the need for component tests
- Develop extremely accurate and economical design and assessment methods

For steel design methods in general:

- Provide the basis for data-based and AI-driven design and prediction of structural performance of metallic structures

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Thank you for your attention!

Prof. Dr. Andreas Taras
taras@ibk.baug.ethz.ch

ETH Zurich
D-BAUG – IBK
HIL D36.1
Stefano-Franscini-Platz
8093 Zurich

https://taras.ibk.ethz.ch/