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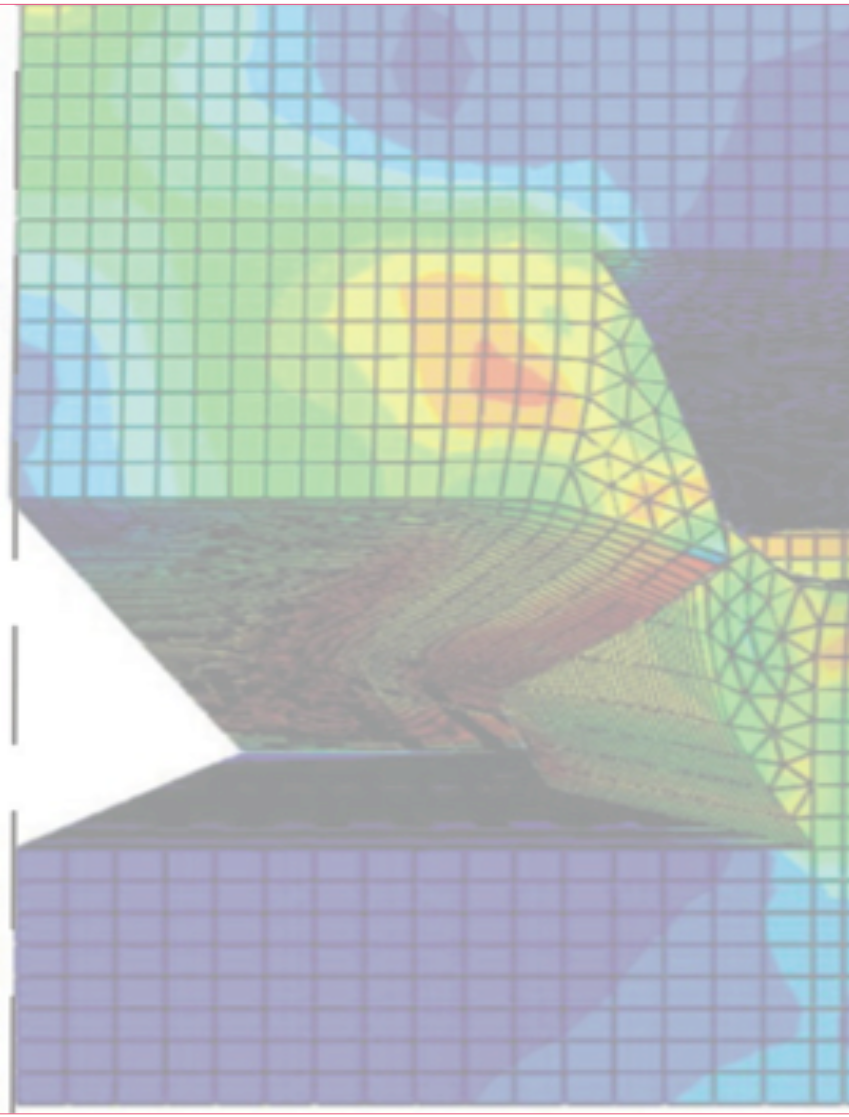
Snap-fit connections

Hèrm Hofmeyer

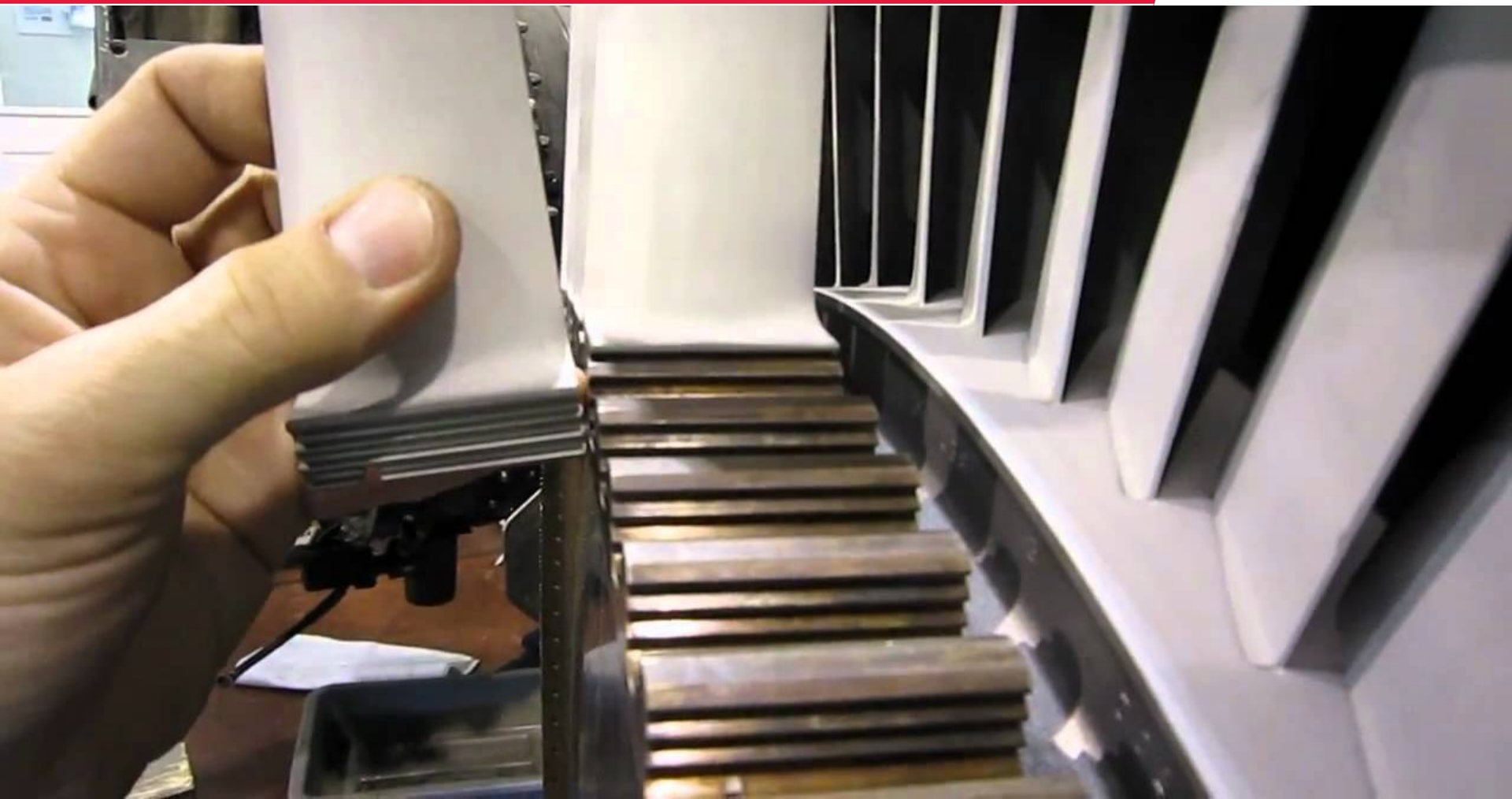


- Steel structures: columns and beams, connected by labour intensive bolted connections or welds
- Dovetail connections as an alternative option
- Already used in other domains

theconstructor.org

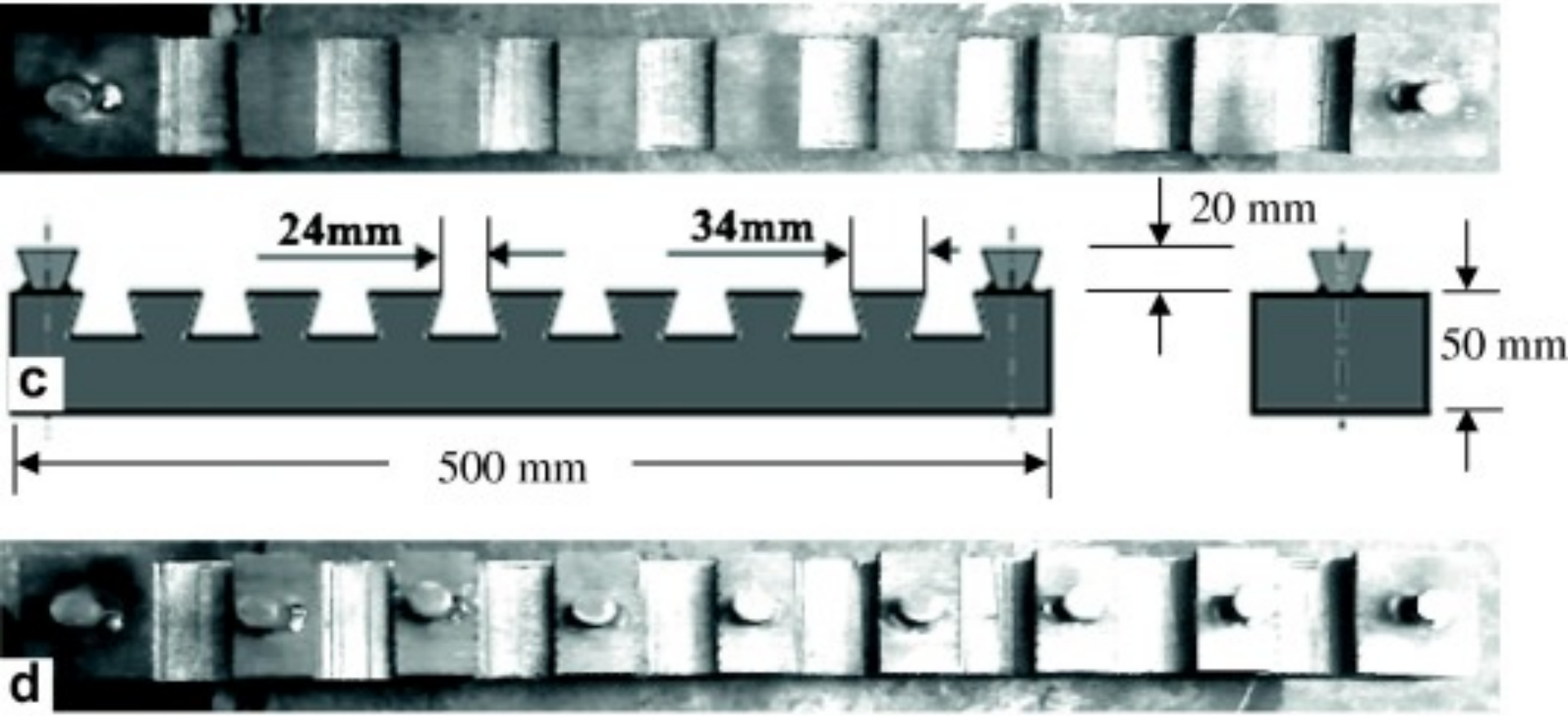
Aircraft engine

www.youtube.com/watch?v=1Vzbd3kO7kU



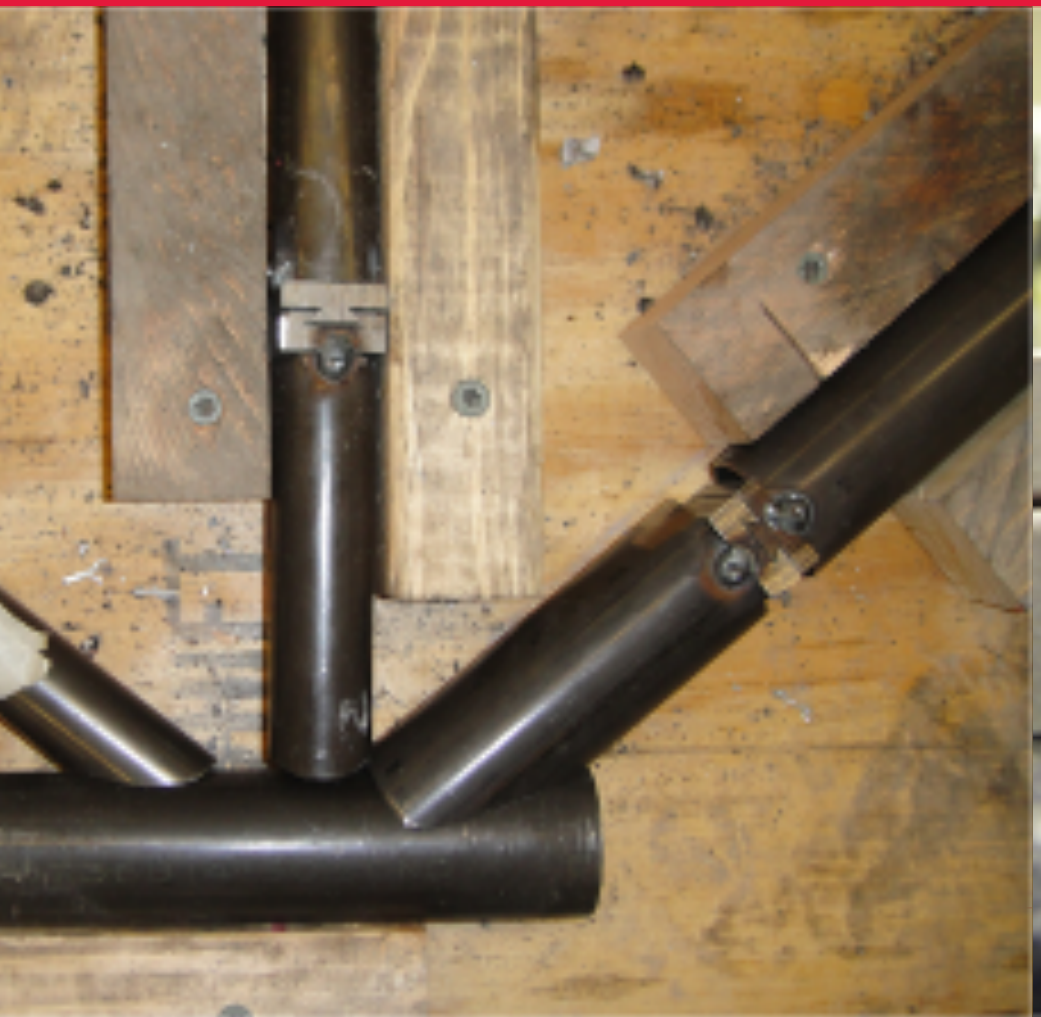
Steel bimetal beams combine resistance to abrasion and ductility for e.g. mining equipment

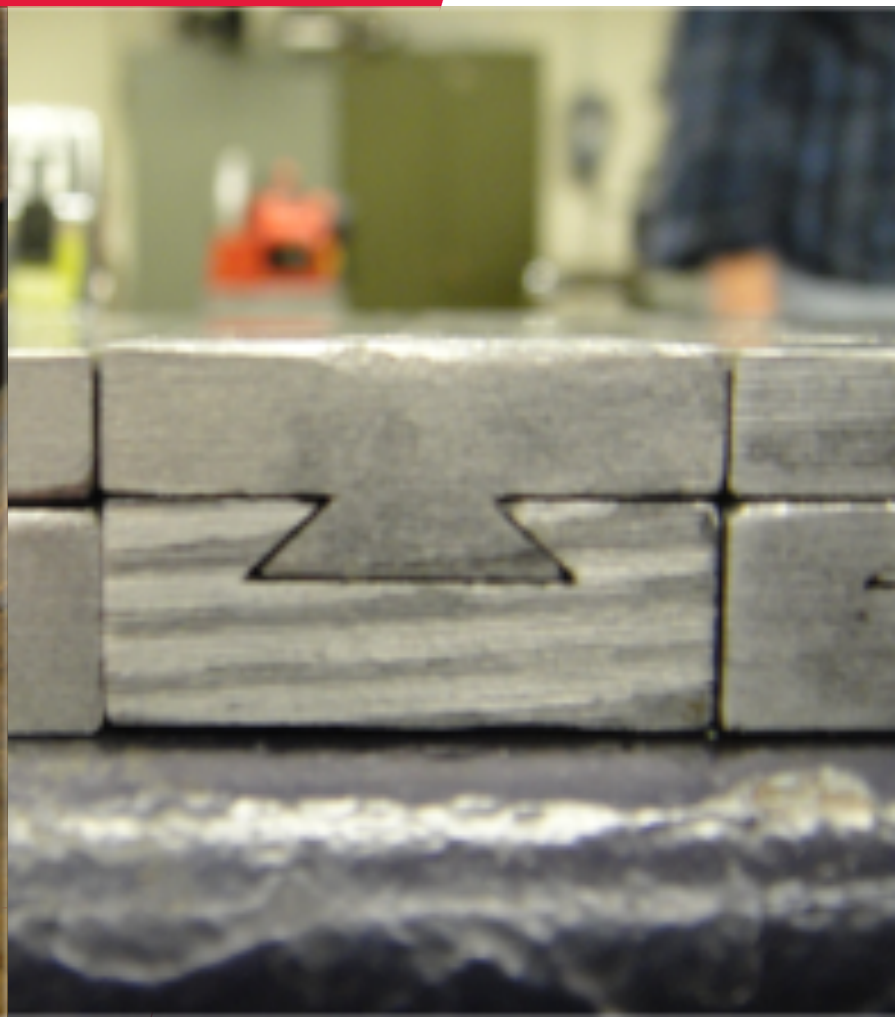
Materials & Design 52, 2013, 974-980



1/10th scale steel bridge project Kansas State University

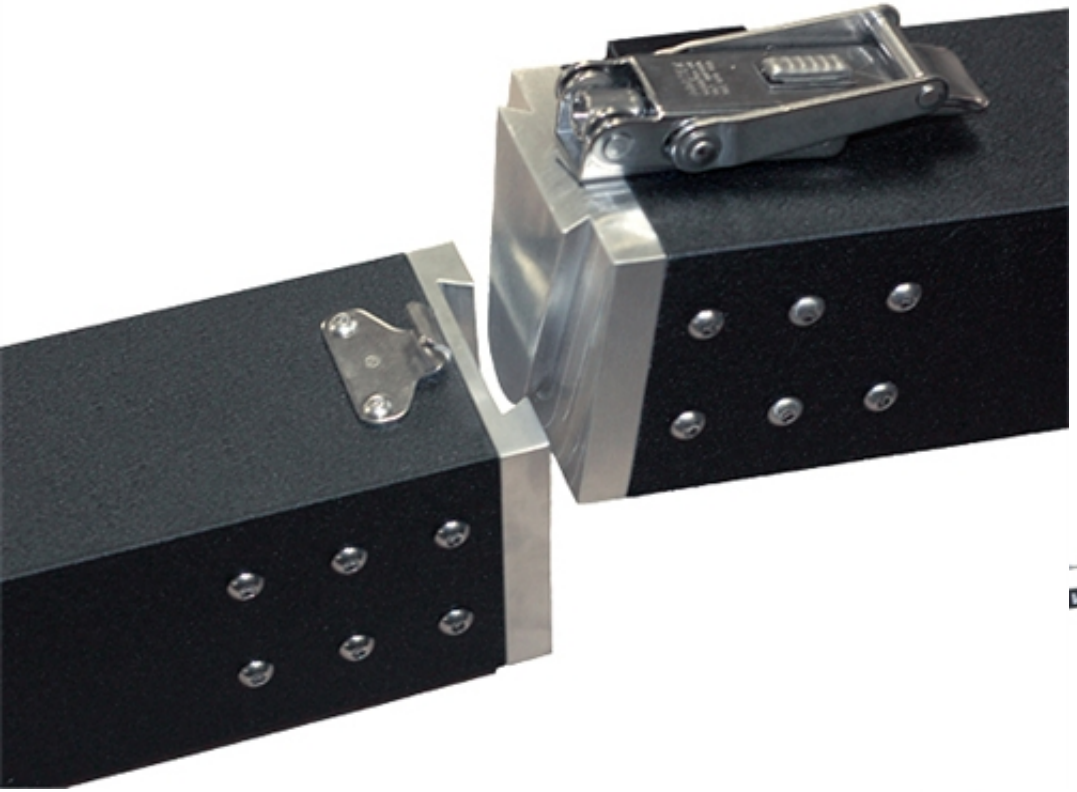
http://www.engg.ksu.edu/asce/steel%20bridge





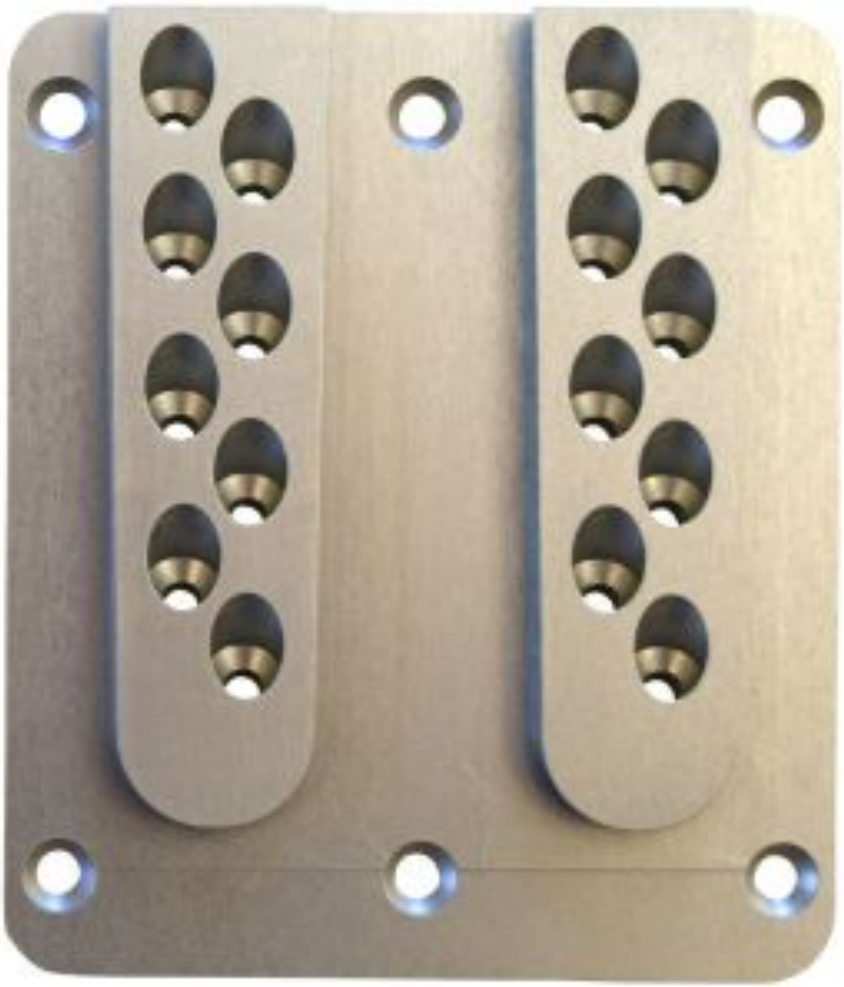
Dovetail connection for camera crane

https://www.varizoom.com/product/vzsnapcrane16/

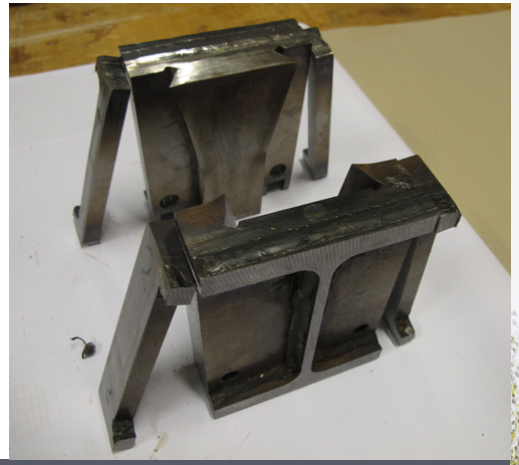


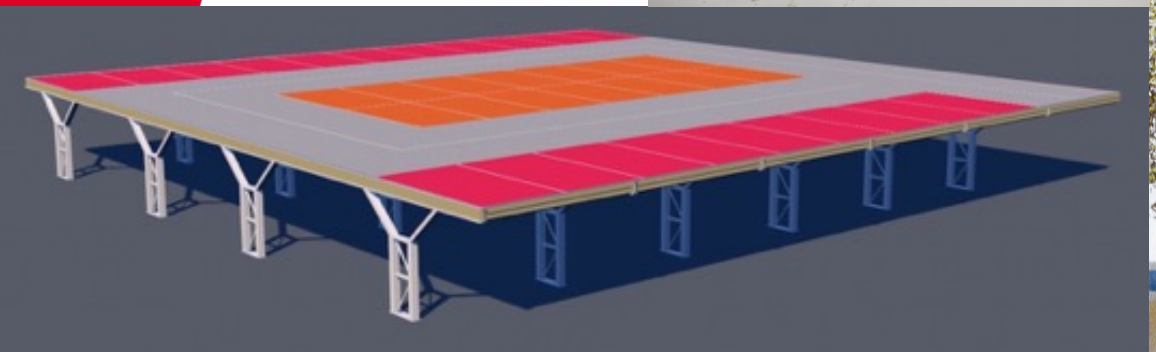
Connectors for wood-wood, wood-steel, and wood-concrete

https://www.pitzl-connectors.com/en/products/produkt/882142000-1/



- Although these existing connections: a new patent for a Dutch dovetail connection on the structural building level
- As part of a building system with floors made from sandwich steel-mineral wool panels

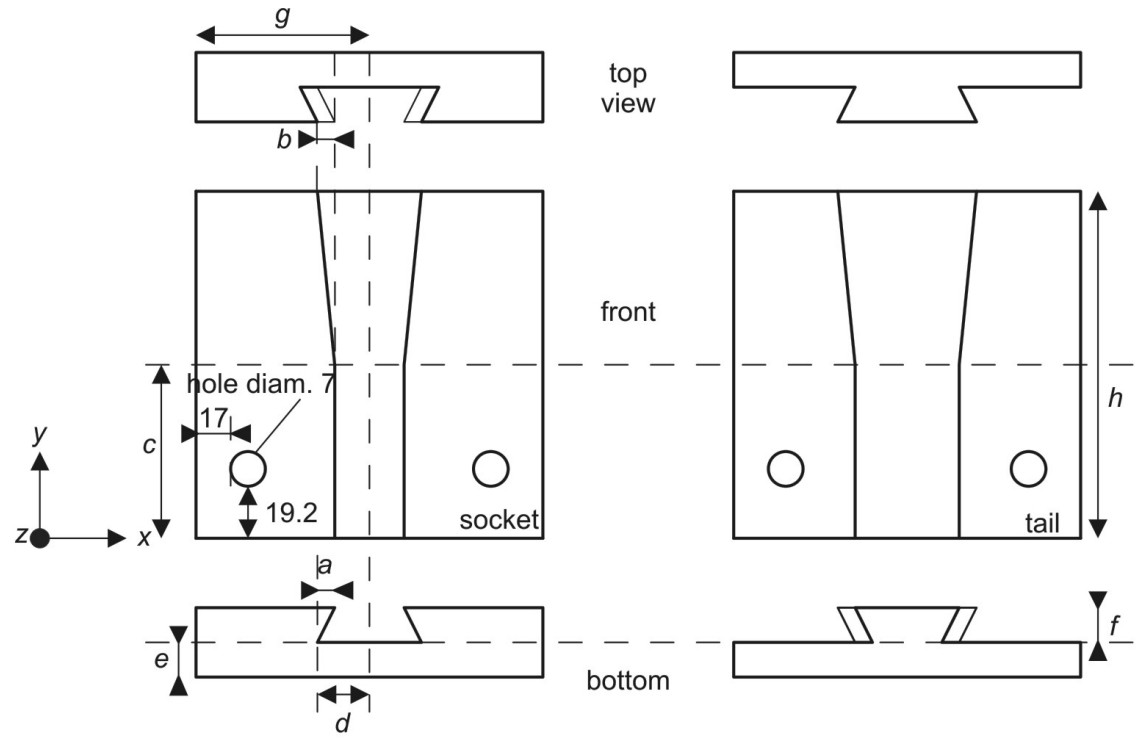


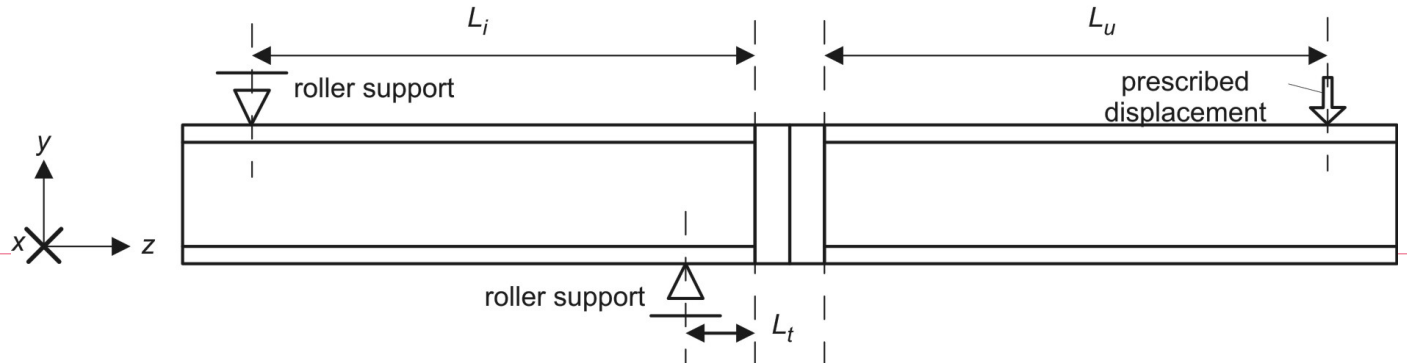


- MSc-project to investigate structural behaviour of snap-fit connection
- Reseacher: **Sergio Moriche Quesada**
- Design: Ad Verbossen
- Supervisors: Herm Hofmeyer, Bert Snijder, Ad Verbossen
- Structures Laboratory Eindhoven

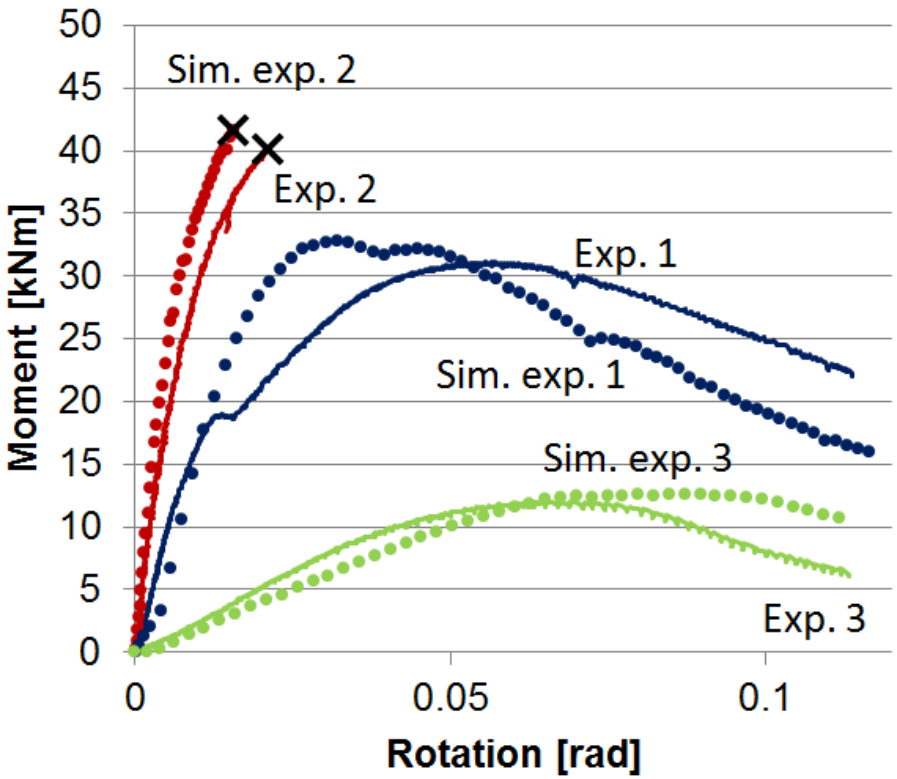
- **Experiments**
- **Finite element model**
- **Sensitivity study**
- **Comparison with bolted connections**
- **Parameter study**
- **Alternative design**
- **Conclusions**

- **Experiments**

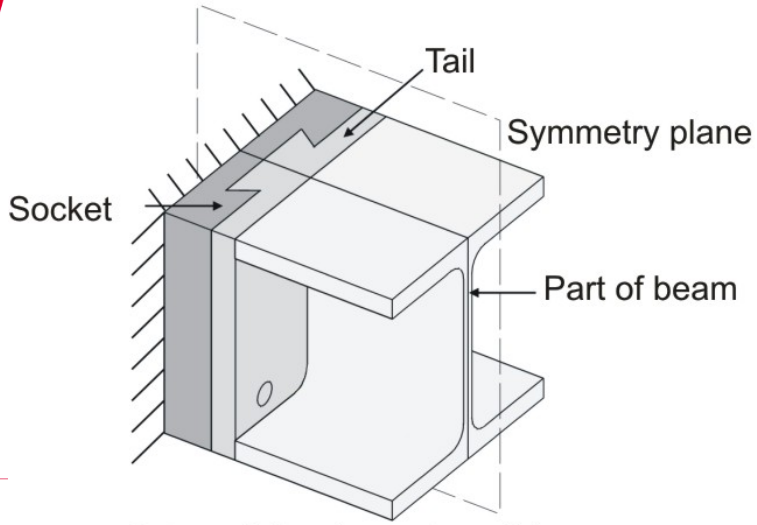




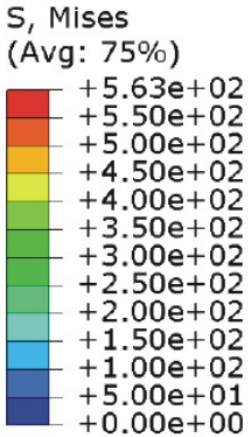
- Experiment 1: no locking pins, grease: shift of tail and socket
- Experiment 2: only local yield for exp. 1, so thicker tail and socket: fracture of socket
- Experiment 3: shallow tail lip: strong plastic behaviour and no cracking

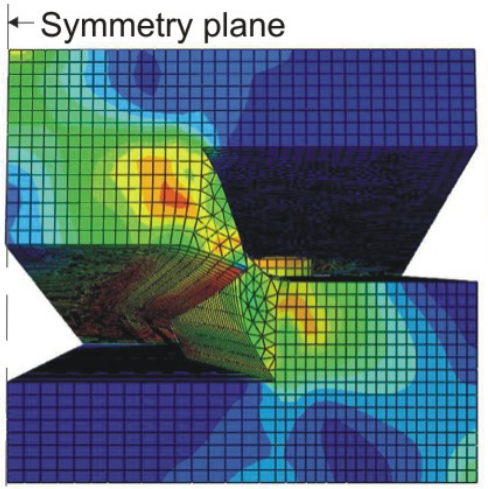


- **Finite element simulations**
- Volume elements, size via convergence study
- Contact modelling, including friction
- Load via beam element
- Exp. 1: friction coefficient sensitivity
- Exp. 2: locking pin with contact modelled
- Exp. 3: halt for principal tensile strain > 13 %



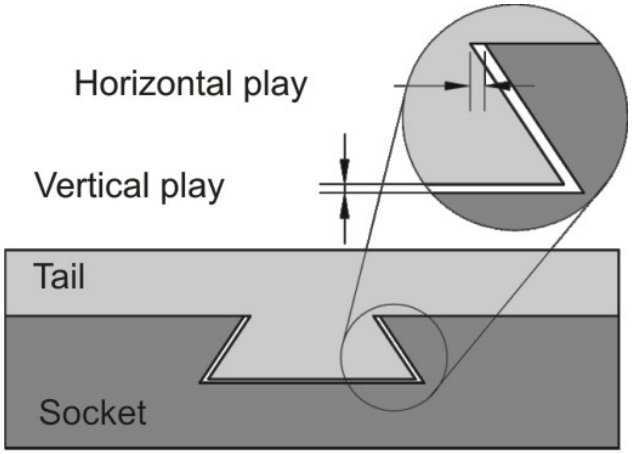
Set-up finite element model

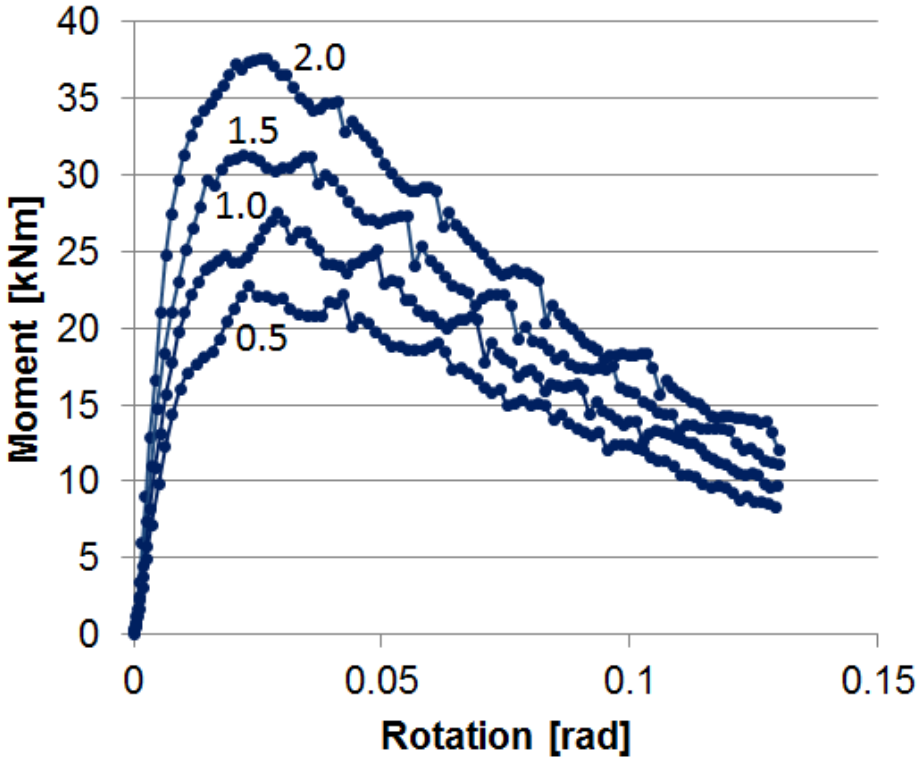




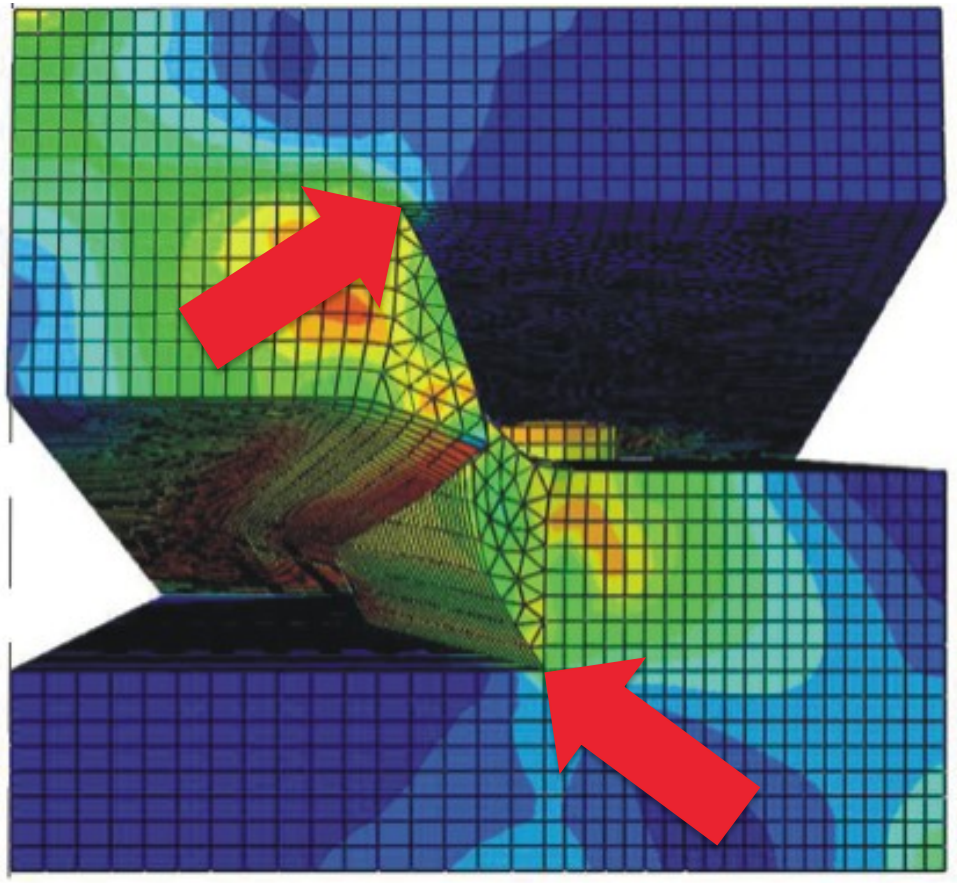
Top view

- **Finite element simulations**
- Exp. 1: horizontal play between tail and socket has significant influence



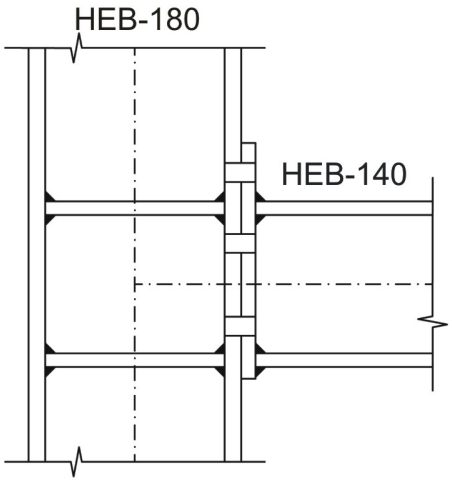


- **Finite element simulations**
- If highest stresses are at sharp internal corners, results are nonsense

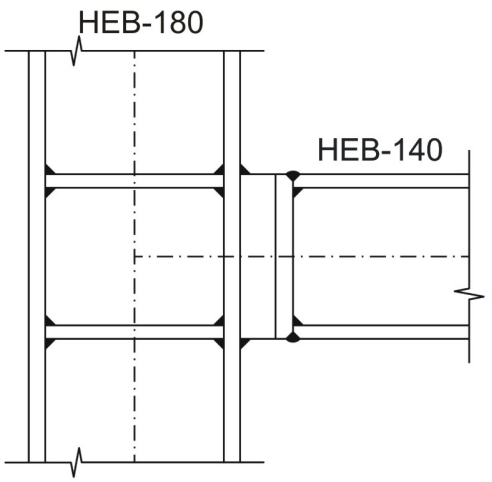


- **Sensitivity study**
- Validating the FEM model for following aspects
  - Level of friction → not important for locking pins
  - Horizontal and vertical play → see slide 13
  - Influence of shear force → no effect
  - Location back plate welds → minor differences
  - Rounding of corners → increase of strength and ductility, no max. stresses at sharp internal edge, so better convergence study
  - Inclination of tail → higher inclination increases strength and reduces ductility, maximum stresses may shift to internal edges, so possibly incorrect results

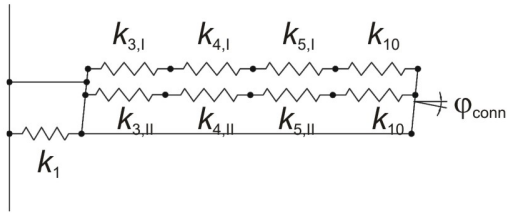
- **Comparison with bolted connections**
- Dovetail is part of complete connection
- Comparison with traditional connection by component method (COP and hand calculations)



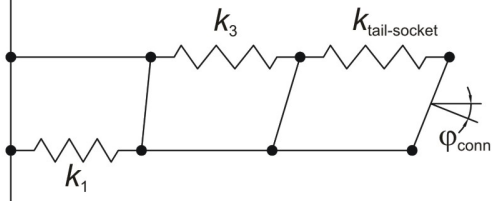
Extended end-plate connection with stiffeners



Dovetail connection with stiffeners

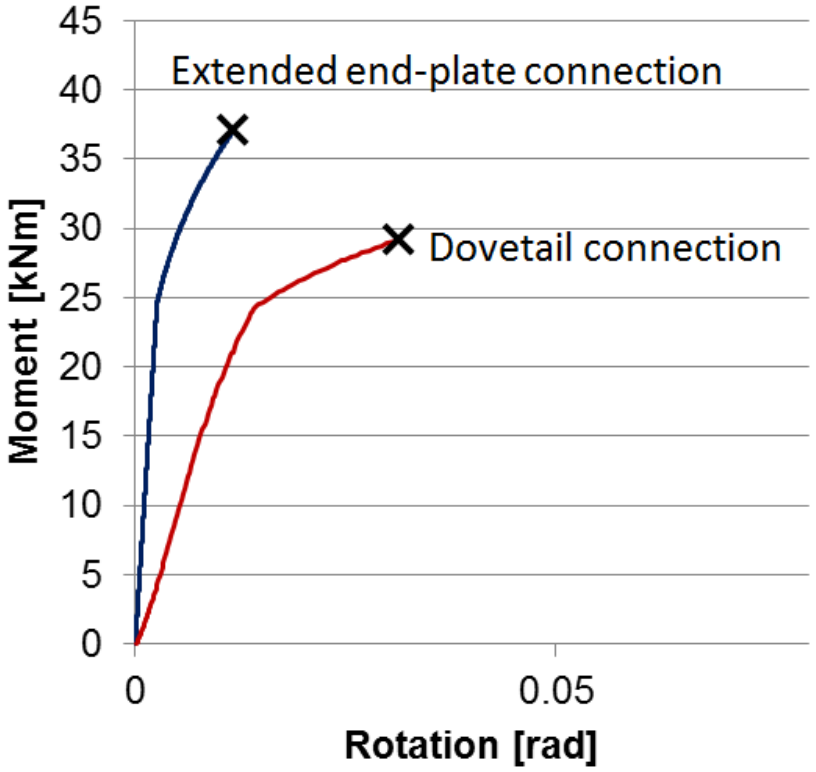


Component model extended end-plate connection

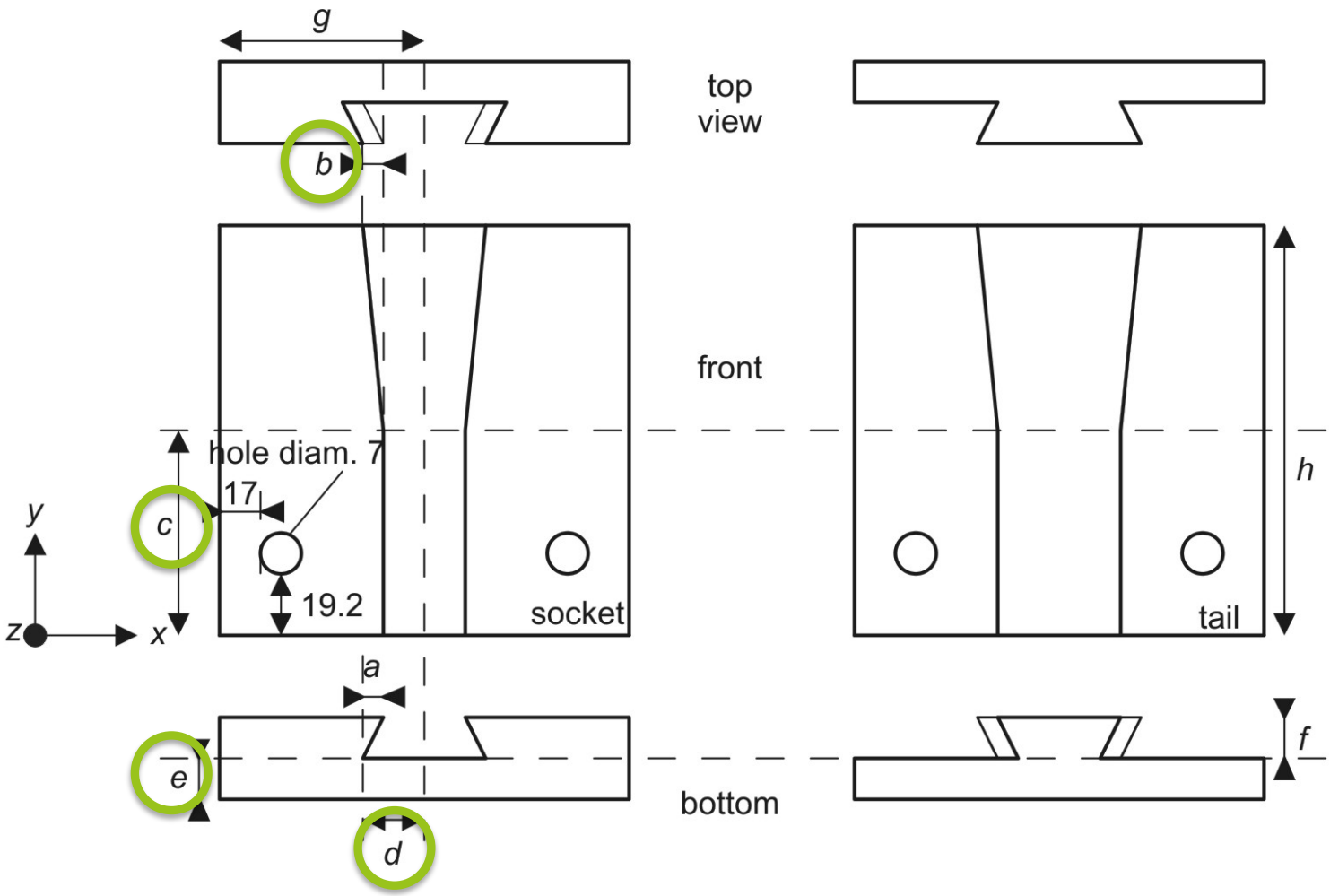


Component model dovetail connection

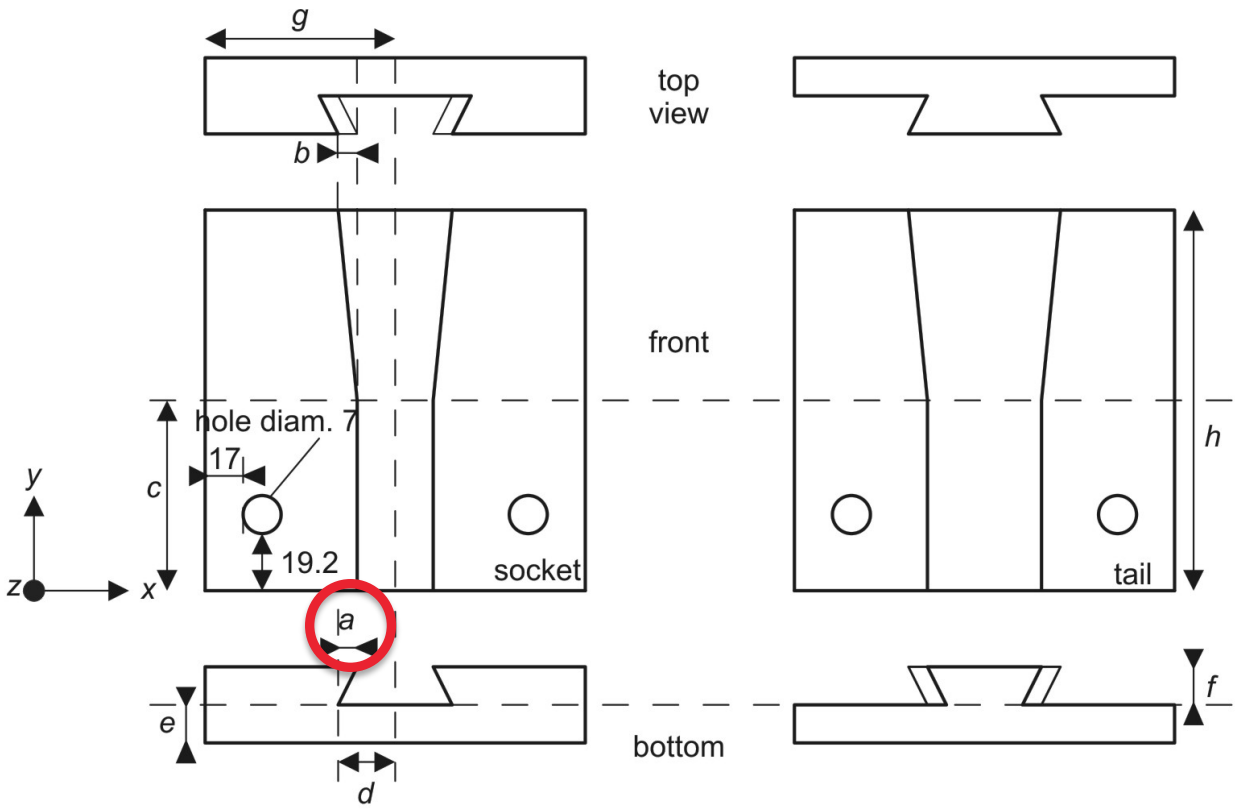
- **Comparison with bolted connections**
- Exp 2 selected for its much higher strength
- Both connections type: max tension due to bending end-late, max pressure due to shear column web
- Initially same strength, however fracture in dovetail
- Improvements?



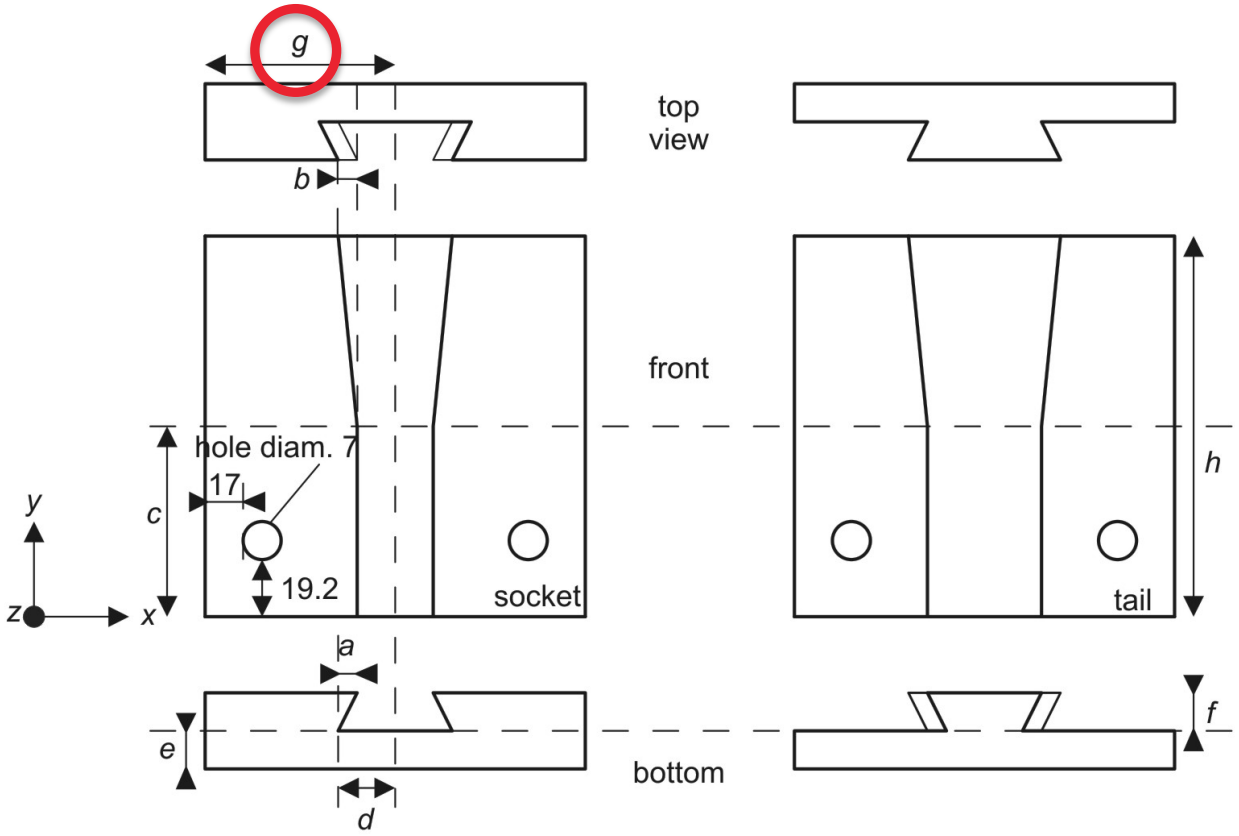
- **Parameter study**



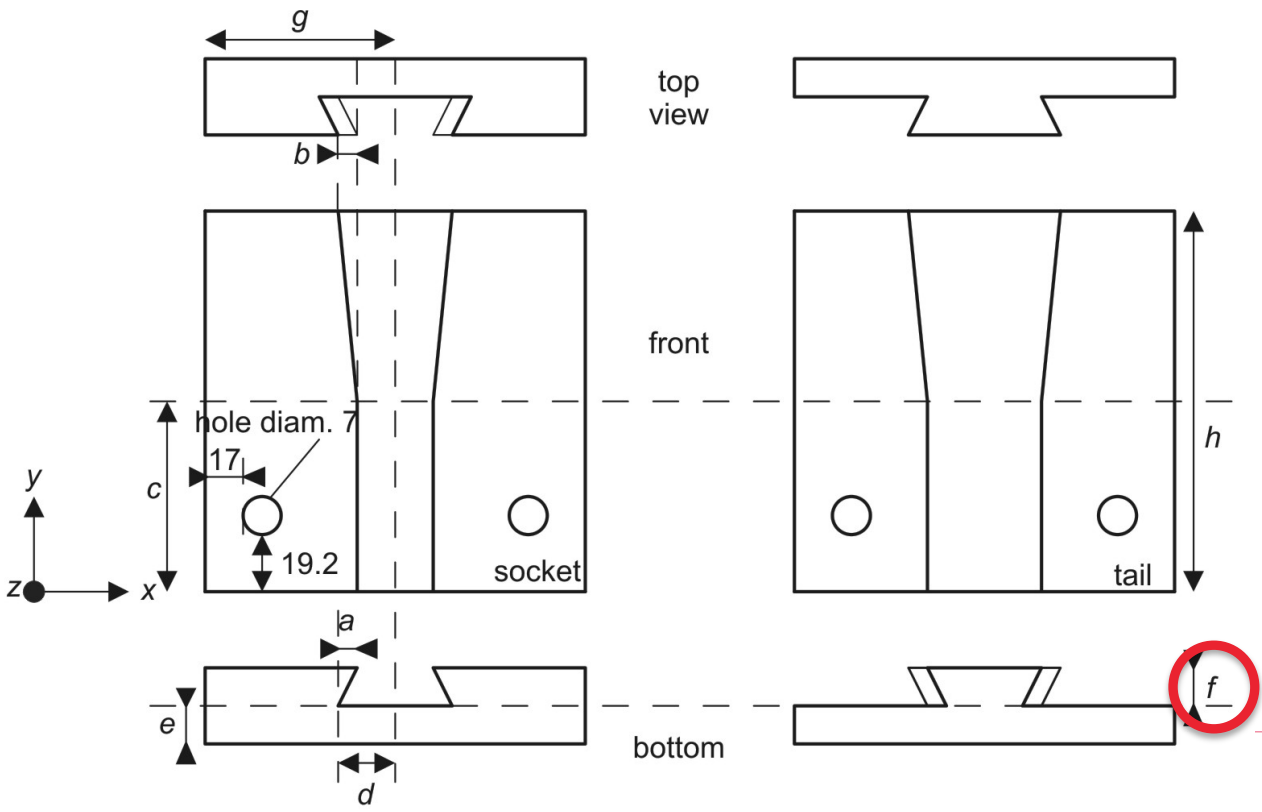
- **Parameter study**
- Larger *a* (more inclined and wider tail lip) → more stiff and strong connection
- But if > 12.5 mm, only partial yielding, effectiveness reduces



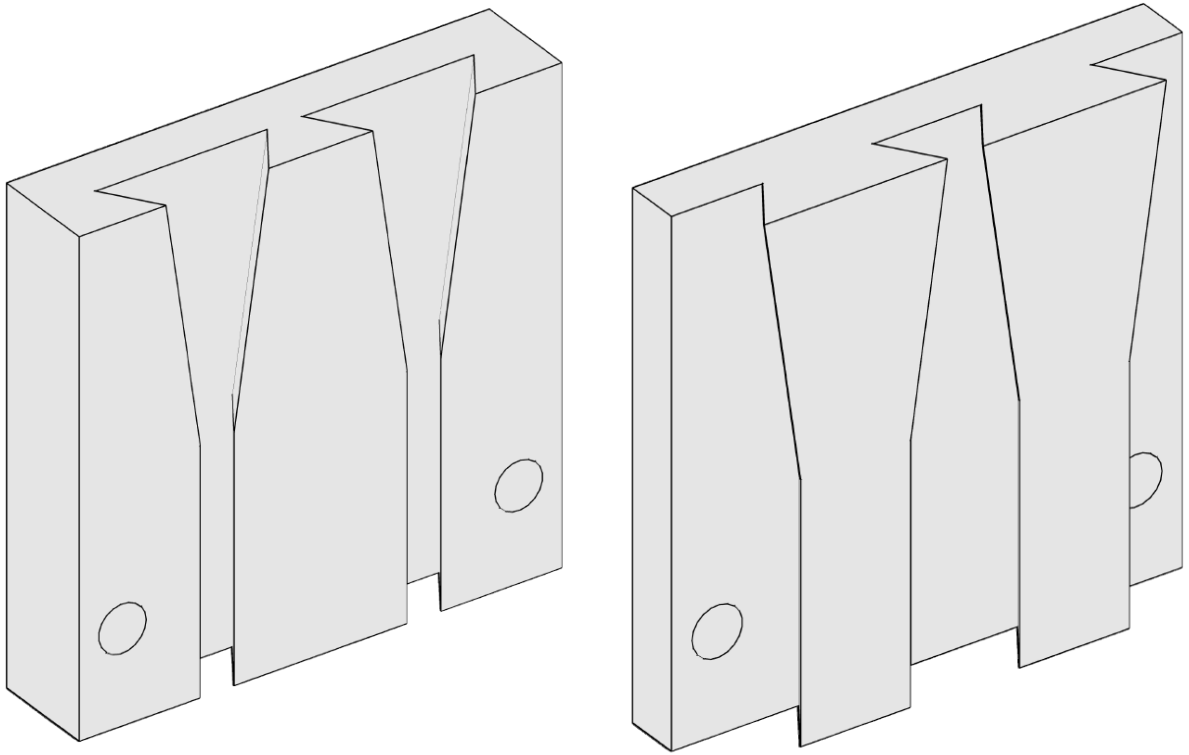
- **Parameter study**
- Width *g* too small, socket plate gets disconnected, width *g* too large, only partial yielding



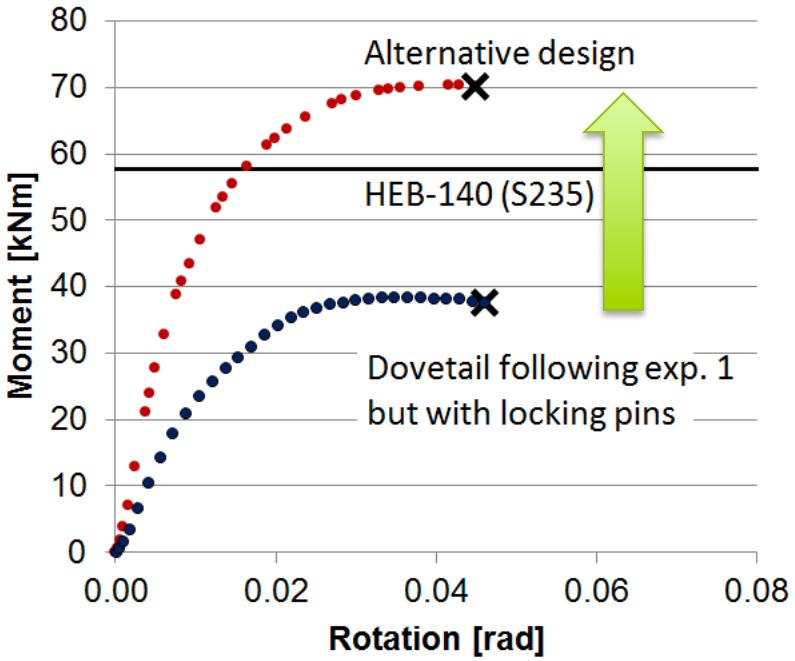
- **Parameter study**
- Larger *f* (thicker tail) → more stiff and strong connection



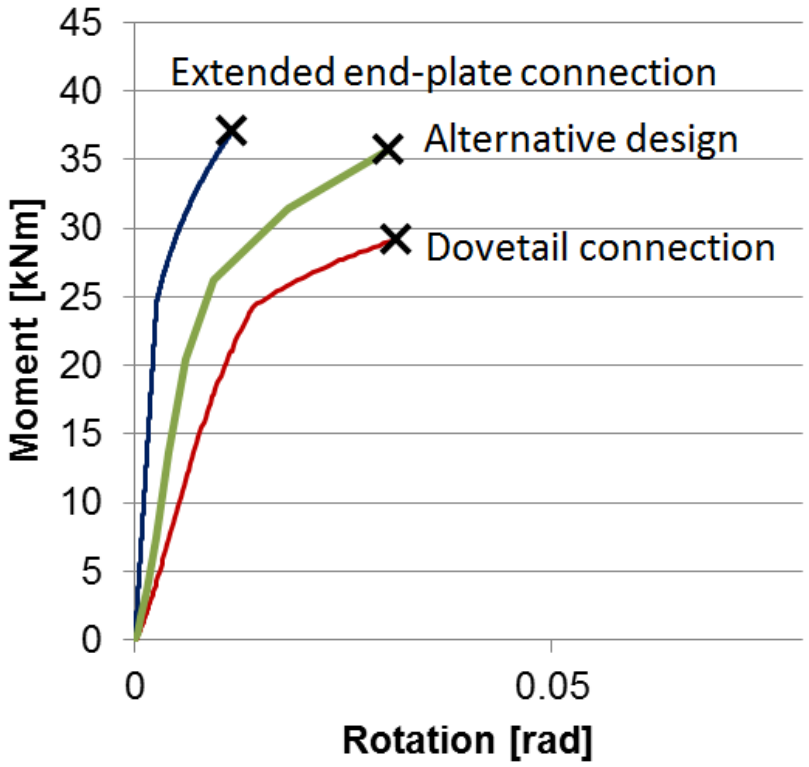
- **Alternative design**
- Systematic variation *a*, *f*, and *g* in combination: no further improvements possible
- Alternative: single connection with 2 dovetails



- **Alternative design**
- Inclination tails lips designed such that maximal tensile strain in interior, not at sharp edge, so FEM solutions can be trusted
- New convergence study: 4x4x4 mm elements
- Other small improvements



- **Alternative design**
- Component method
- Compared to extended end-plate almost same strength, much more ductile



Conclusions

- Steel dovetail connections exist, but this is the first **on the structural scale**
- Several **experiments**
- Validated finite element model showed sensitivities: horizontal **play** and **inclination tail lip**
- Dovetail is only part of a complete connection: component method: dovetail **performs less** than bolted connection
- **Alternative design** via FEM is equally strong and more ductile than bolted connection
- **Design does not determine FEM model, but here also FEM steers design**

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Thank you for your attention!

Questions?