

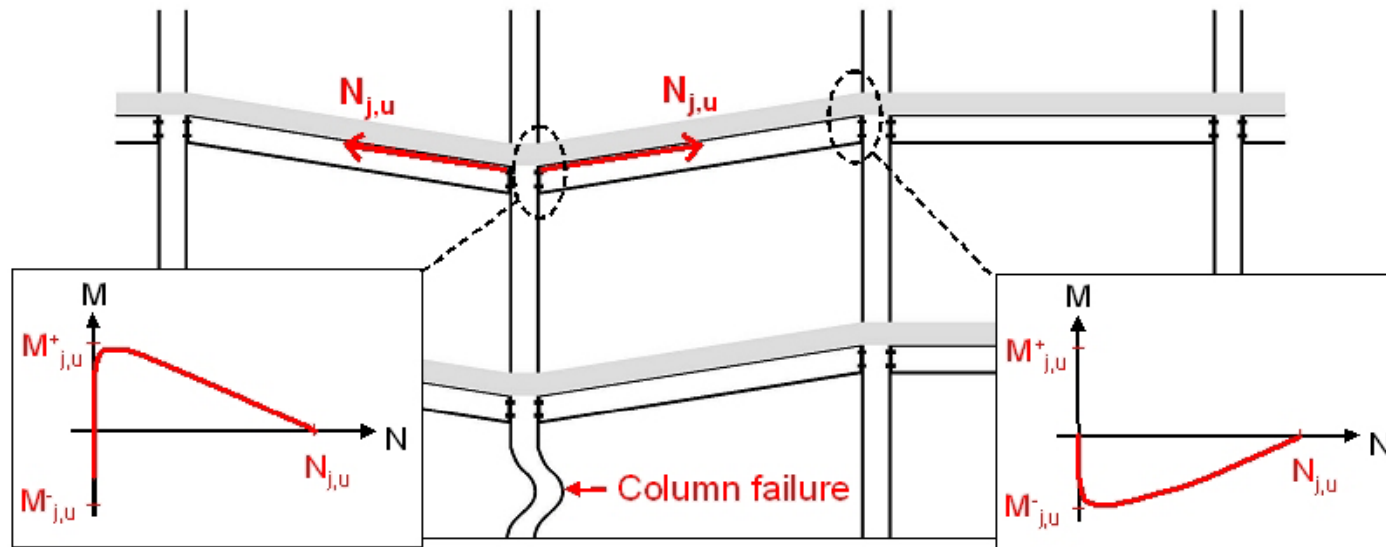
COST ACTION TU0601

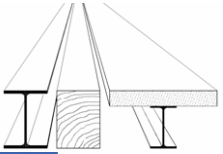
Robustness of Structures

Workshop Coimbra 02./03. March 2009

Ductility of connections - a measure to improve redundancy

Prof. Dr.-Ing. Ulrike Kuhlmann, Dipl.-Ing. Lars Rölle

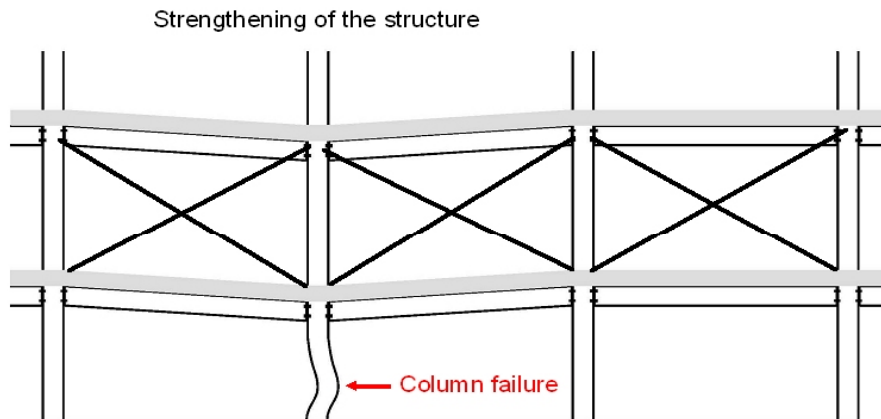




Redundancy within the structural system by alternate load paths

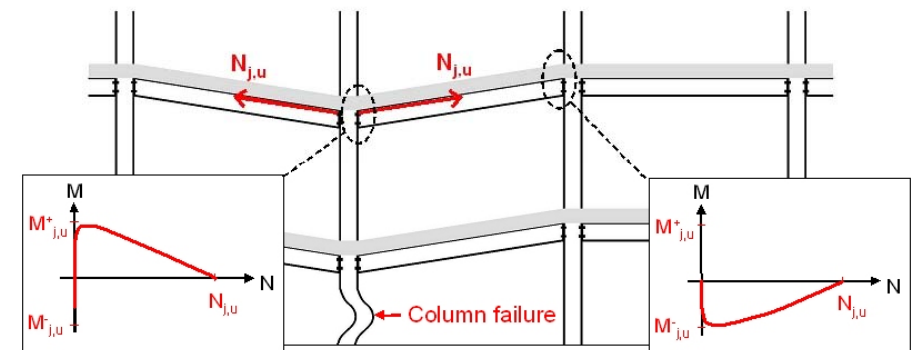
Alternate load path method

strengthening of one/more floors

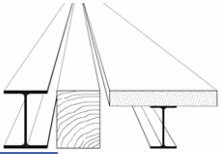


→ causes usually much extra costs

design of joints with sufficiently ductile behaviour and activation of membrane forces



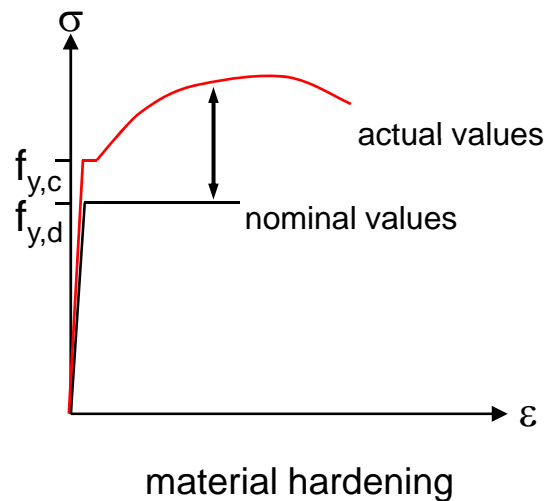
→ less extra costs
→ demands for well-designed connections



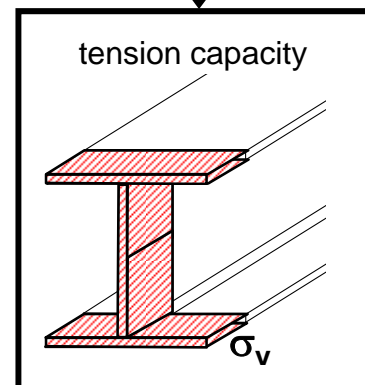
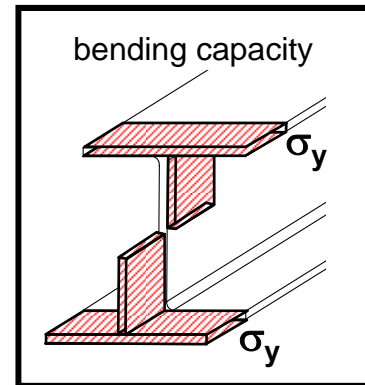
Alternate load path method

alternate load paths may be achieved by various measures

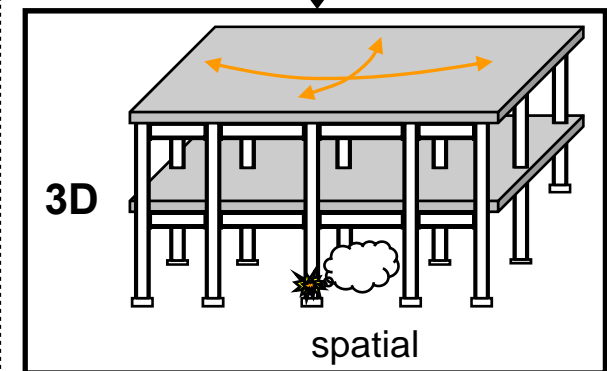
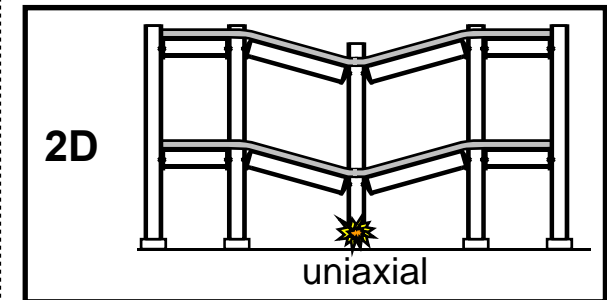
plastic reserves



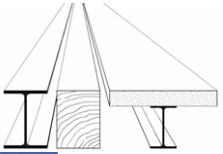
bearing-mechanism



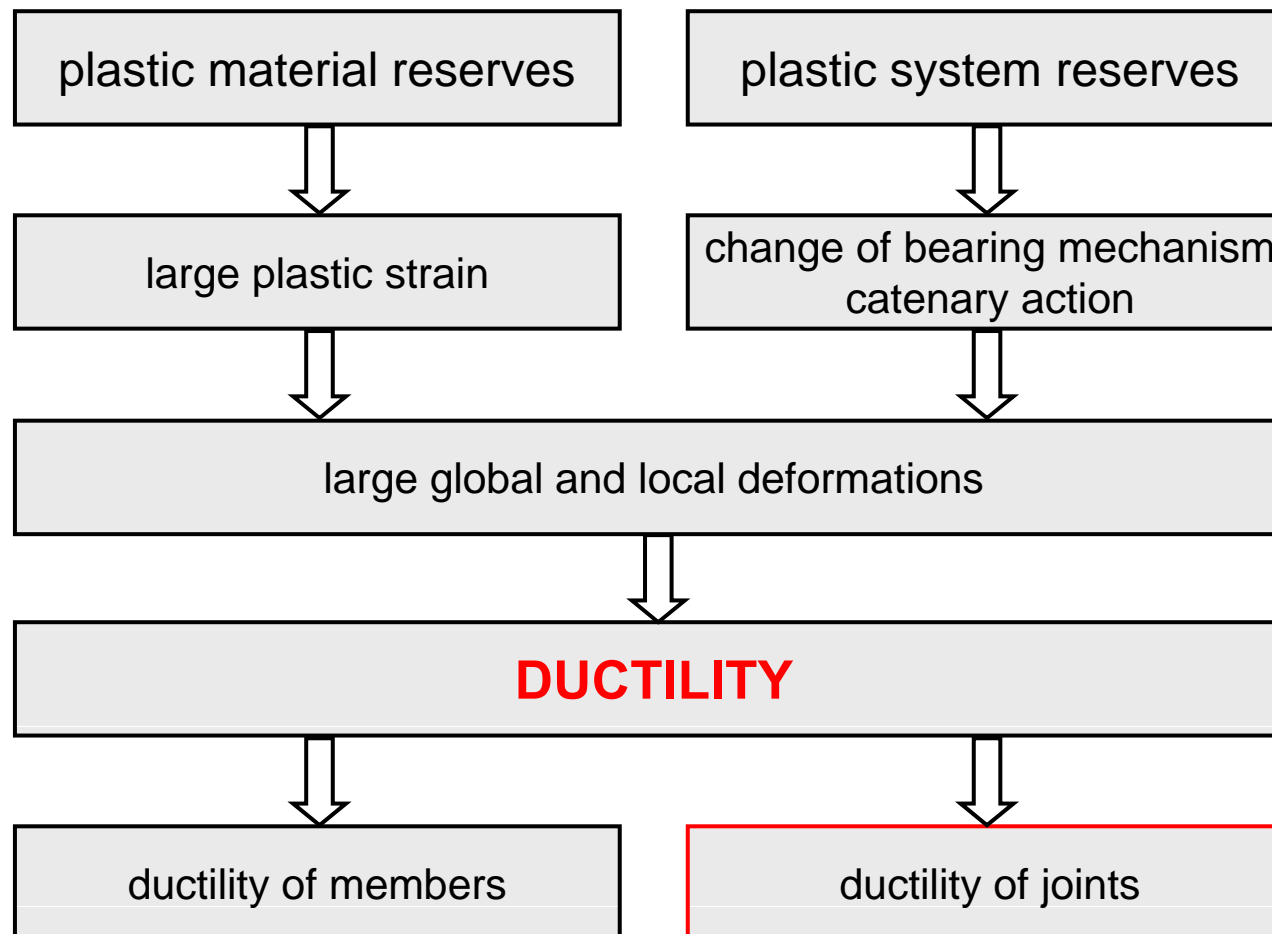
structural behaviour

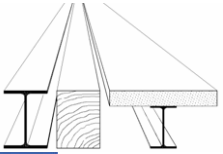


→ requires sufficient available ductility of members and joints



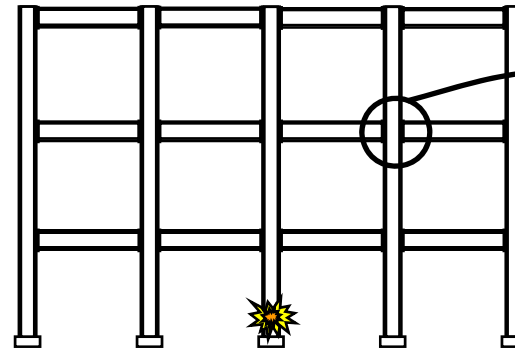
Ductility demands to allow the activation of bearing reserves





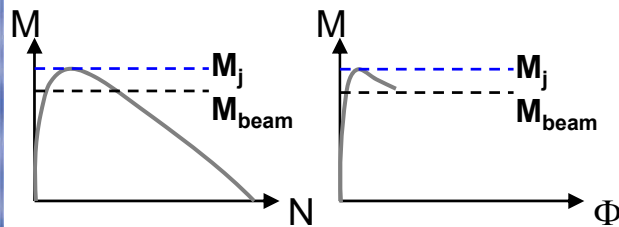
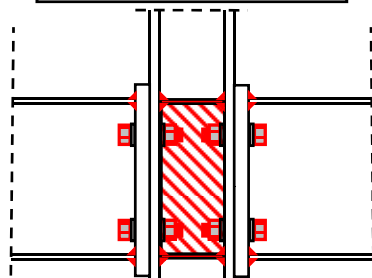
Type of connections influence the global resistance of the structure

joints are usually the weakest link
in a framed structure
→ special focus



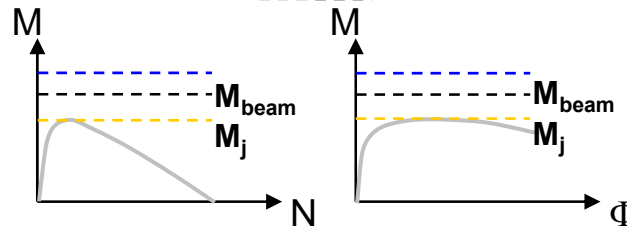
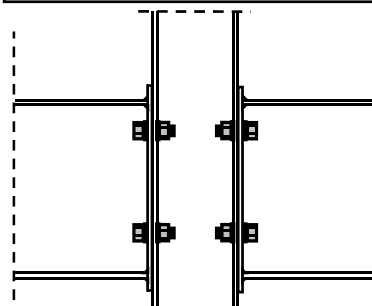
type of
beam-to-column connection

rigid



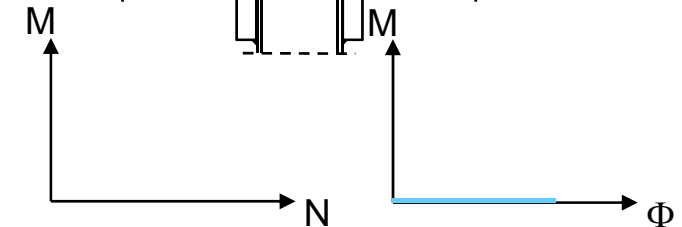
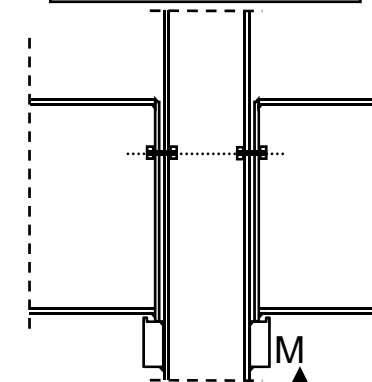
suitable but expensive

partial-strength



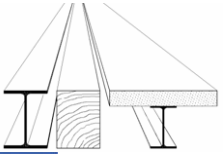
suitable

pinned

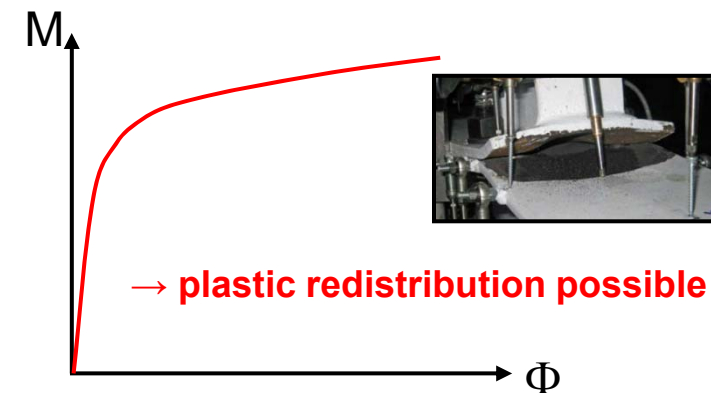
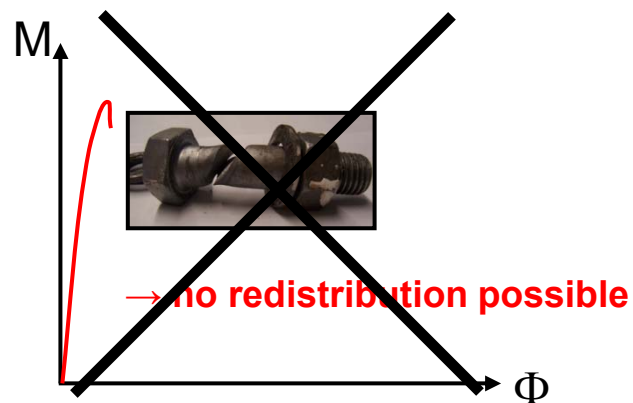
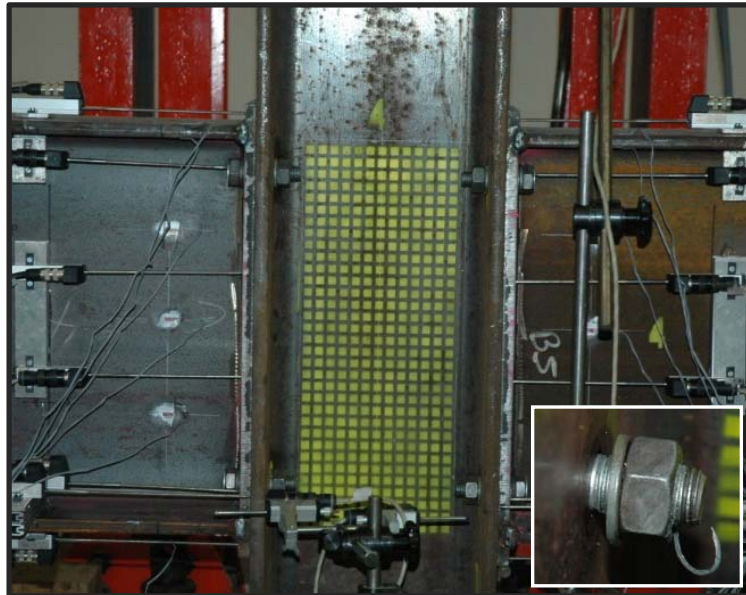


not suitable ⇒ lack of resistance

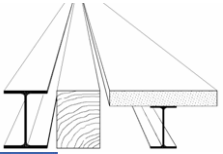
⇒ by adequate resistance and sufficient ductility



Why is sufficiently ductile joint behaviour so important?



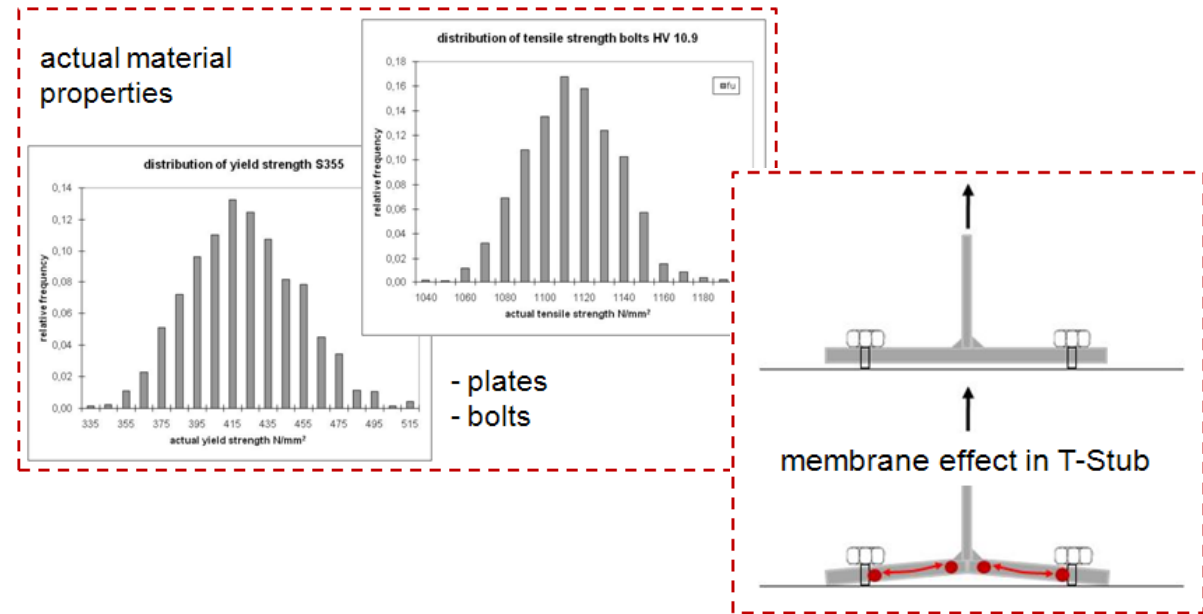
hinge is located in the joint \Rightarrow high requirements concerning joint deformability



Influence of over-strength effects

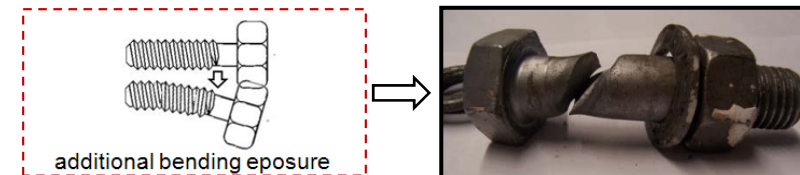
Over-strength effects

- materials
- membrane effects

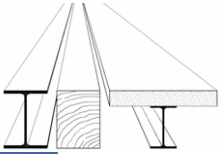


Adjustment of single components

- weakest components always ductile
- oversizing of the bolts

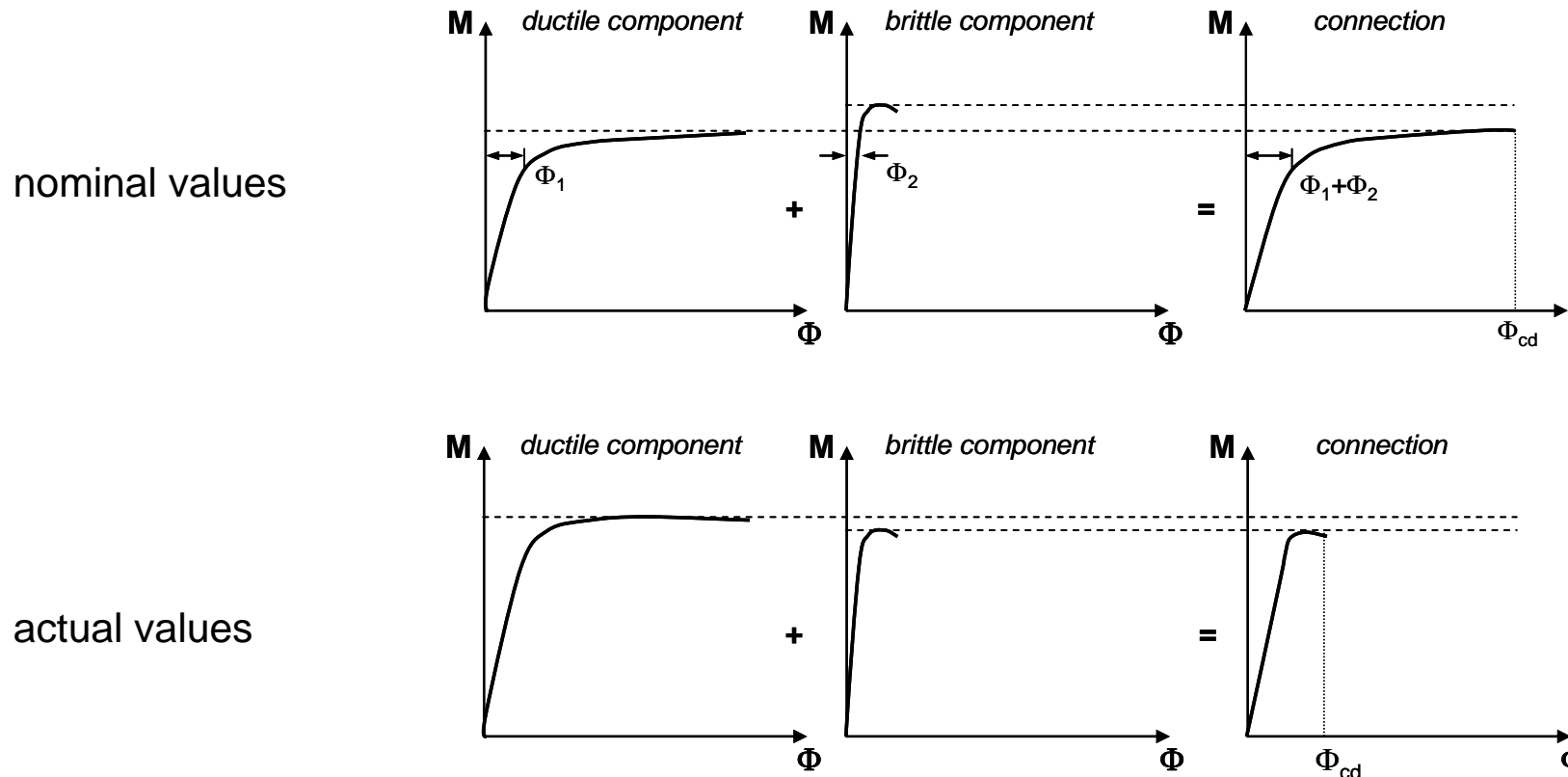


avoiding premature brittle bolt failure with limited ductility of the joint

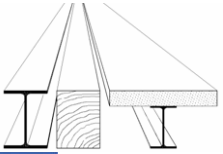


Influence of over-strength effects

Influence to the relevant component



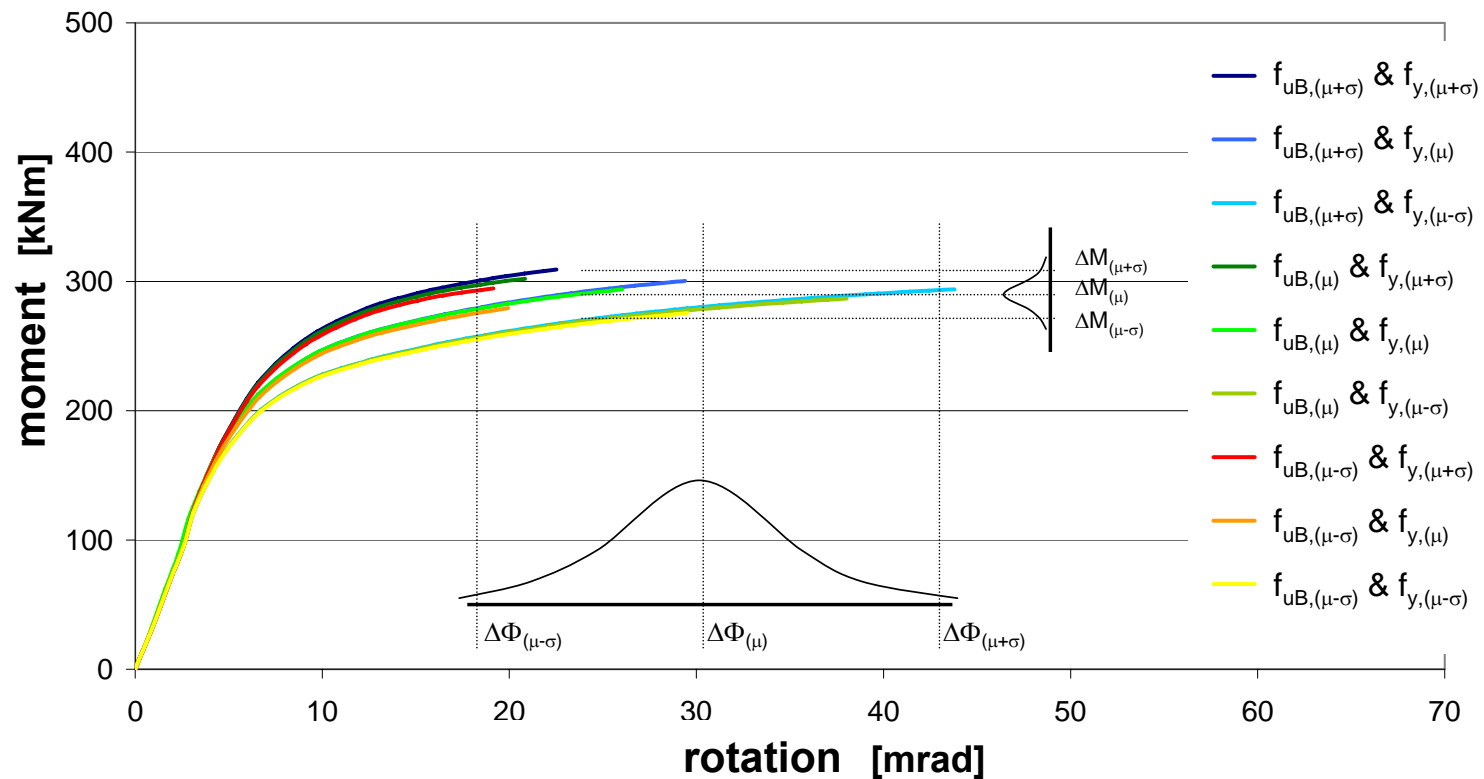
actual values of material strength may limit the deformation capacity clearly



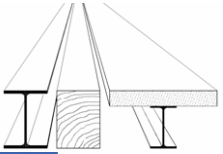
Influence of over-strength effects on resistance and ductility

Influence on the moment-rotation-curve

IPE 500, M24 10.9, t=15 mm

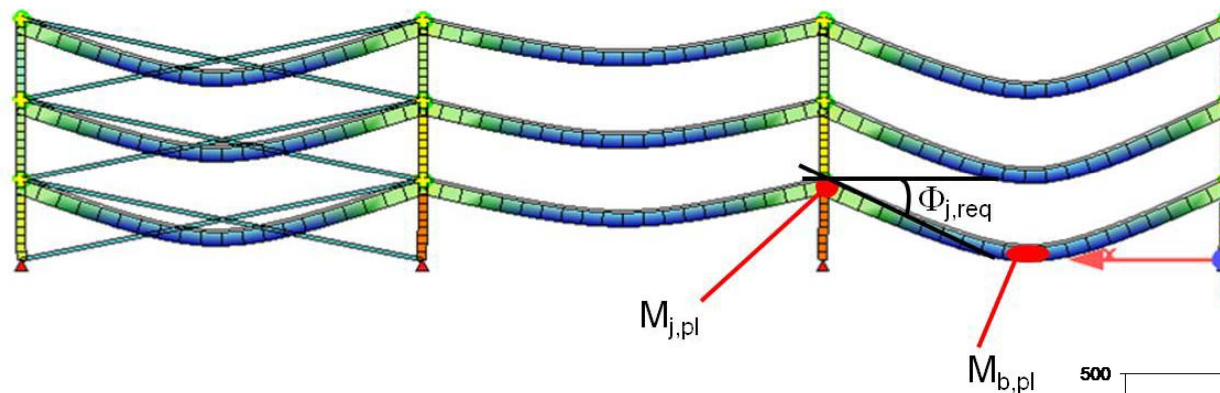


small influence on the resistance, clear influence on the rotation capacity

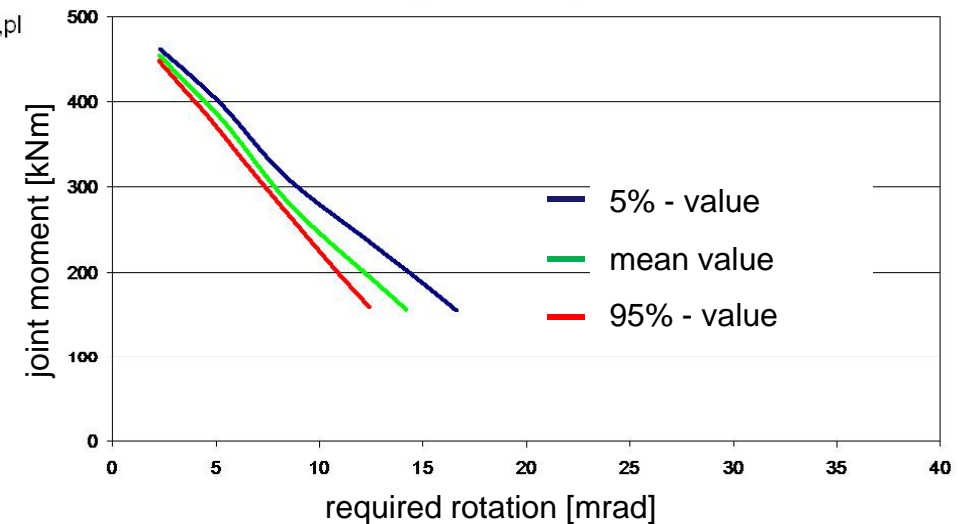


Influence of over-strength on the structural response

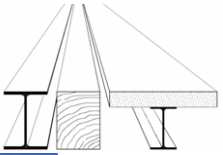
structural response under service conditions



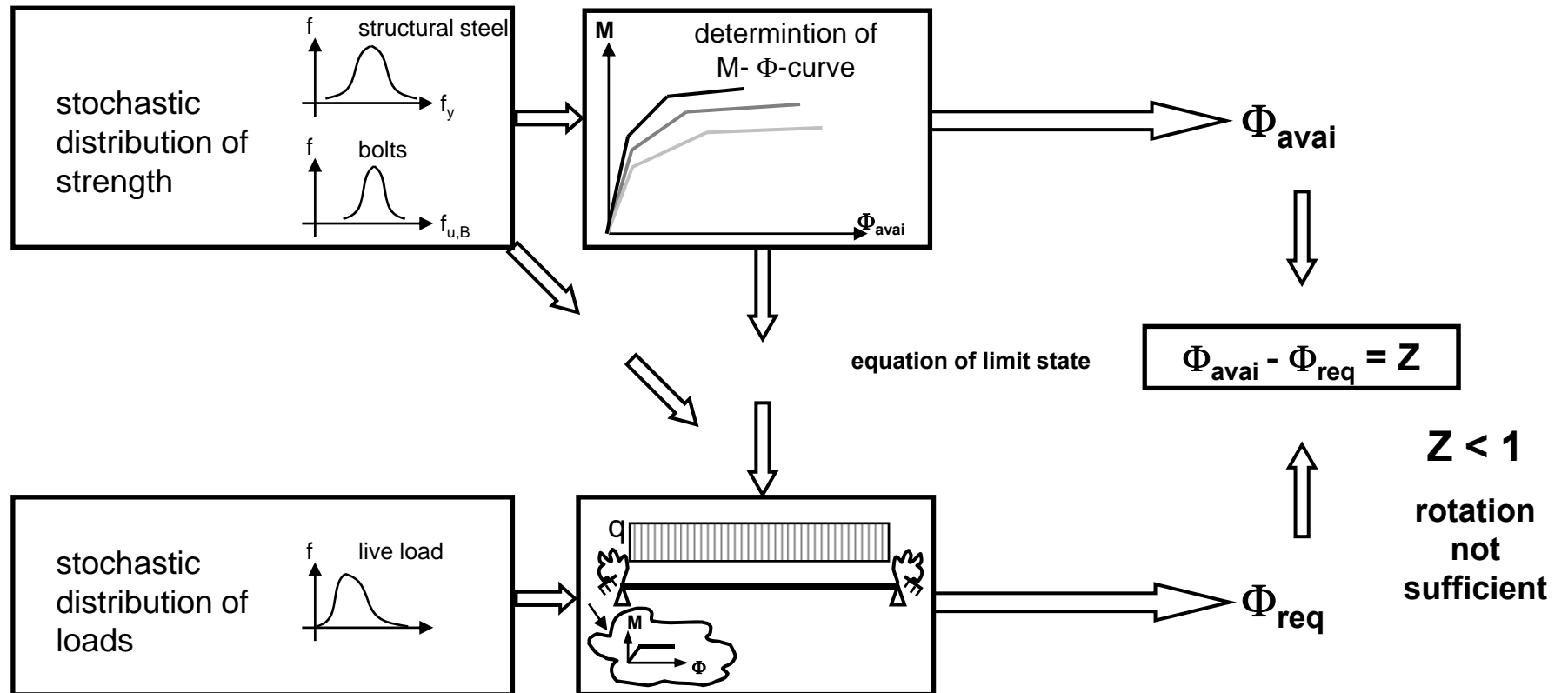
Required rotation at support depends on bending resistance of member and joints that depend on material strength



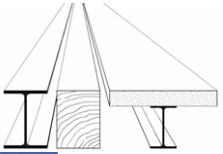
Variation of material strength → influence also structural response



Probabilistic analysis to assess sufficient rotation capacity

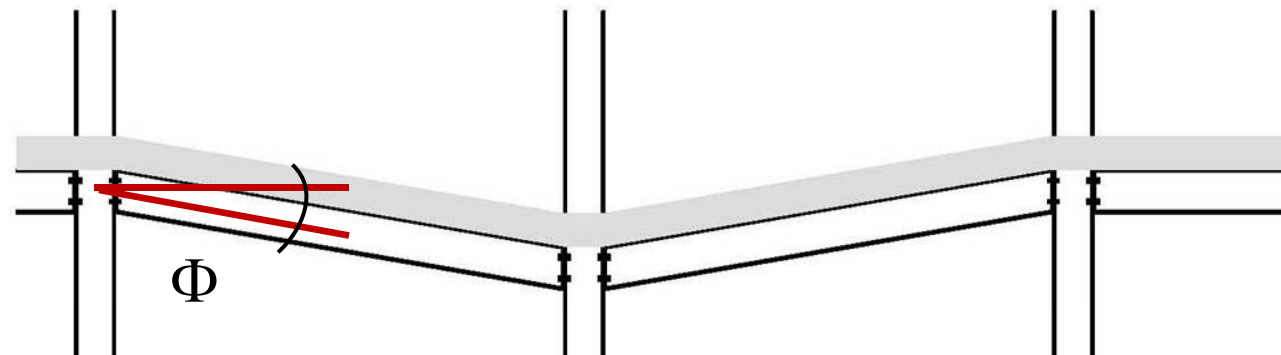


method to assess the geometrical criteria for sufficiently ductile joint behaviour

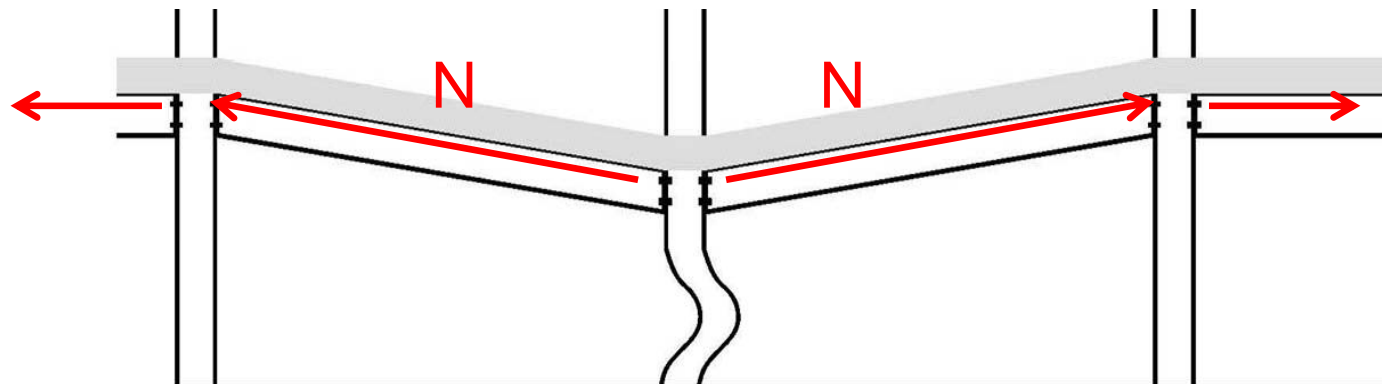


Redundancy by allowing force redistribution

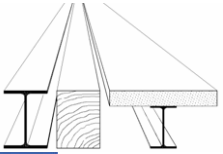
→ requires large deformations



→ demands for sufficient resistance (M-N), beside ductility

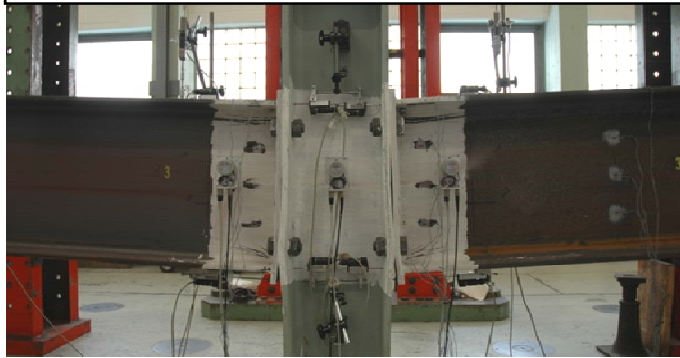


activation of alternate load paths requires joint ductility **and** sufficient M-N resistance

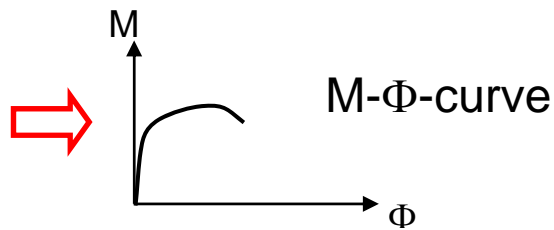


Experimental test simulation of steel and composite joints

Steel Joint Tests



bending test

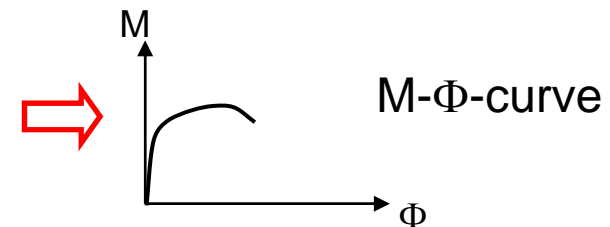
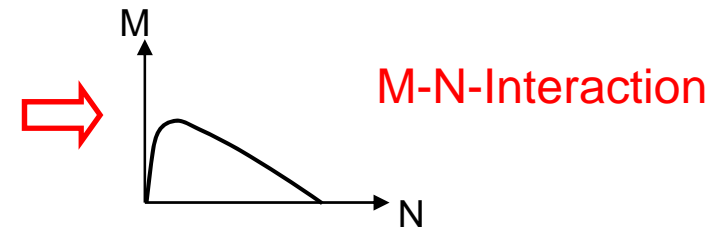


determination of requirements
and design criteria for
highly ductile behaviour

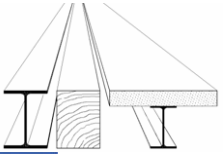
Composite Joint Tests



bending and tension

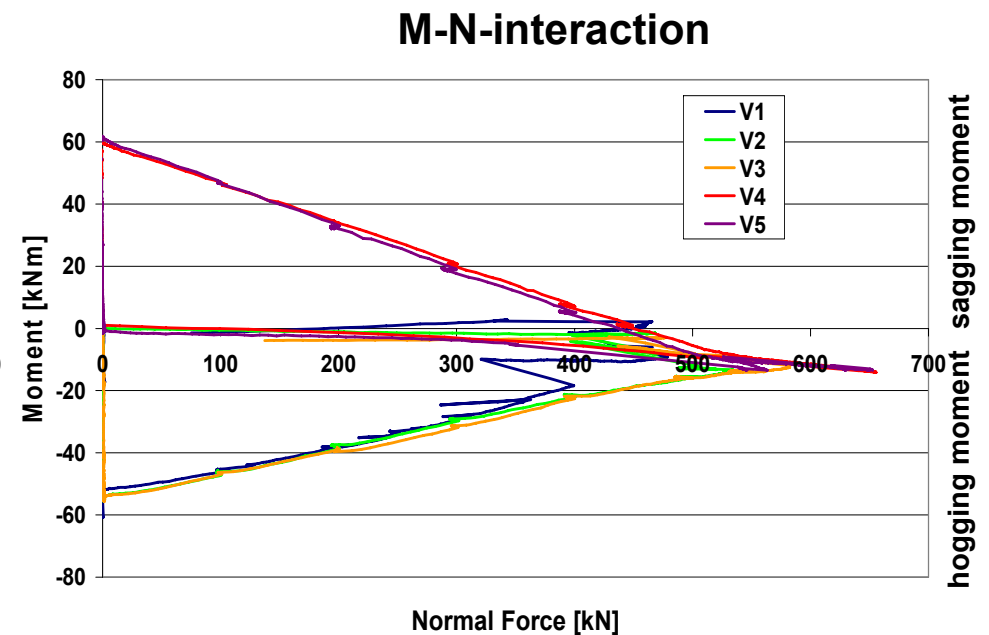
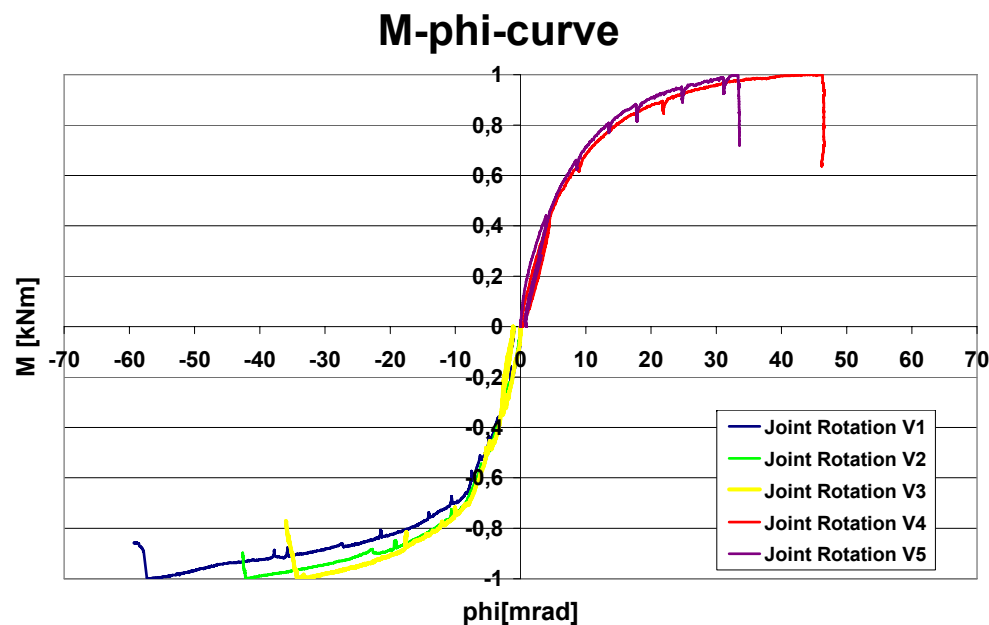


for hogging and sagging moment

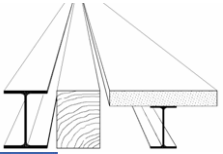


Composite joints under bending and tension

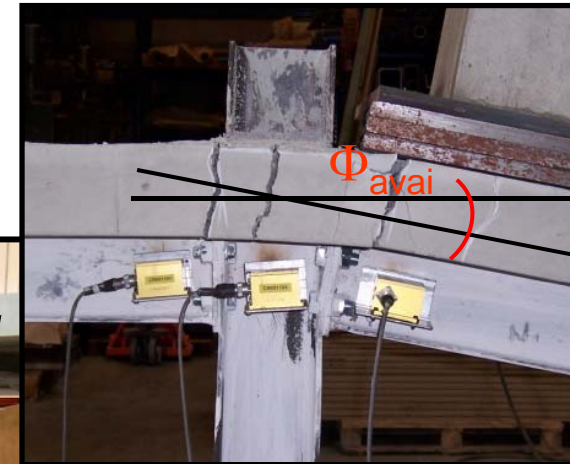
Test results



→ Joints have been able to follow the whole M-N-curve from pure bending state to pure tension state due to **sufficient ductility**

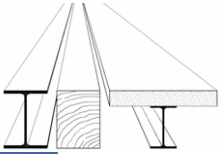


Joint tests confirmed by a Substructure test



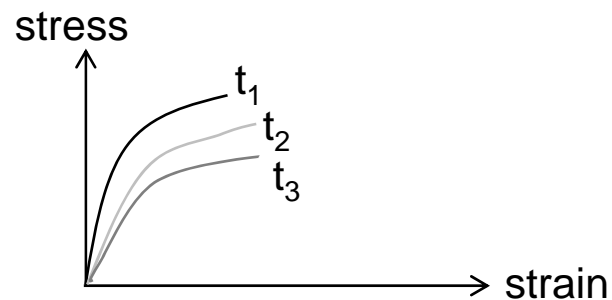
[Substructure test
Liège]

structural response allows force redistribution by activation of membrane effects

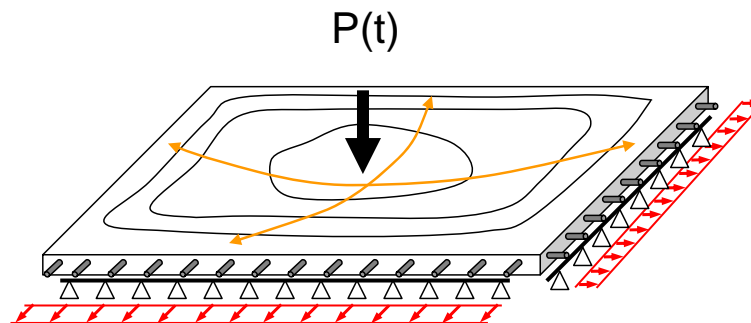


Outlook

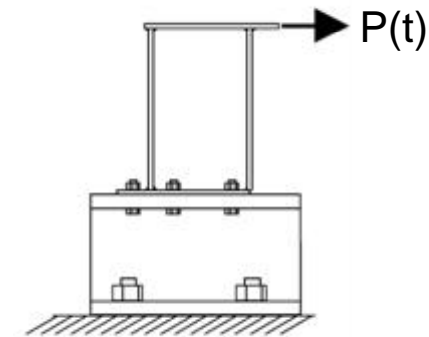
further numerical and experimental investigations are planned



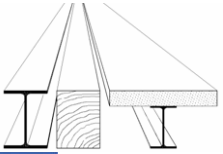
determination high stress-strain rates
of plates and bolts



including additional bearing effects
→ 3D effects



component response under high velocity
loading
→ rotation capacity and strength?



Thanks for attention !

Universität Stuttgart

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