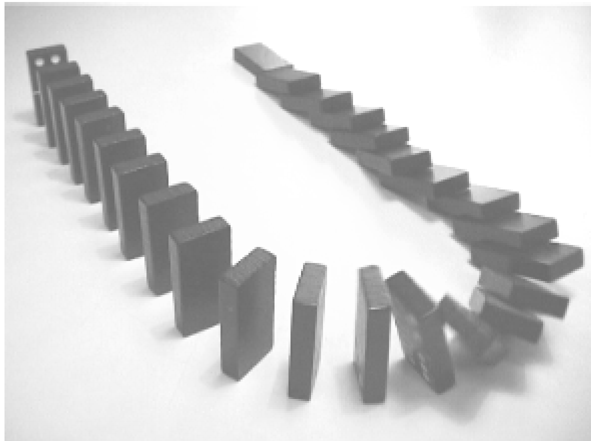
COST ACTION TU0601

Robustness of Structures

Final Conference Prague, 30th of May 2011

Factsheets: **STEEL STRUCTURES AND COMPOSITE STRUCTURES**



AS OUTCOME OF WG2

Ulrike Kuhlmann
Lars Rölle

FACTSHEET STEEL STRUCTURES

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FACTSHEET STEEL STRUCTURES

CONTENT

- structural properties - general
- geometrical properties
- material characteristics
- ductility and over-strength effects
- redundancy of members and connections → global redundancy
- example: collapse load factor of a steel frame
- strain rate effects

FACTSHEET STEEL STRUCTURES

STRUCTURAL PROPERTIES - GENERAL

CHARACTERISTICS PROVIDED BY STEEL

- high strength
- good ductility
- plastic reserves
- high energy dissipation
- high residual strength

⇨ ADVANTAGEOUS FOR PROGRESSIVE COLLAPSE MITIGATION

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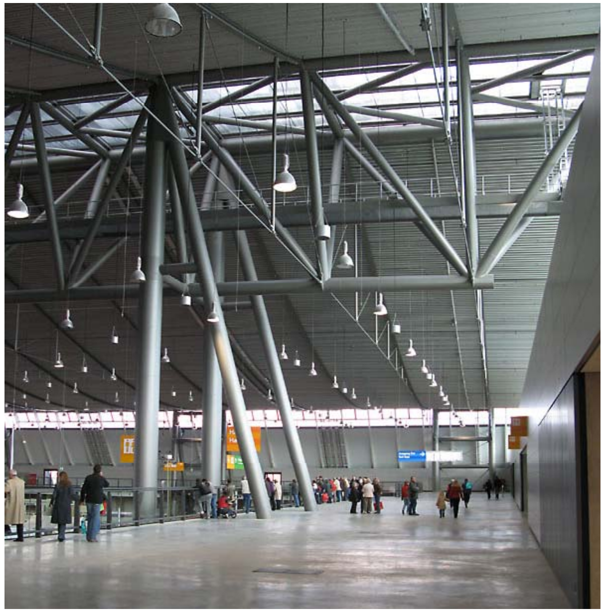
GEOMETRICAL PROPERTIES


[Trade Fair Center Stuttgart @ www.mayr-ludescher.de]



- rolled or welded structural steel profiles
- high material strength allow for slender cross-sections → lightweight structures
- reducing of mass in upper storeys

Factsheet Steel structures

Geometrical properties

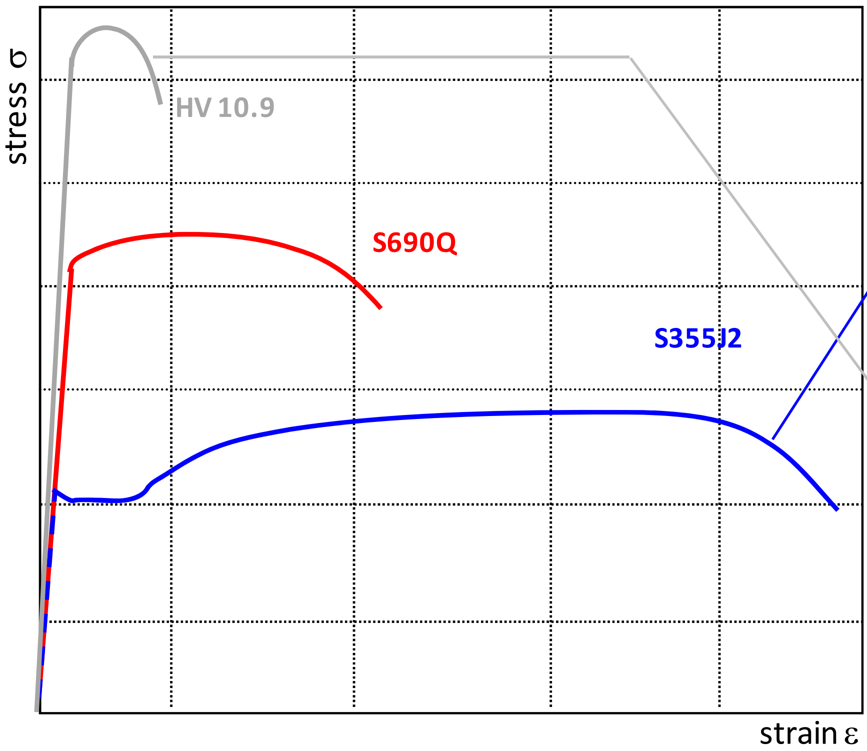

[www.oebb.at]

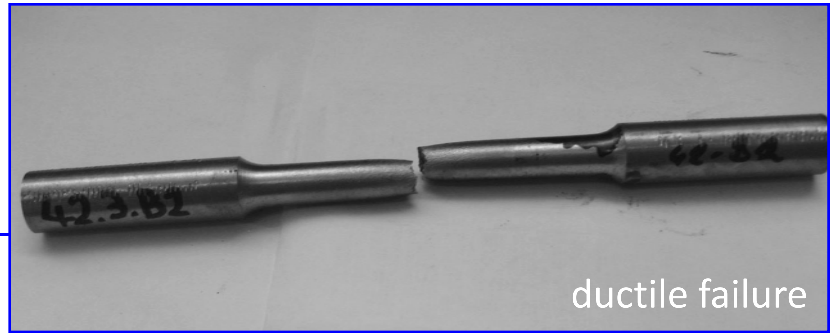

[www.karl-und-probst.de]

- massive concrete members are generally regarded as “robust by nature“
- light steel (framed) structures have to provide evidence of sufficient robustness

Factsheet Steel structures

Material characteristics





- for robustness issues high ultimate strain is of advantage
- choice of steel grade (per member) influences the **local**/global ductility of the structure

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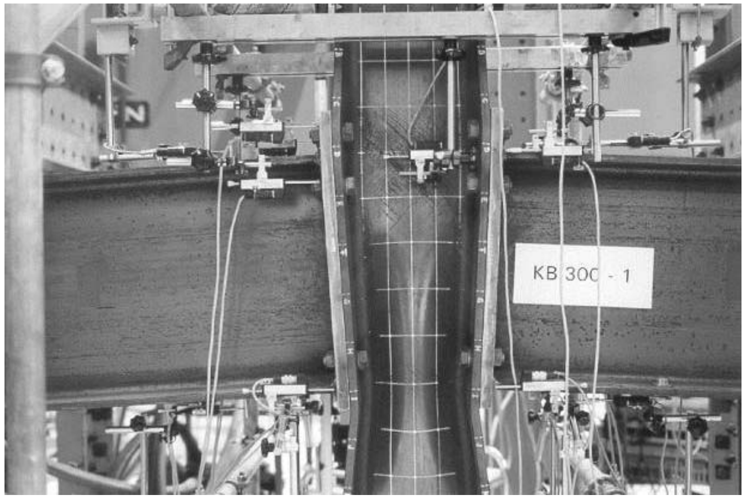
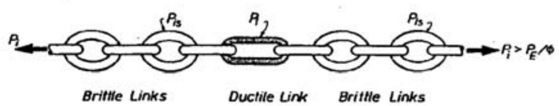
DUCTILITY

Capacity design philosophy





- weakest link should be always very ductile
- brittle links have to have sufficient strength
- over-strength effects of ductile links have to be considered for design of brittle links

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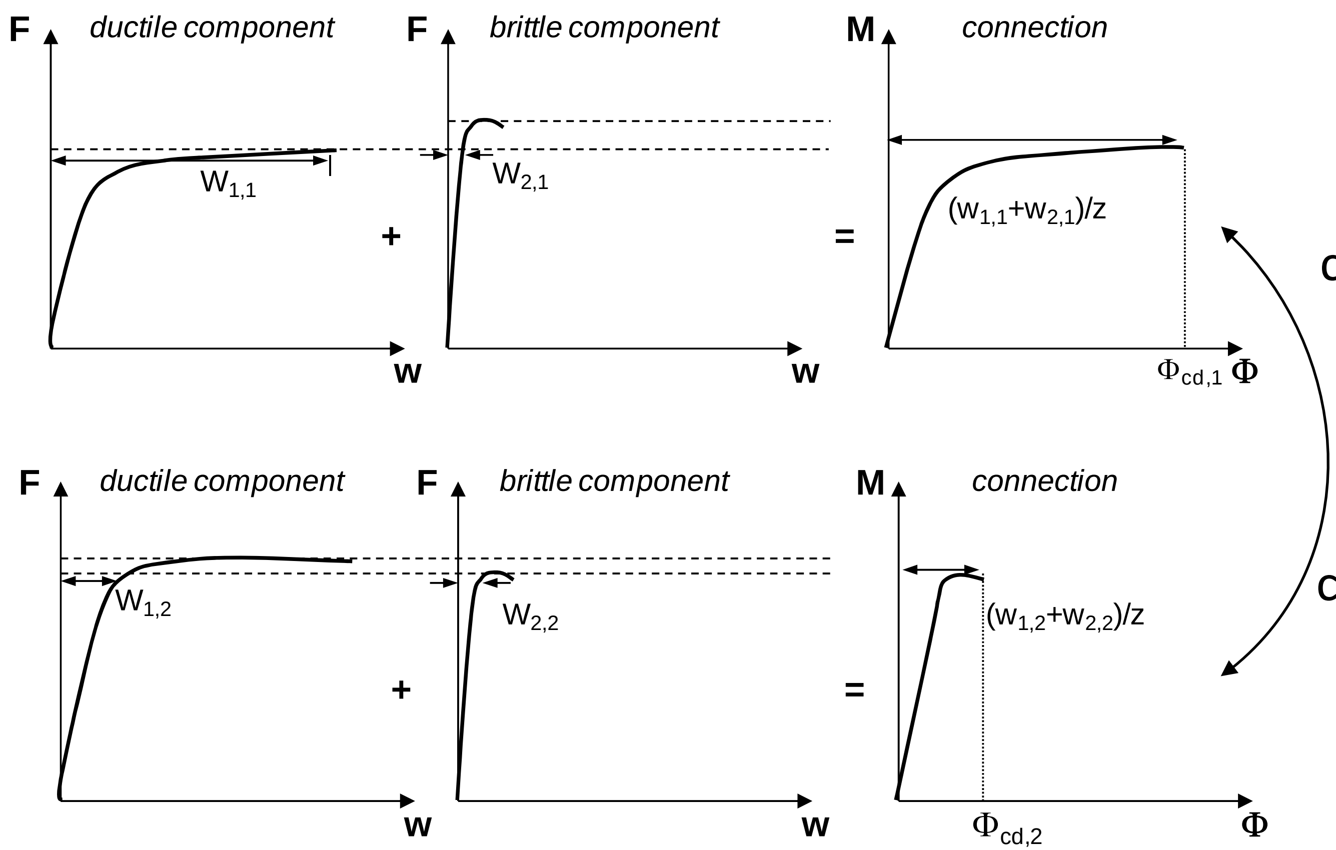
DUCTILITY

"Design of ductile steel structures"

① Nominal material values

② actual material values



connection response acc. the decisive component

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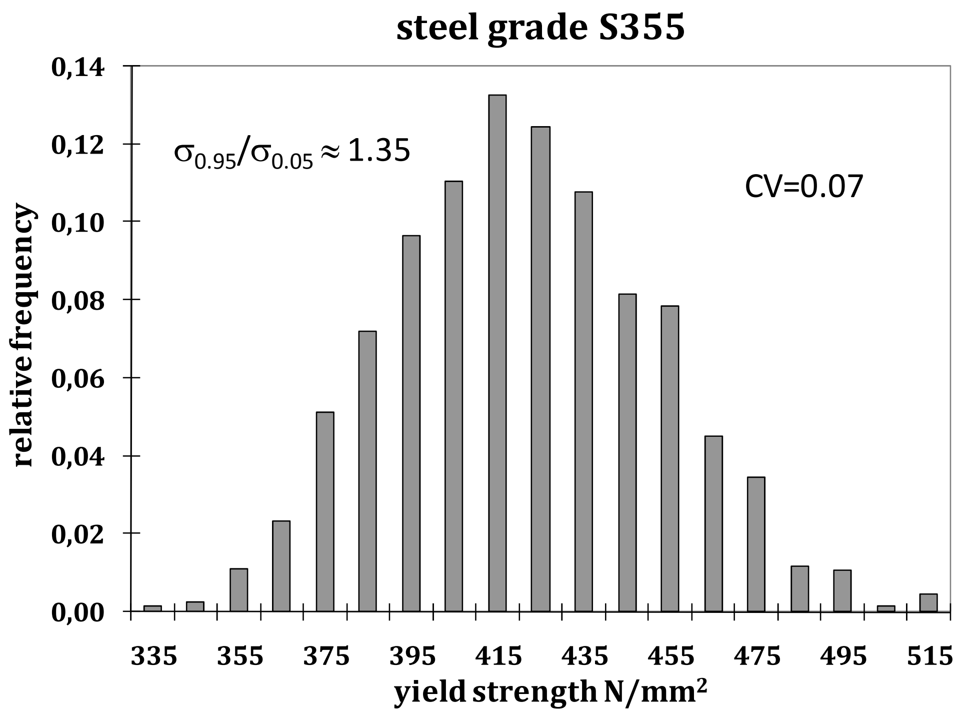
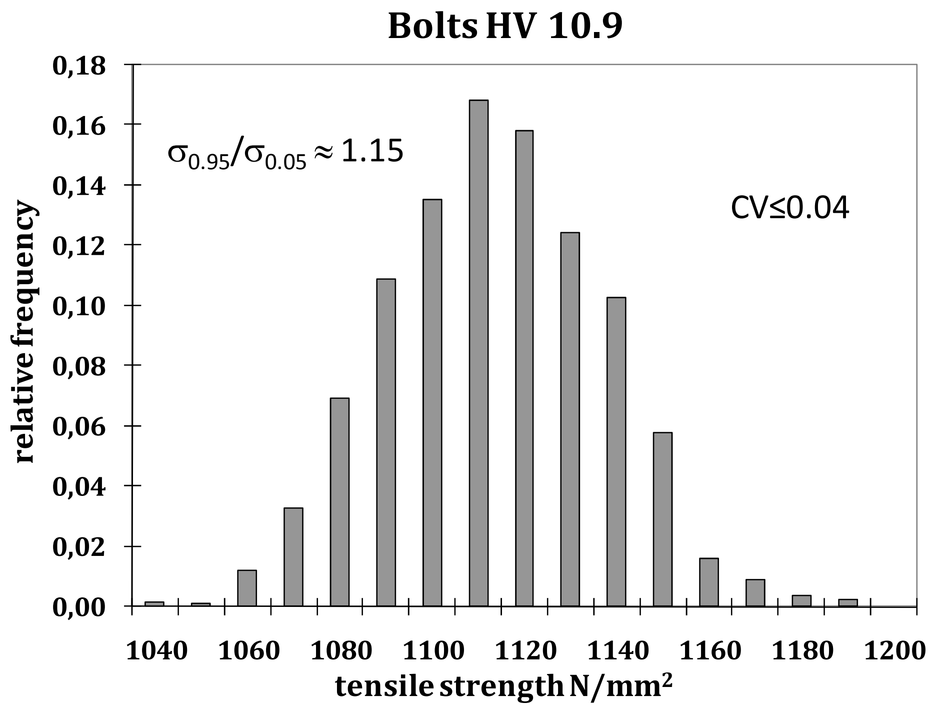
OVER-STRENGTH EFFECTS





- distribution of material strength acc. the probabilistic model of JCSS
- **over-strength-factor** to account for material uncertainties and strain hardening effects

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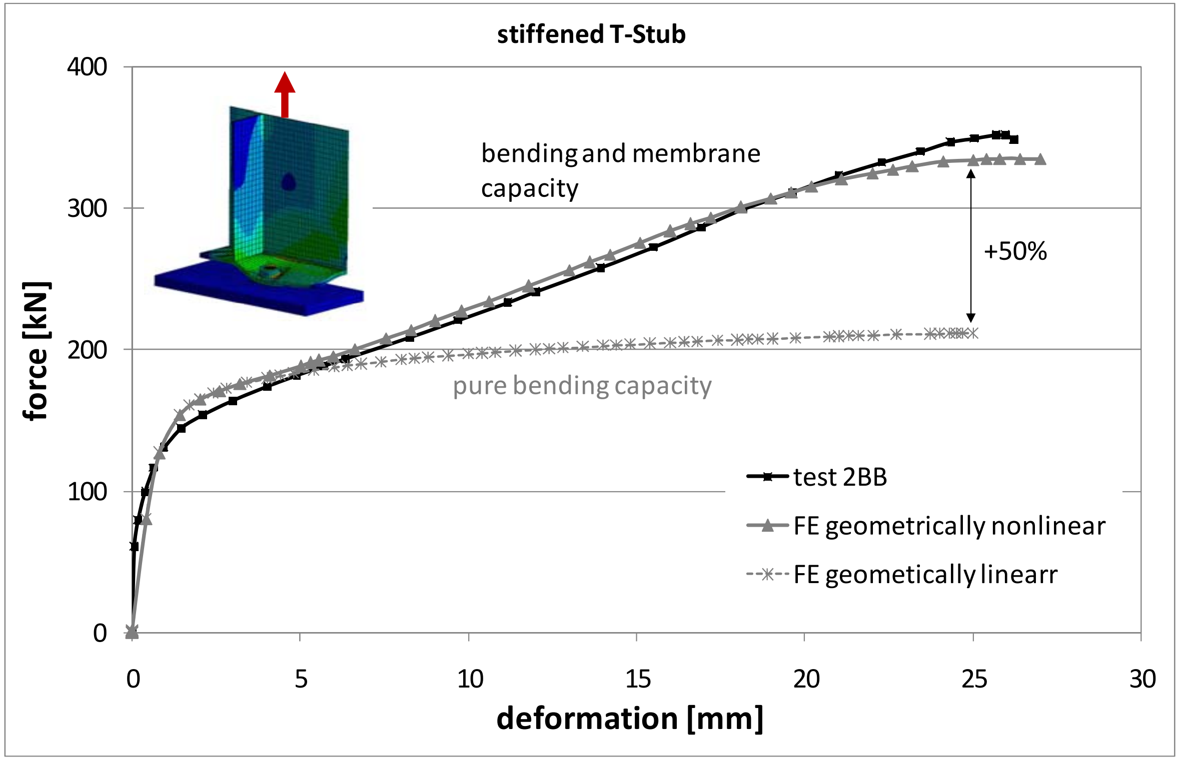
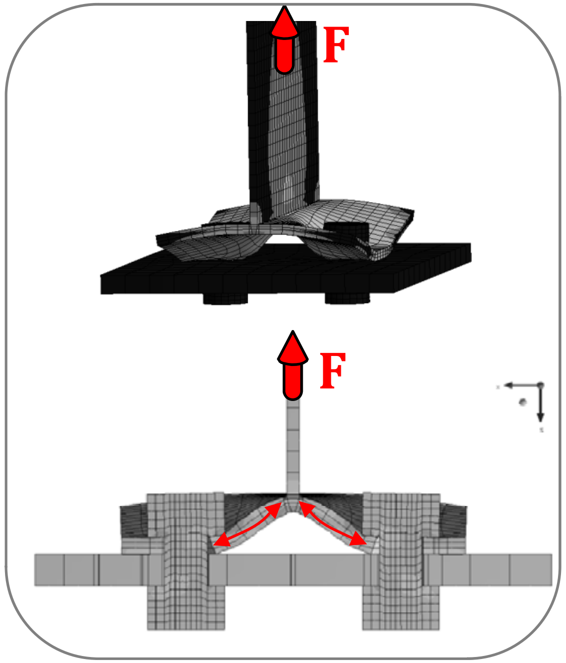
Further Over-strength effects





- activating additional **local** bearing mechanism
- by providing high deformation capacity > but consider for design of bolts

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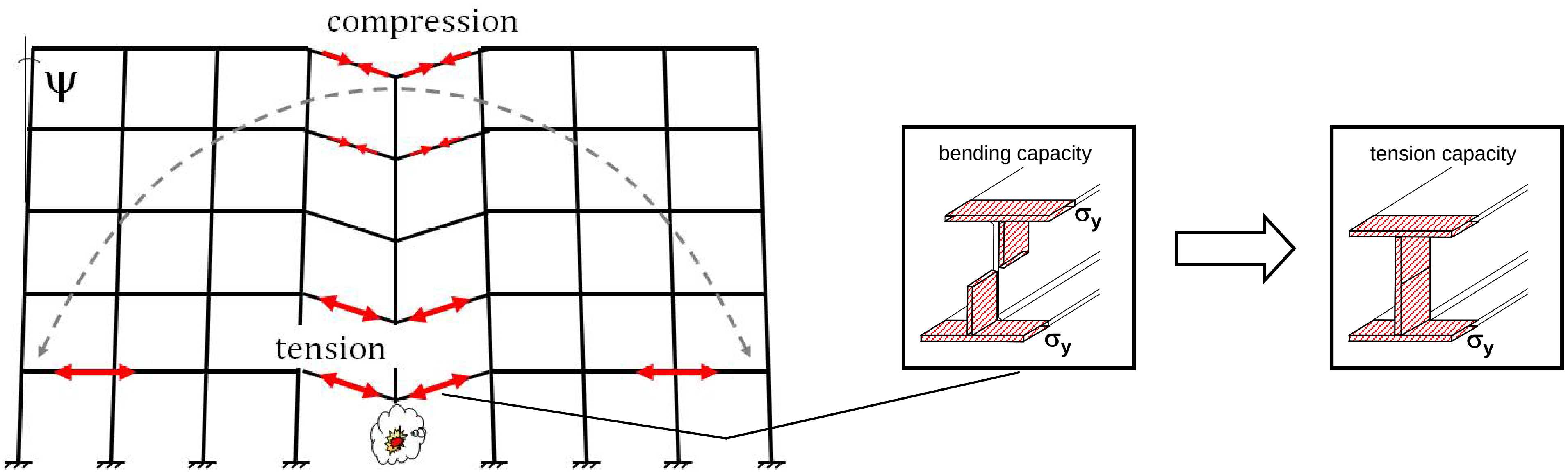
REDUNDANCY OF MEMBERS AND CONNECTIONS → GLOBAL REDUNDANCY

additional bearing mechanism



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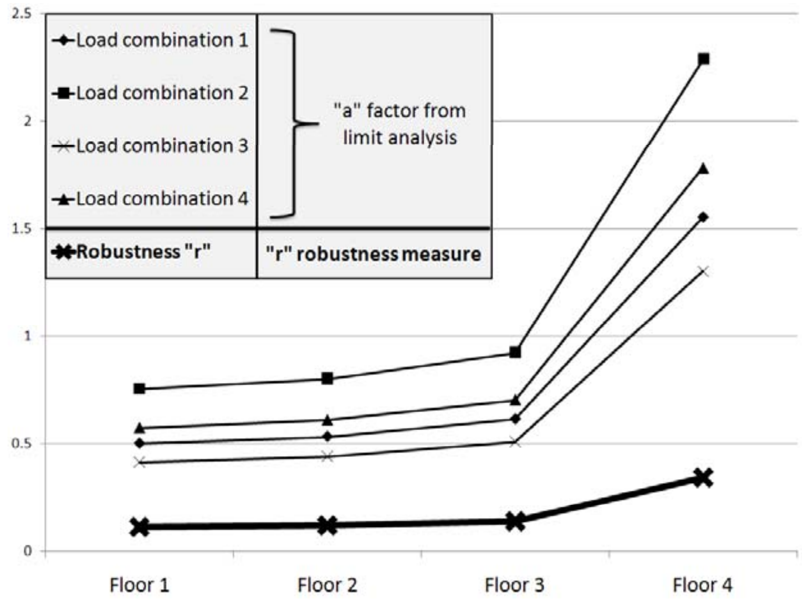
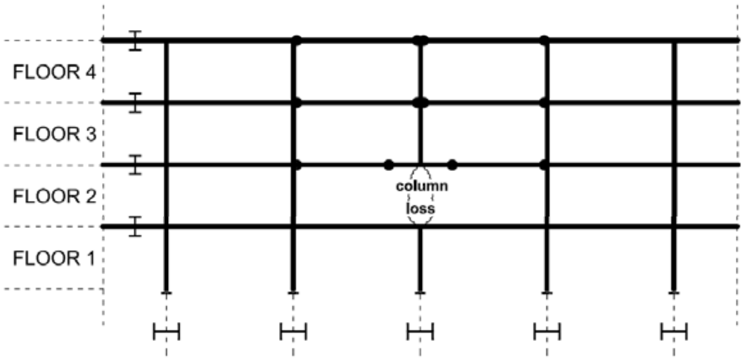
EXAMPLE: COLLAPSE LOAD FACTOR OF A STEEL FRAME AS MEASURE OF DEGREE OF REDUNDANCY

$$r = a_{Damaged} / a_{Undamaged}$$

ratio of load multiplier of partially damaged to undamaged state





Undamaged structure		
a = 3.676		
Damaged structure		
Floor of column loss	Limit analysis "a" factor	Robustness "r"
Floor 4	1.297	0.353
Floor 3	0.509	0.138
Floor 2	0.449	0.122
Floor 1	0.425	0.116

Example of steel frame:
Loss of column in lower floor leads to smaller r- value i.e. more critical

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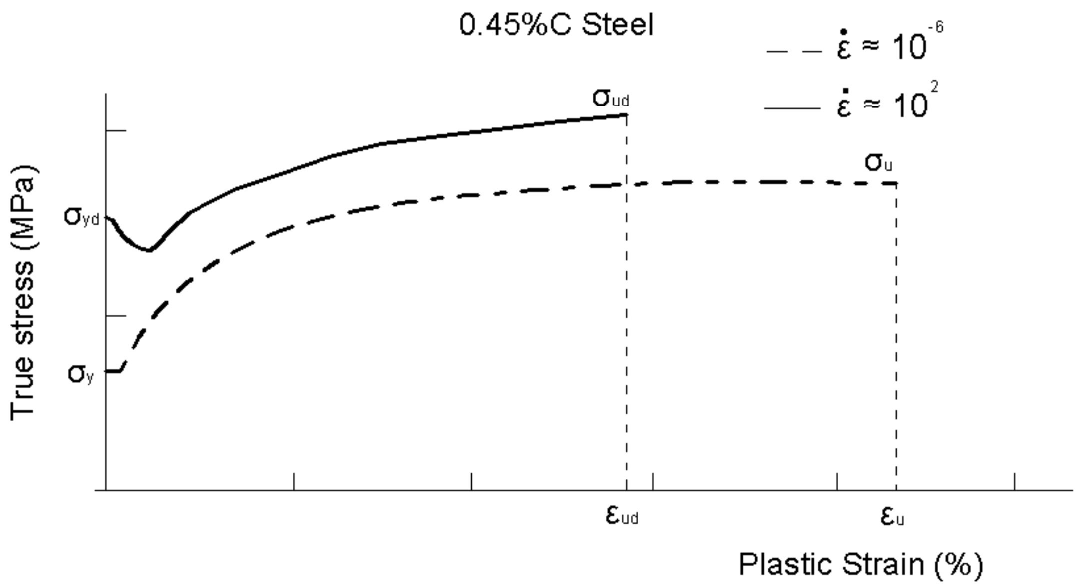
STRAIN RATE EFFECTS



- elastic modulus is unaffected,
- <u>ultimate tensile strength increases</u> slightly with strain rate,
- yield strength has a much higher increase in comparison
- <u>ultimate tensile strain reduces</u> with strain rate → **limited ductility**

FACTSHEET COMPOSITE STRUCTURES

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FACTSHEET COMPOSITE STRUCTURES





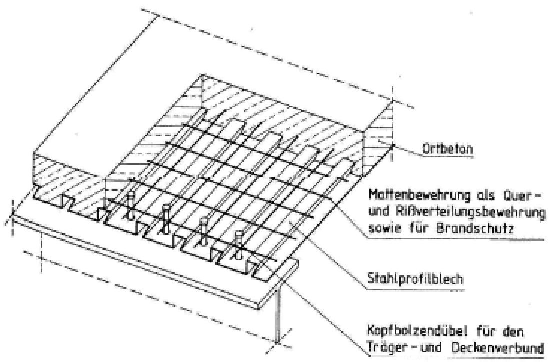
CONTENT

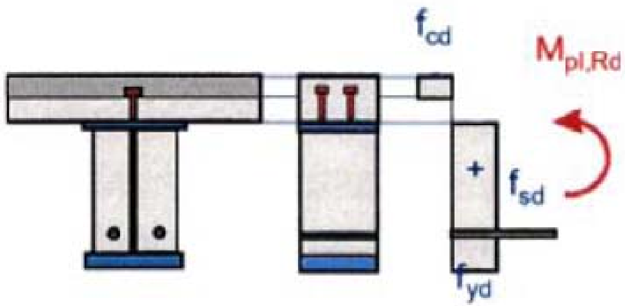
- structural geometrical properties – general
- material characteristics
- steel-concrete shear connection
- redundancy in comparison to pure steel and pure concrete structures

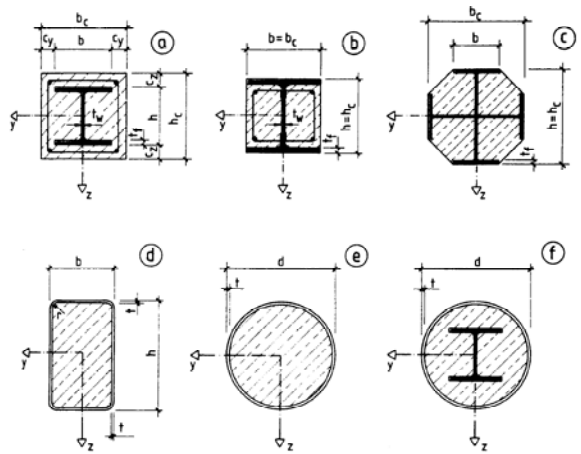
  by slab system and composite columns
- modeling of composite structures

FACTSHEET COMPOSITE STRUCTURES

STRUCTURAL AND GEOMETRICAL PROPERTIES







- both materials complement one another
- steel = tension zone and concrete = compression zone
- composite systems avoids formwork for concreting
- concrete serves as fire protection for the steel profile

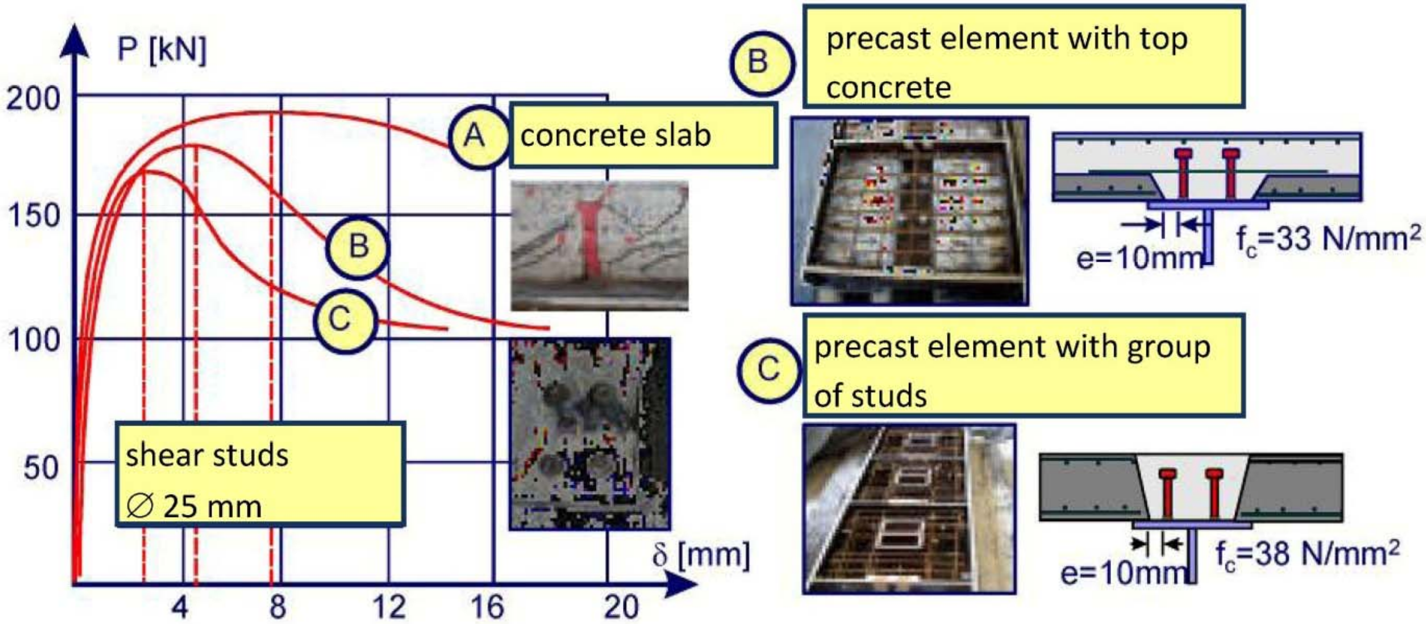
Factsheet Composite structures

Material characteristics

at least 4 different type of materials

FACTSHEET COMPOSITE STRUCTURES

STEEL-CONCRETE SHEAR CONNECTION

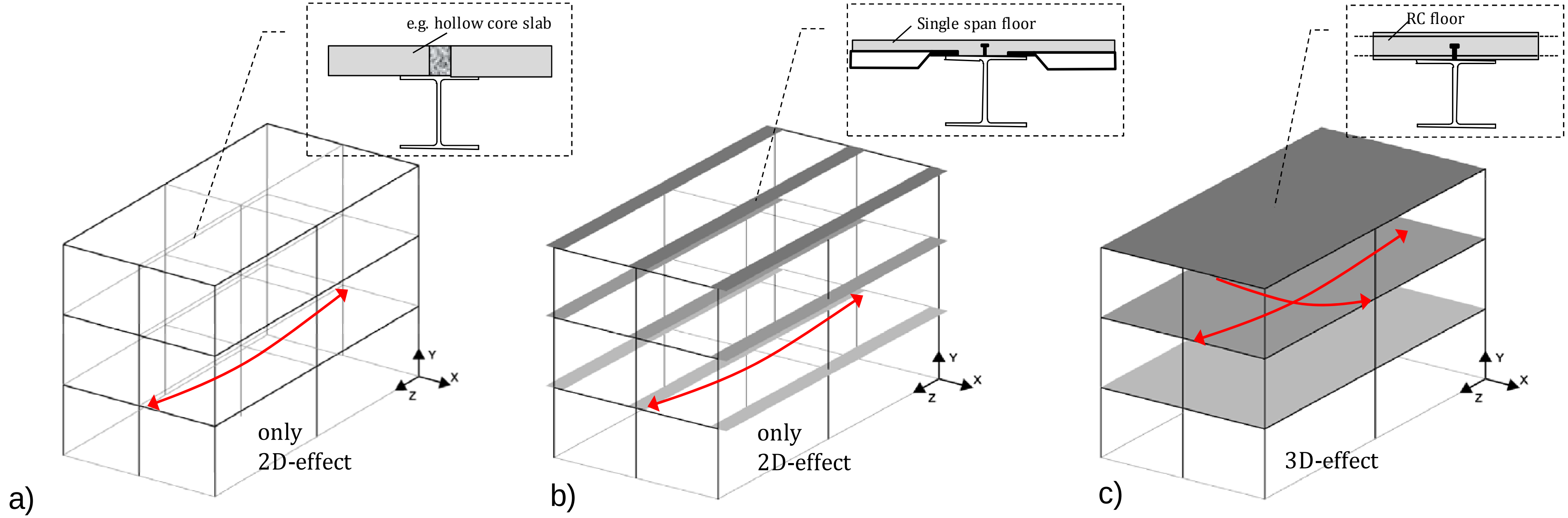


[Hanswille, 2005]

- behavior of the common cross-section is influenced by the behavior of the shear connection
- strength and deformability of the connection are decisive

FACTSHEET COMPOSITE STRUCTURES

REDUNDANCY DEPENDING ON THE SLAB-SYSTEM



- slab system has significant influence on the global redundancy
- horizontal ties preferable b) in the composite beams and c) composite slab

Factsheet Composite structures

Redundancy of composite columns
in comparison to concrete and steel columns

pure concrete column

spalling of concrete

pure steel column

under impact or blast loading

buckling of steel profile

[www.kcse.com]

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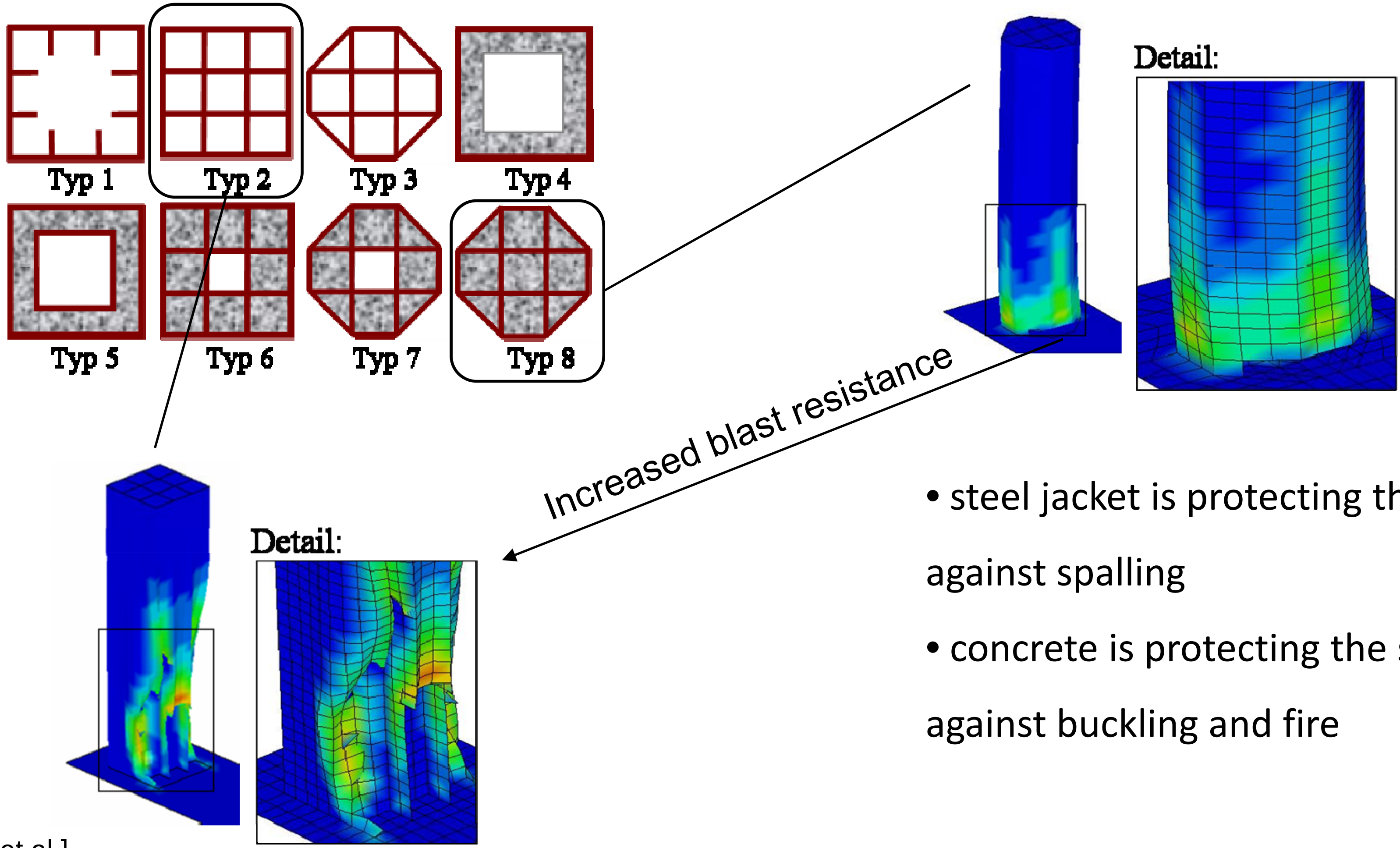
REDUNDANCY OF COMPOSITE COLUMNS AS CONCRETE FILLED SINGLE OR MULTIPLE-CELL STEEL COLUMN



- steel jacket is protecting the concrete against spalling
- concrete is protecting the steel cells against buckling and fire

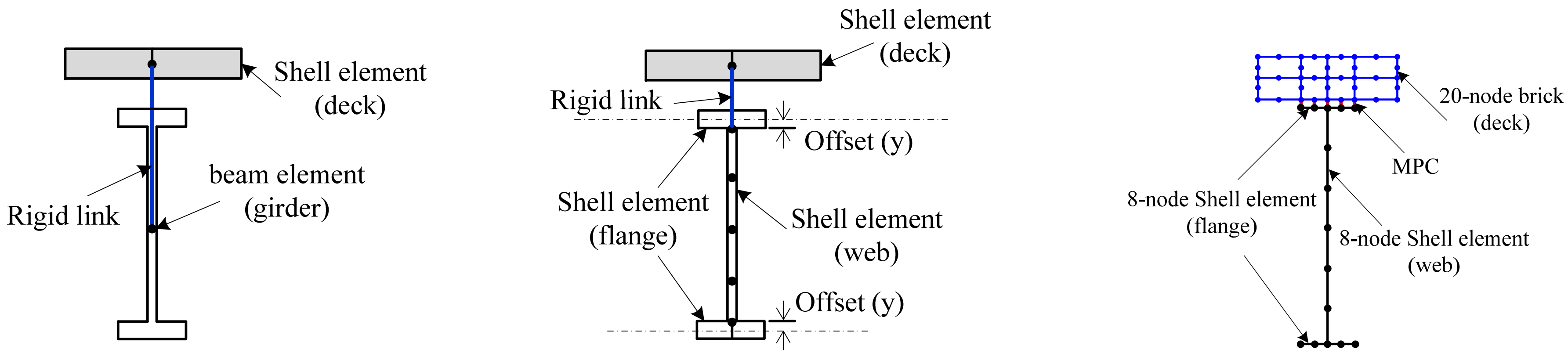
[Rutner et al.]

Factsheet Composite structures

Modeling of composite structures

to cover non-linearities of materials and shear connection

different FE modelling techniques of composite beams



← simplified - sophisticated →

Factsheets Steel and Composite structures

Conclusions

- Steel and steel-concrete composite structures are

  most suitable for designing robust structures

- In comparison to "pure" concrete

  steel composite structures usually enable a reduction of self weight implying lower loads in post failure scenarios

- to allow development of full capacity of members and activate inherent plastic material reserves

  sufficient deformation capacity is decisive