LIÈGE université
School of Engineering

# Ductility assessment of structural steel and composite joints

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Adrien Corman
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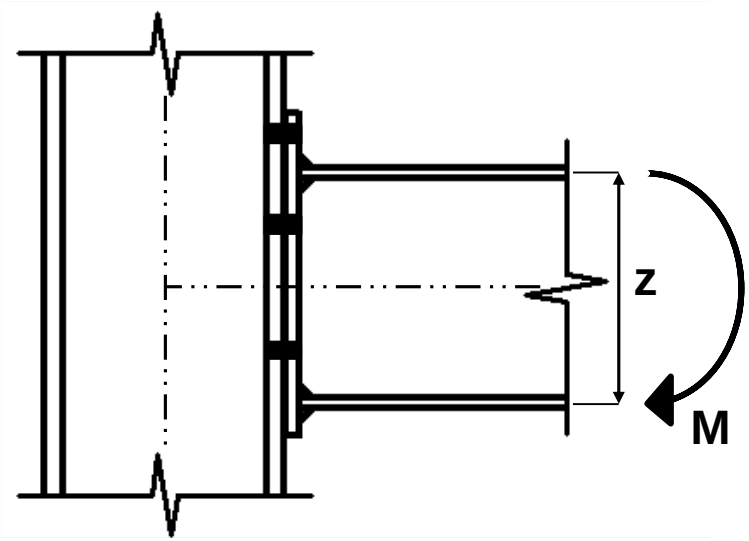
11-13 September 2019, Prague, Czech Republic
The International Colloquium on Stability and Ductility of Steel Structures

UEE
Urban & Environmental Engineering

# Introduction: joint behaviour



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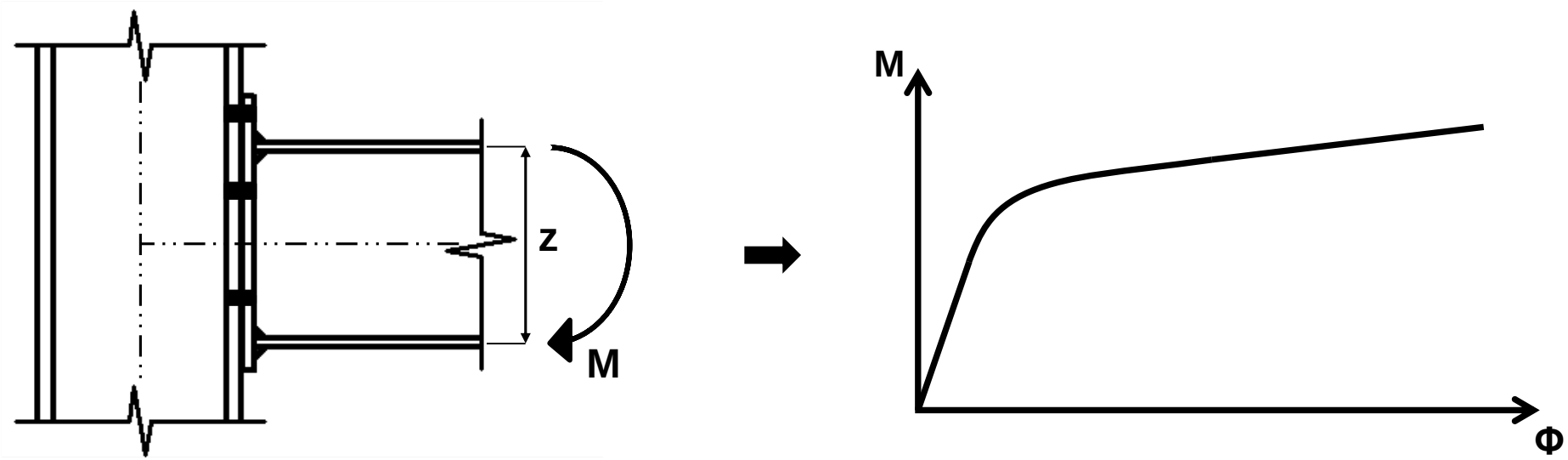

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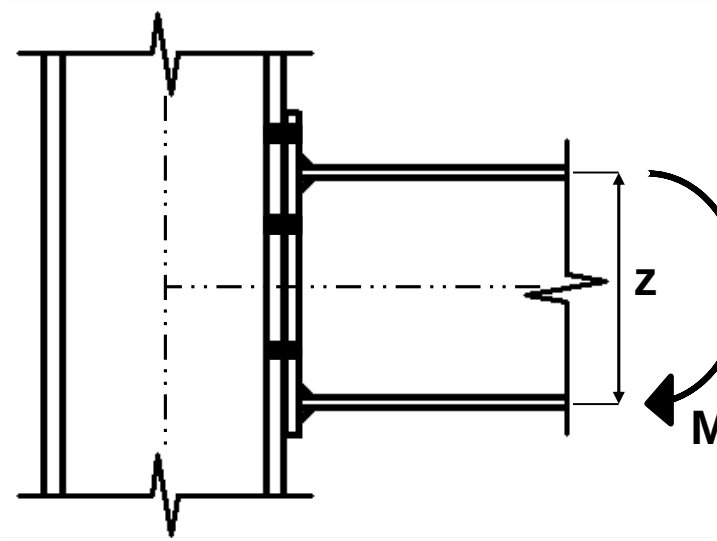

➔ 4 key parameters

- Initial stiffness
- Plastic bending resistance
- Post-plastic stiffness
- Ultimate bending resistance

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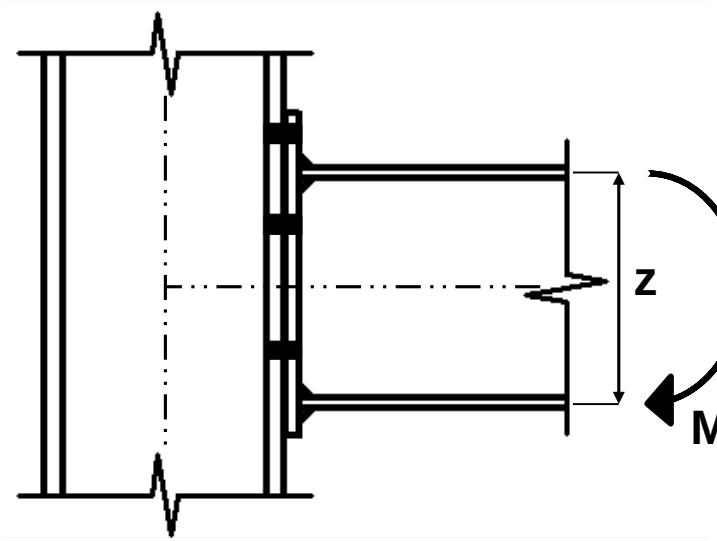


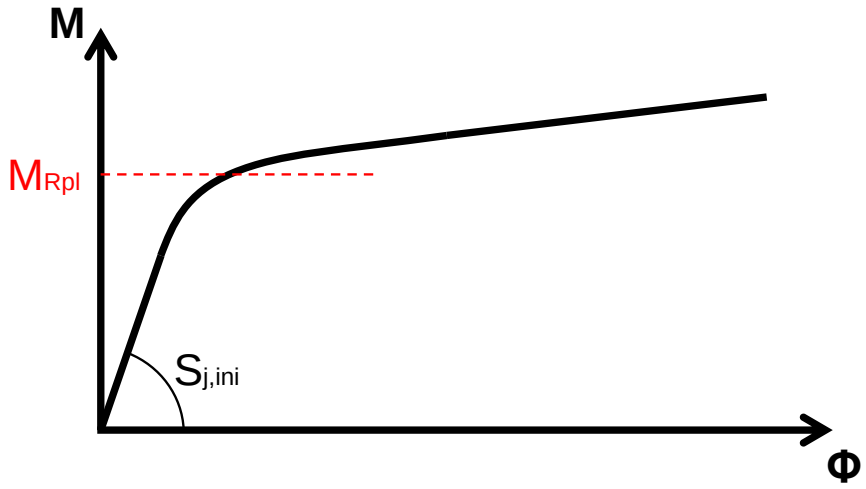


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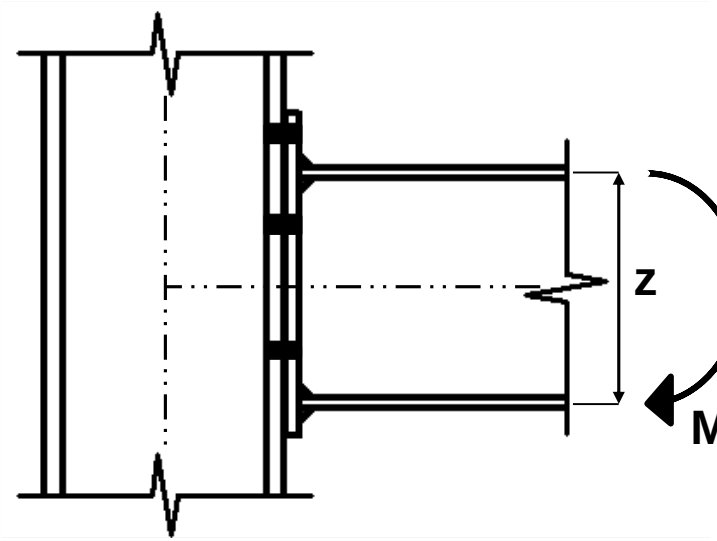


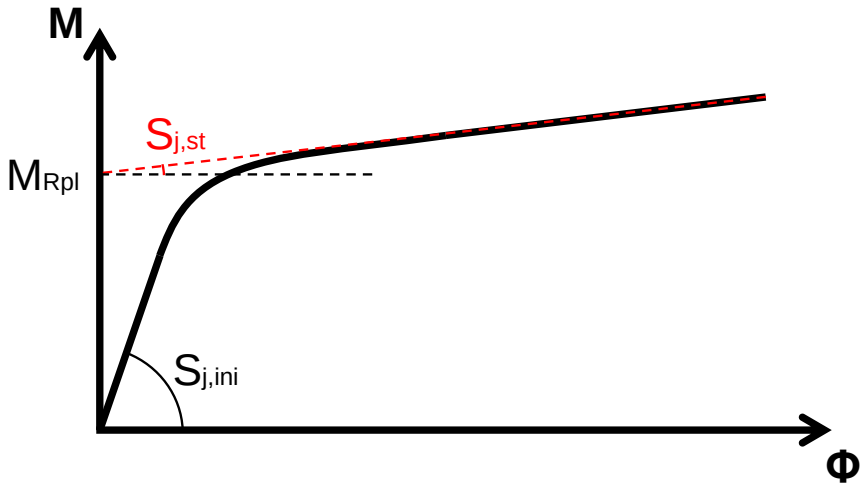


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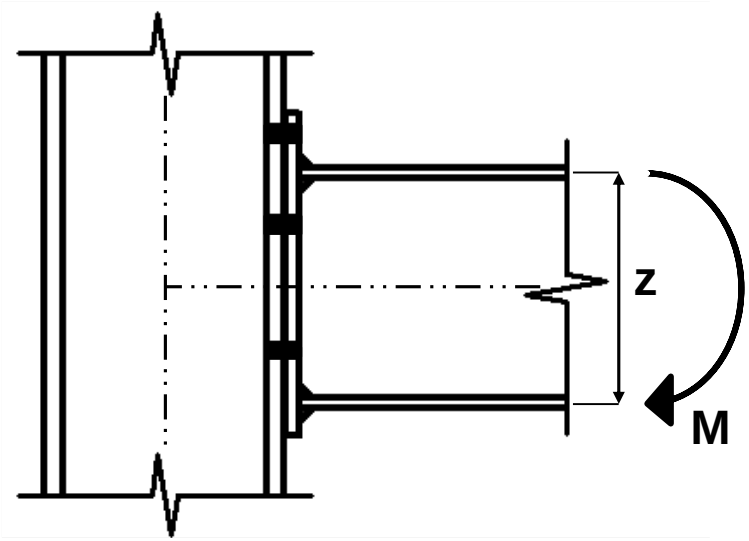


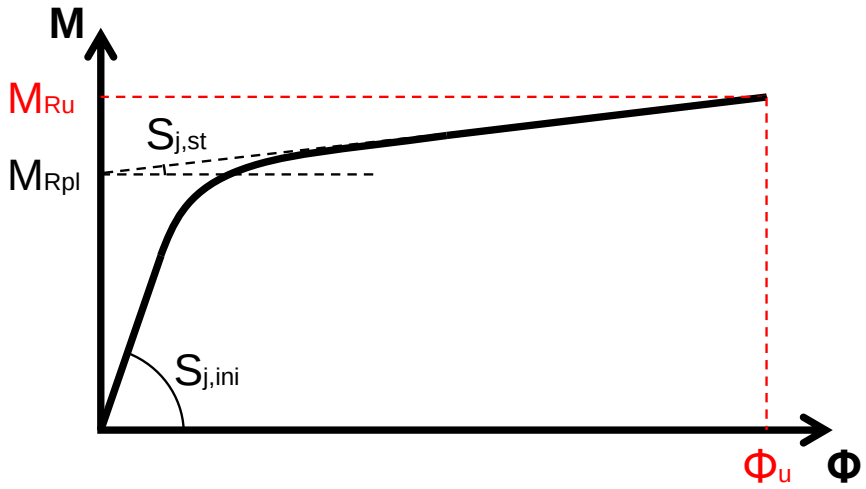


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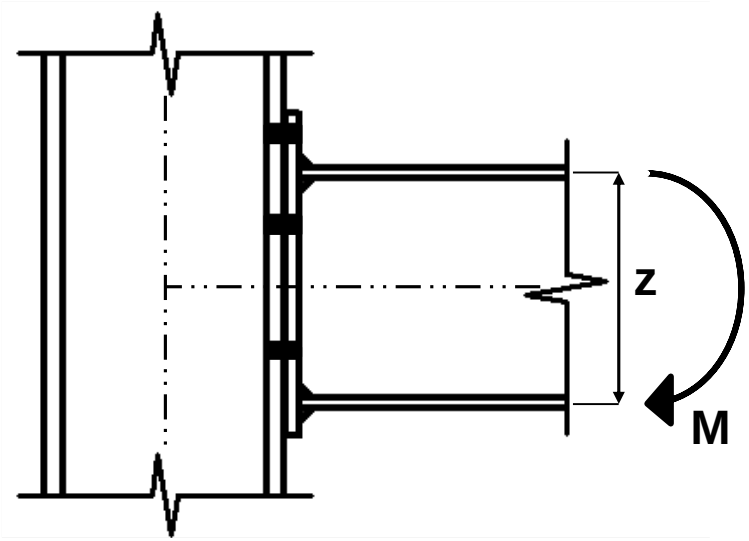


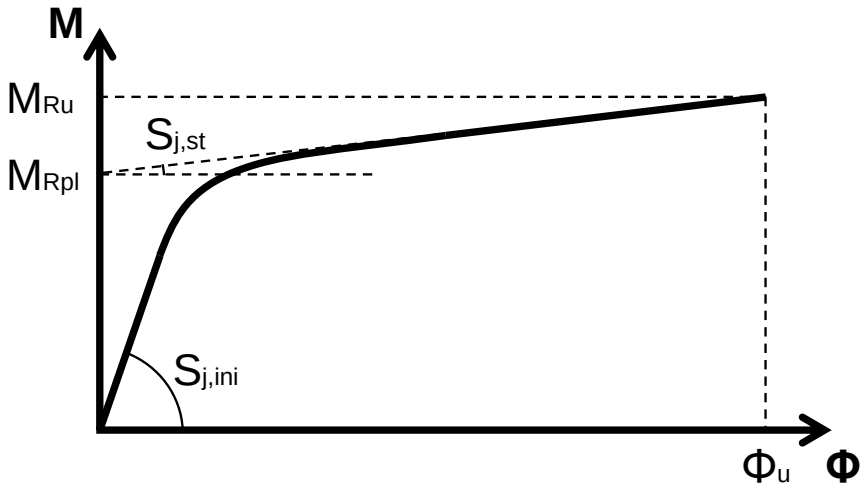


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# Introduction: the component method

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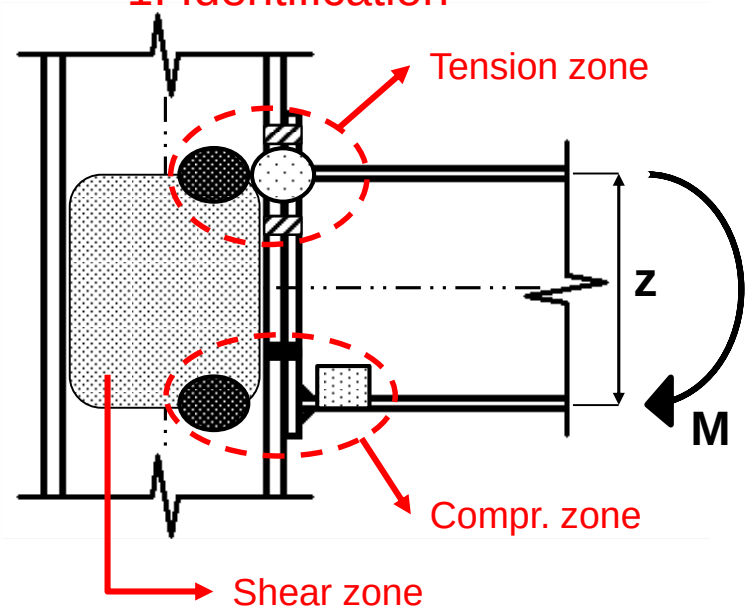


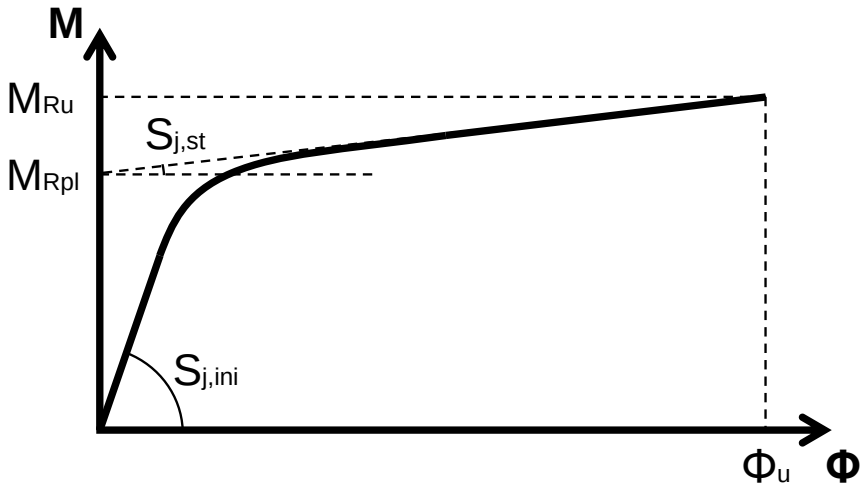


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# Introduction: the component method

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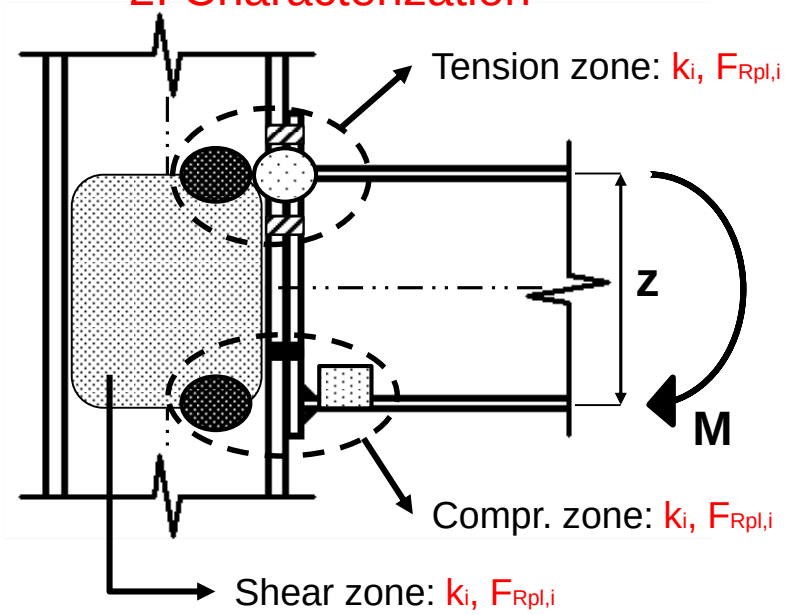


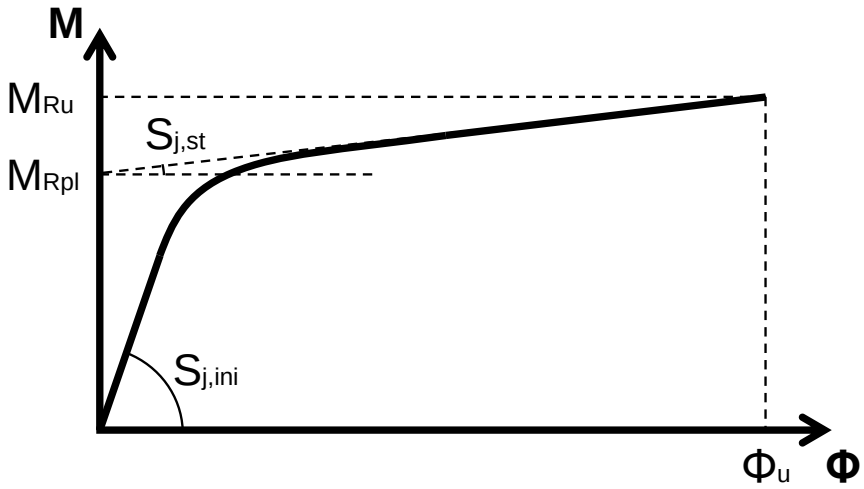


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# Introduction: the component method

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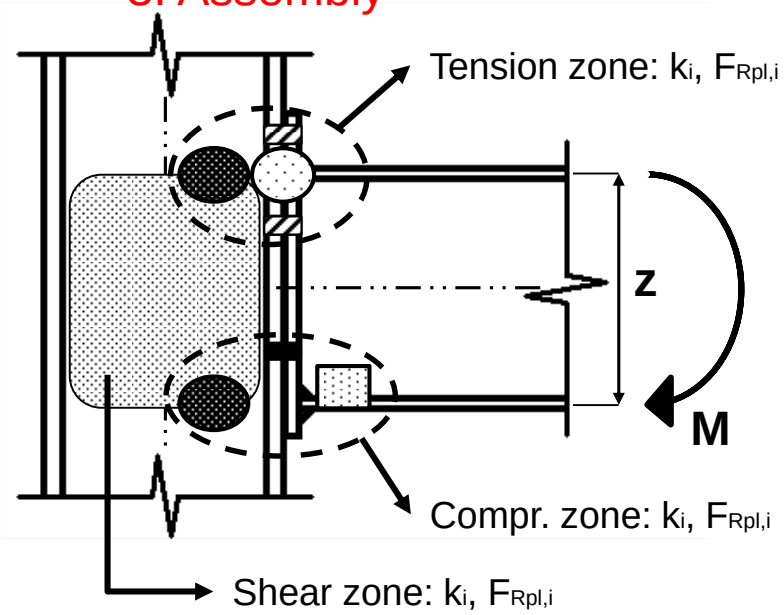


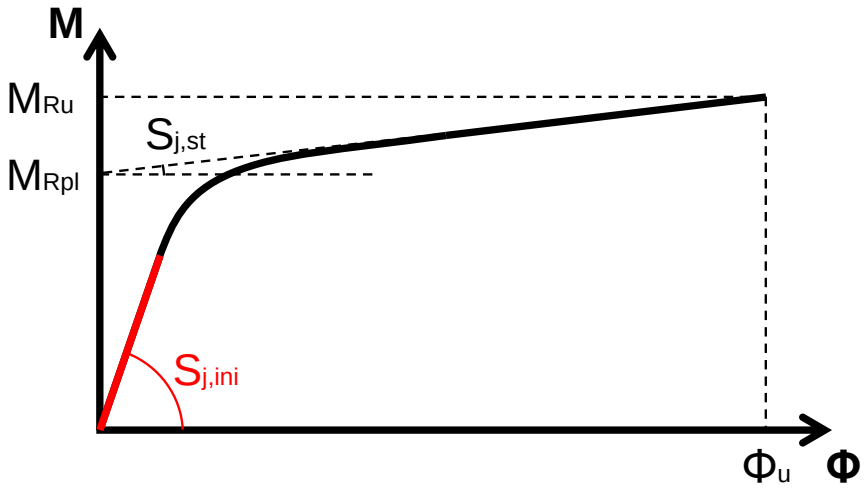


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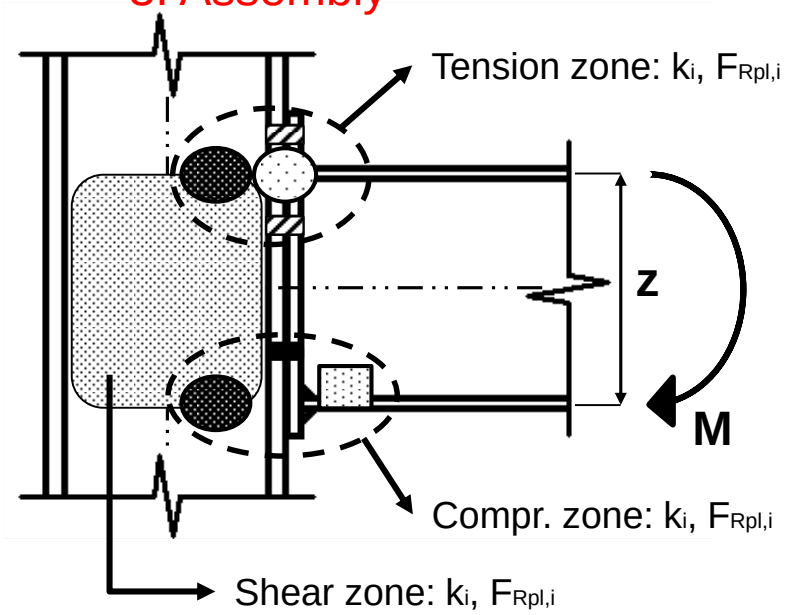


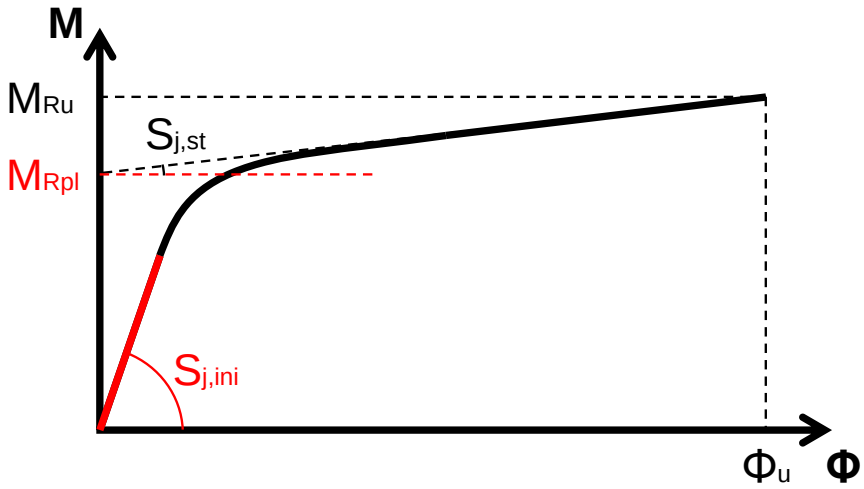


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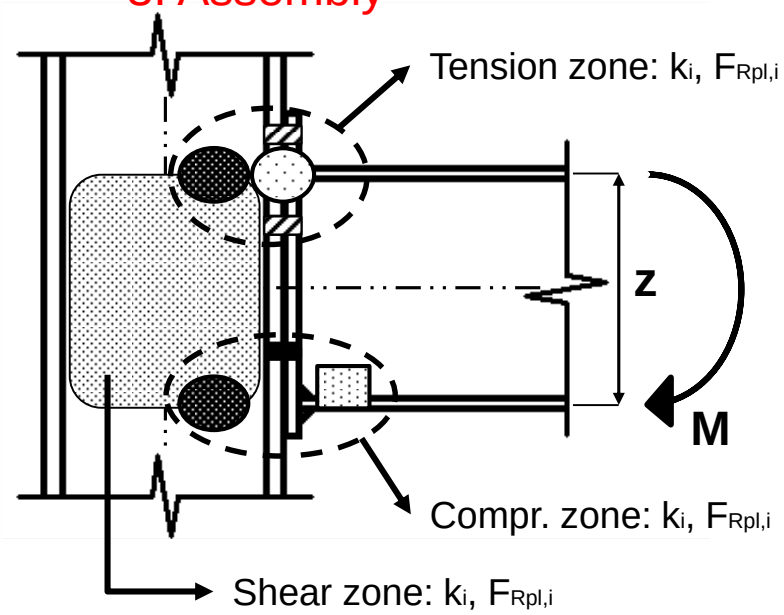


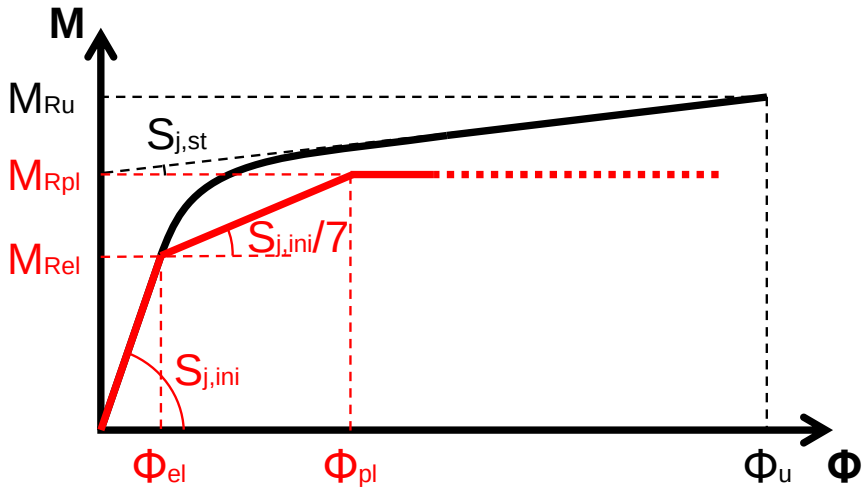


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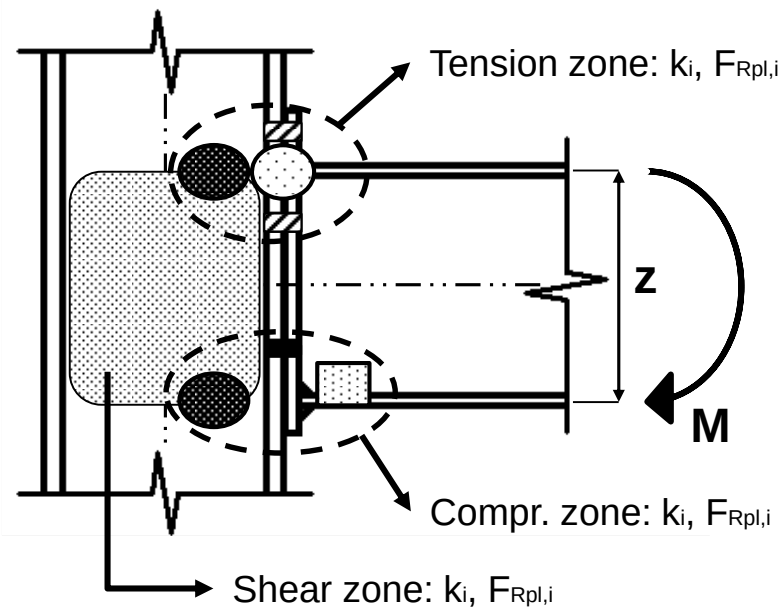


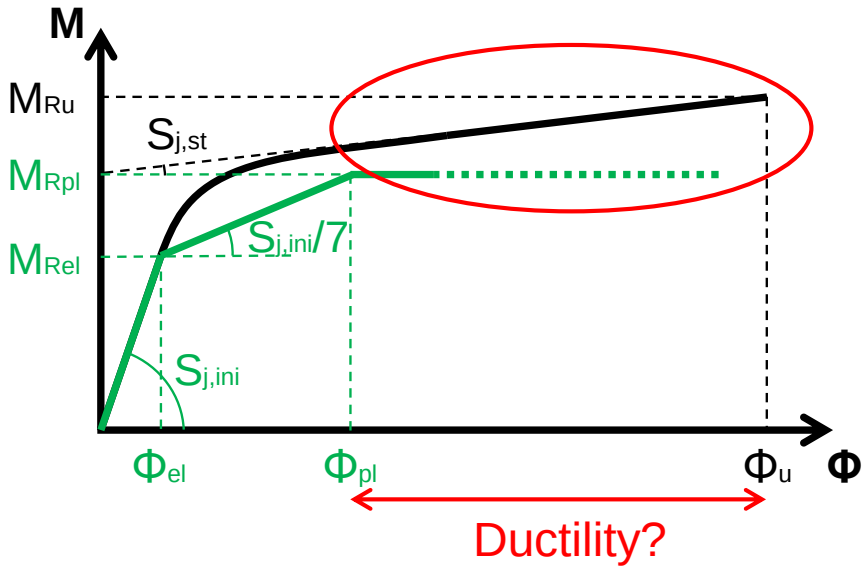


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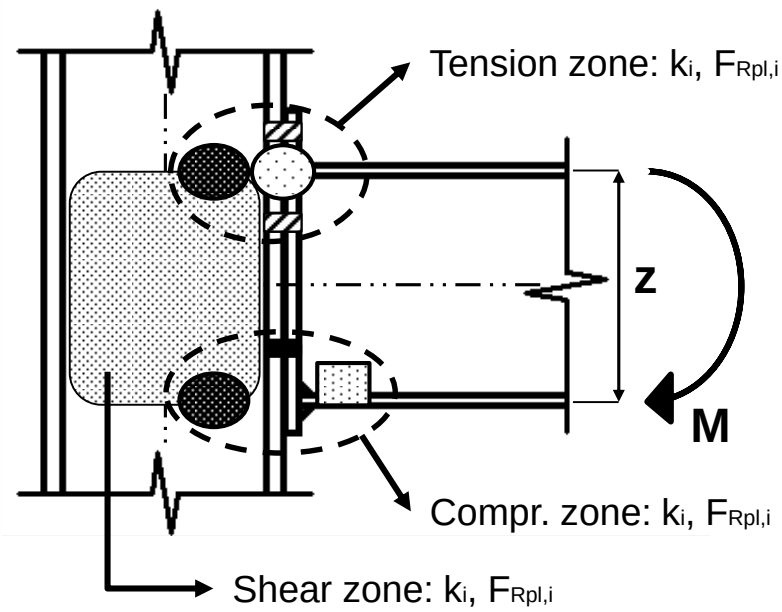


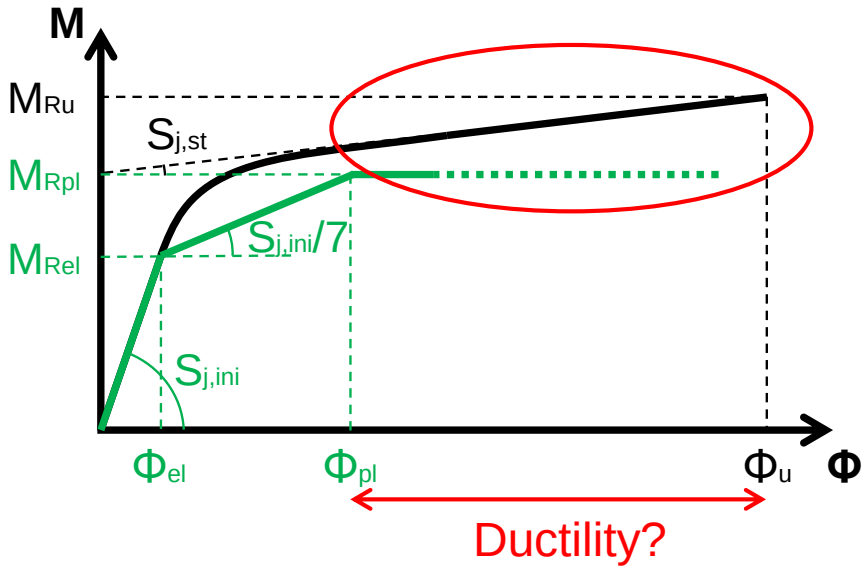


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- Design of a structure based on a plastic global analysis
- Mitigation of the risk of progressive collapse under exceptional loading
- Energy dissipation under earthquakes

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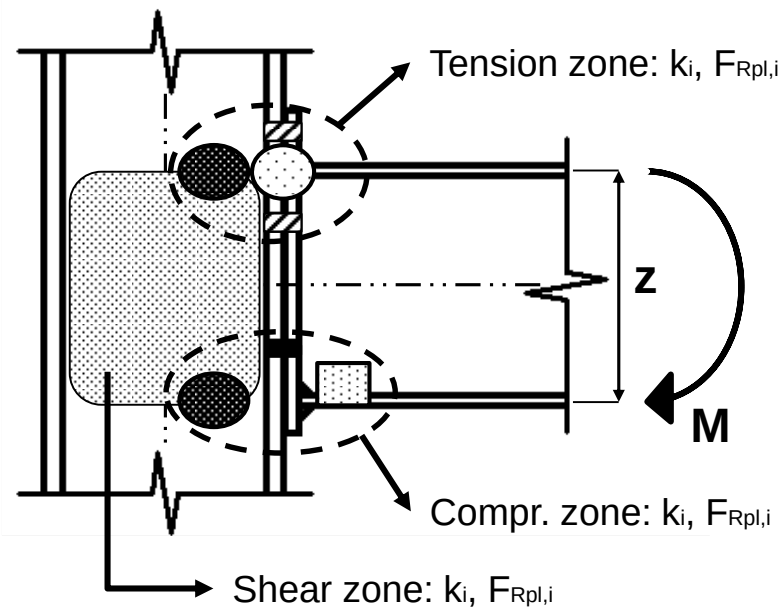


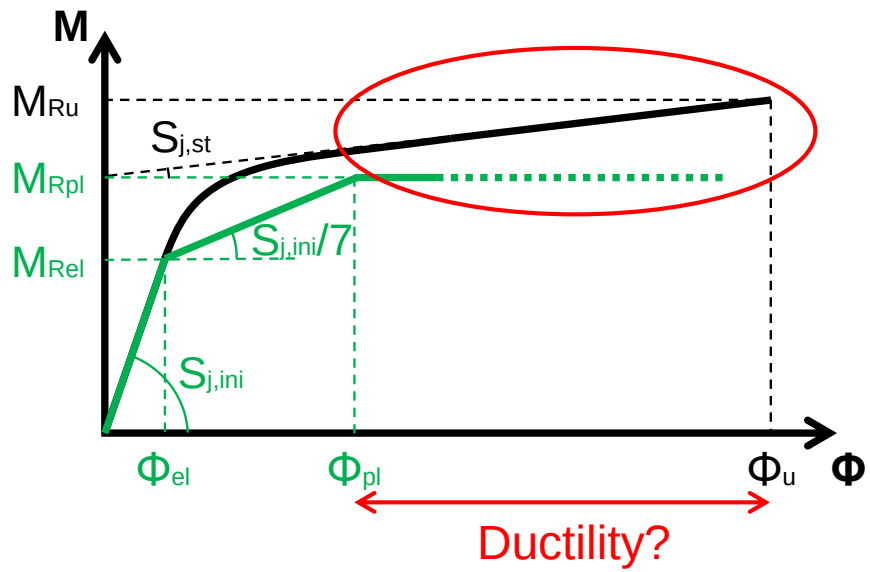


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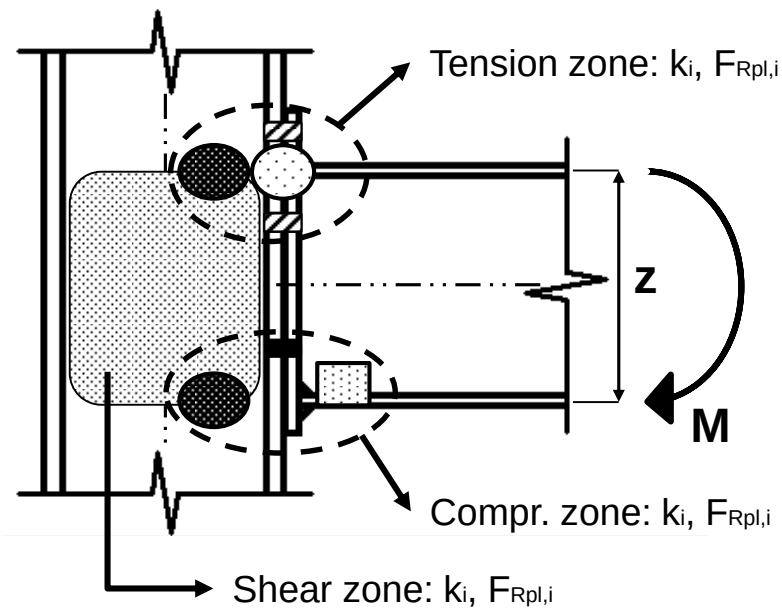


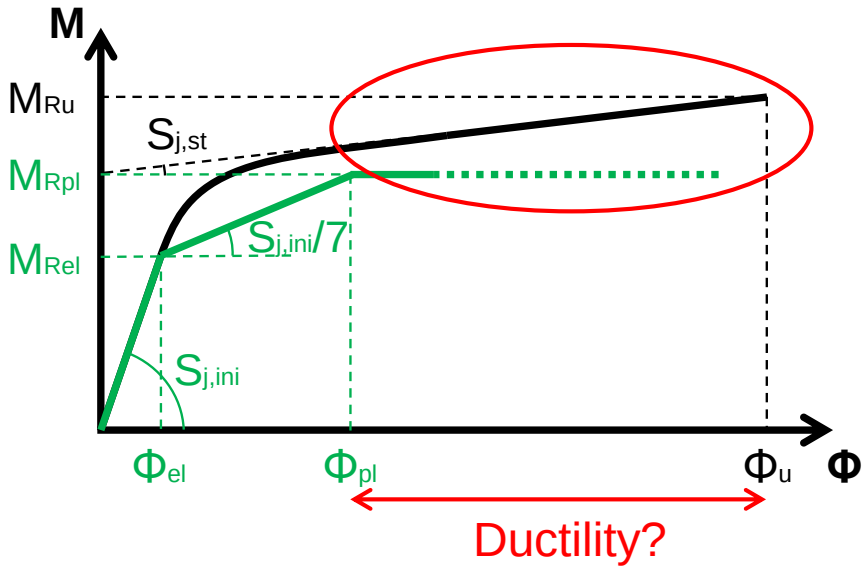


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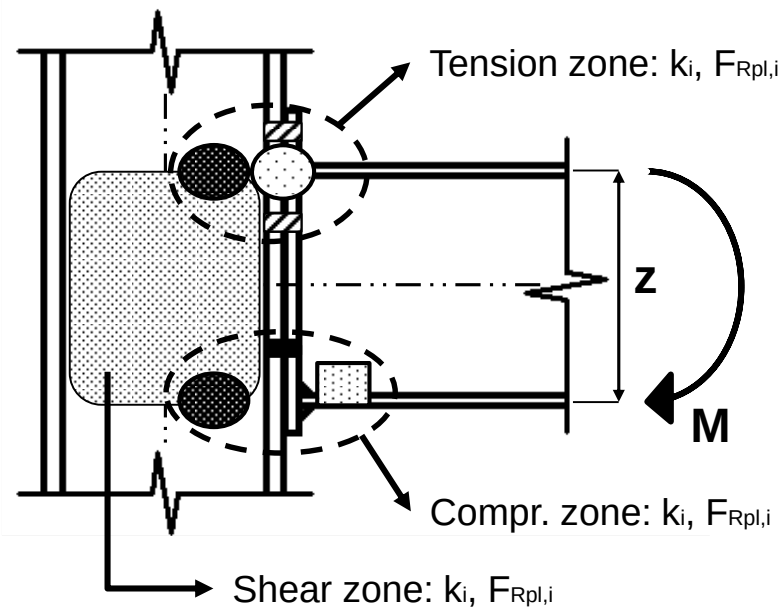


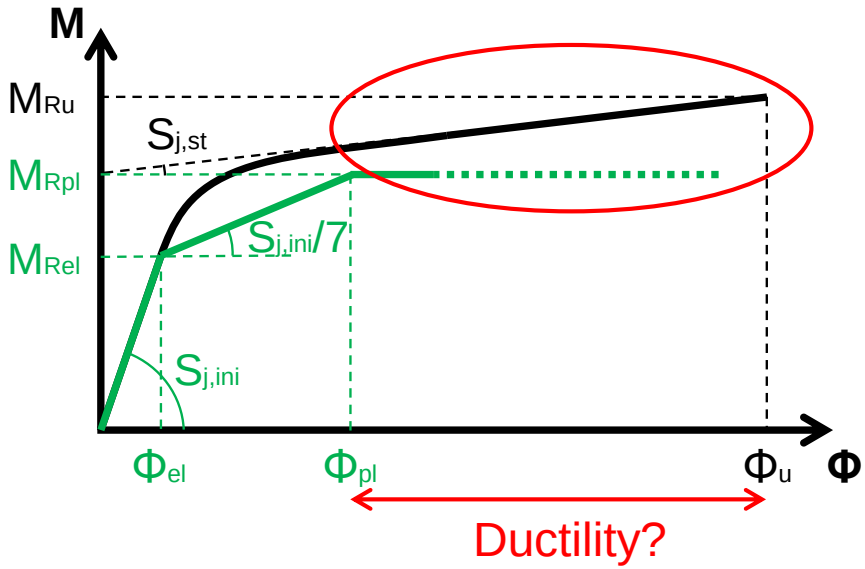


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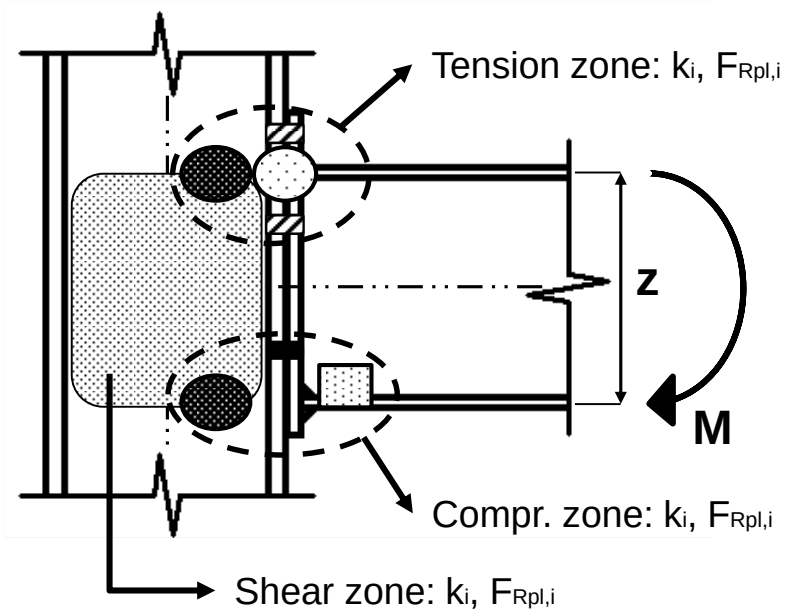


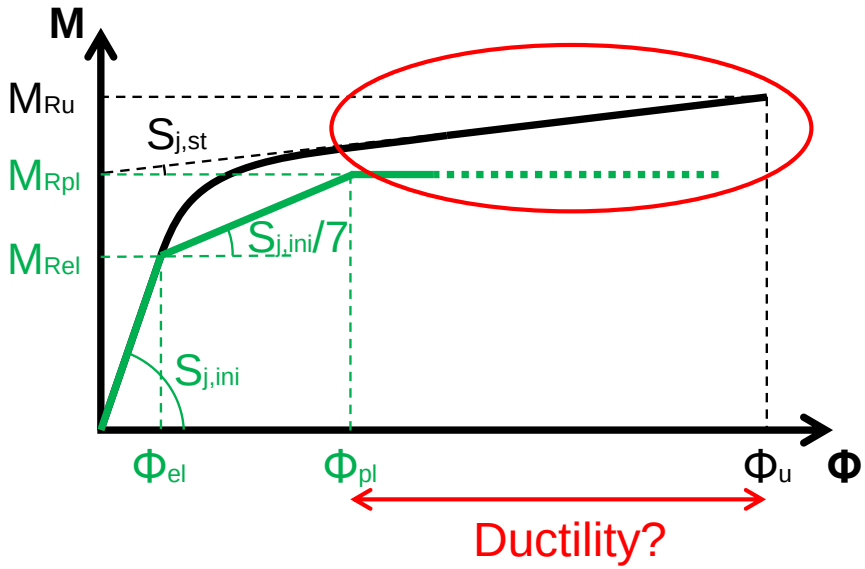


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➔ $\Phi_u$

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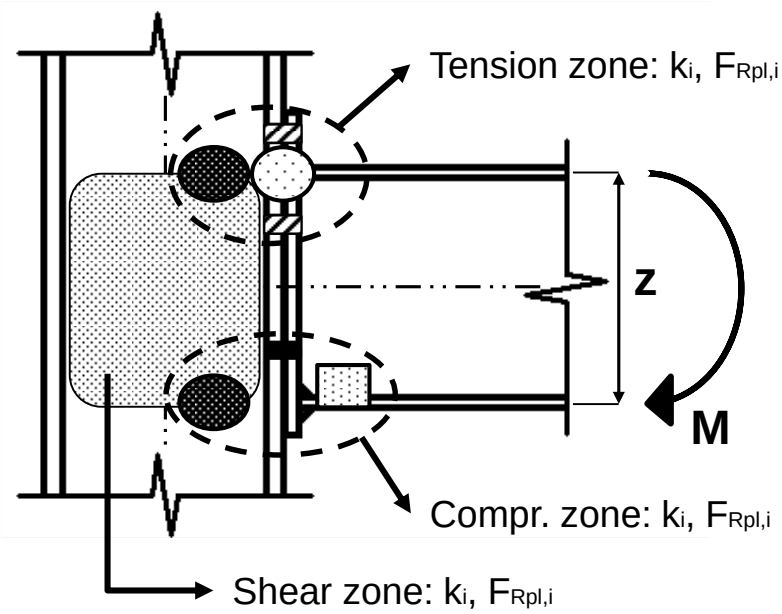


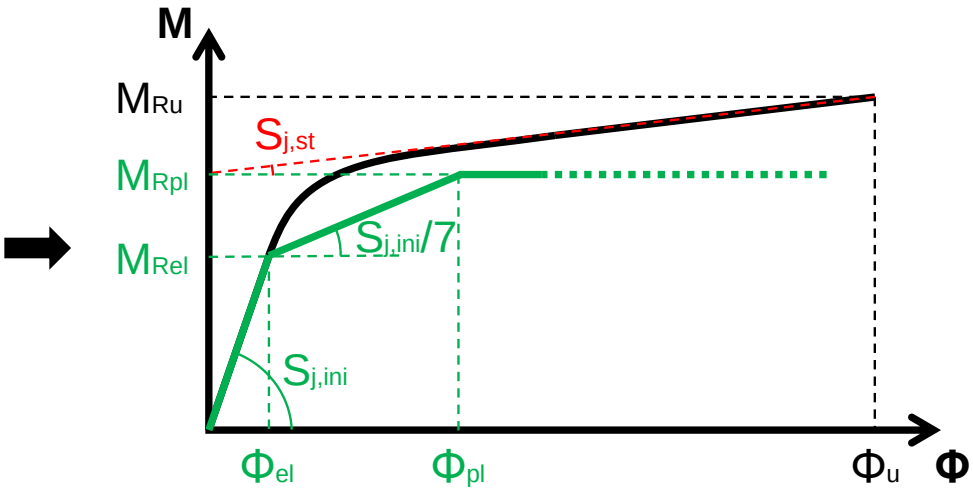


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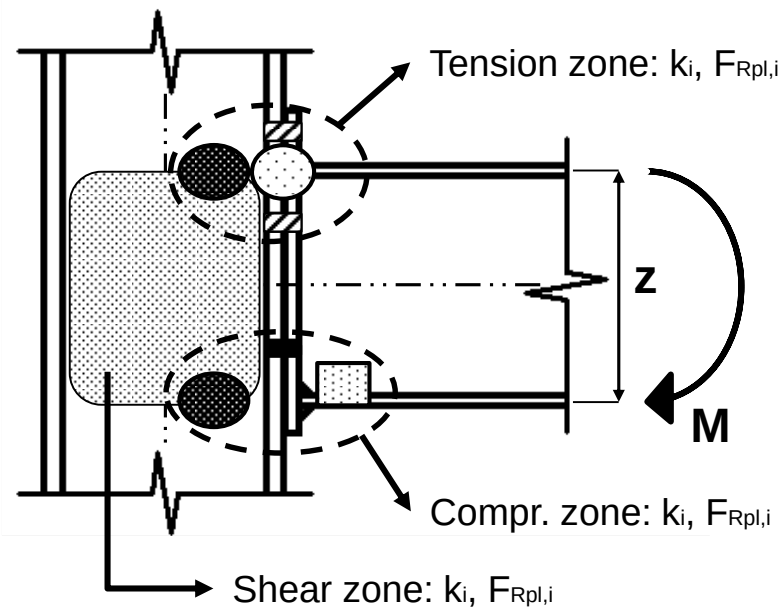


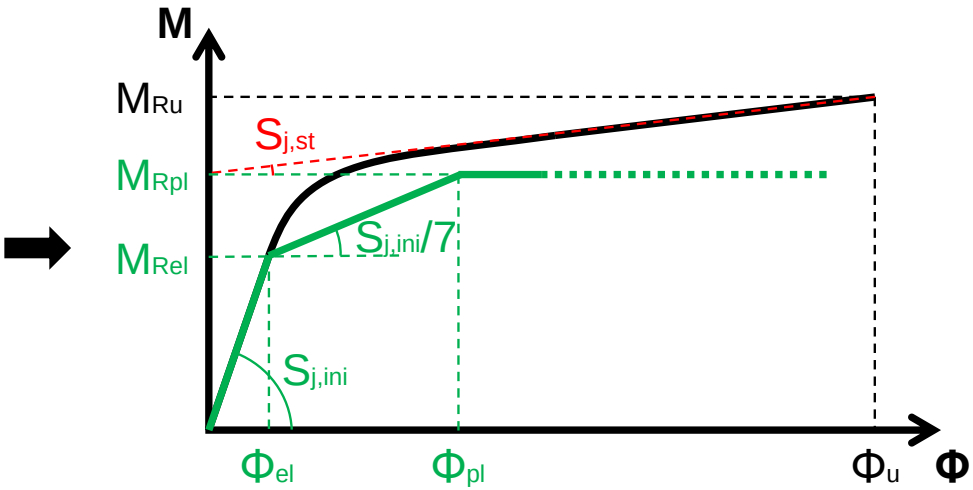


$$S_{j,st} = \frac{Ez^2}{\sum \frac{1}{k^*}}$$

$$\sum \frac{1}{k^*} = \sum_m \left(\frac{1}{k_{i,m}}\right)_{M_{Rpl,m} > M_{Rpl,lim}} + \sum_p \left(\frac{1}{k_{st,p}}\right)_{M_{Rpl,p} \le M_{Rpl,lim}}$$

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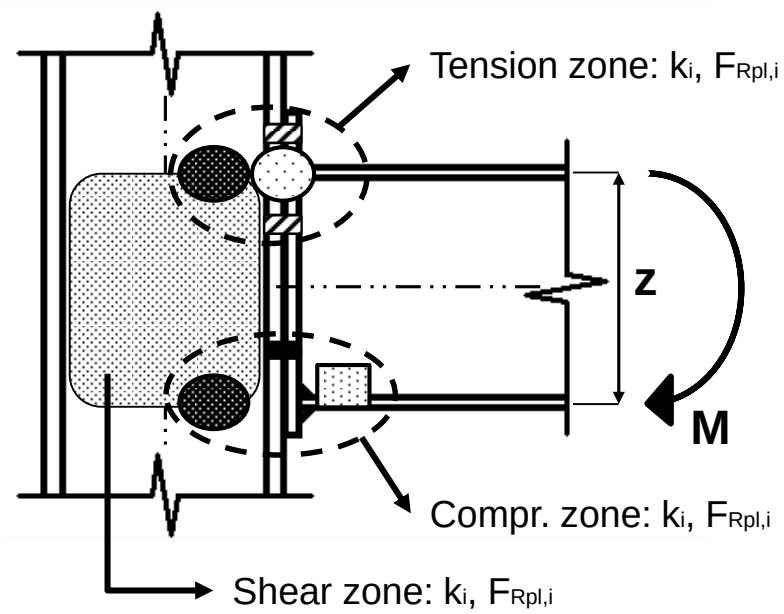


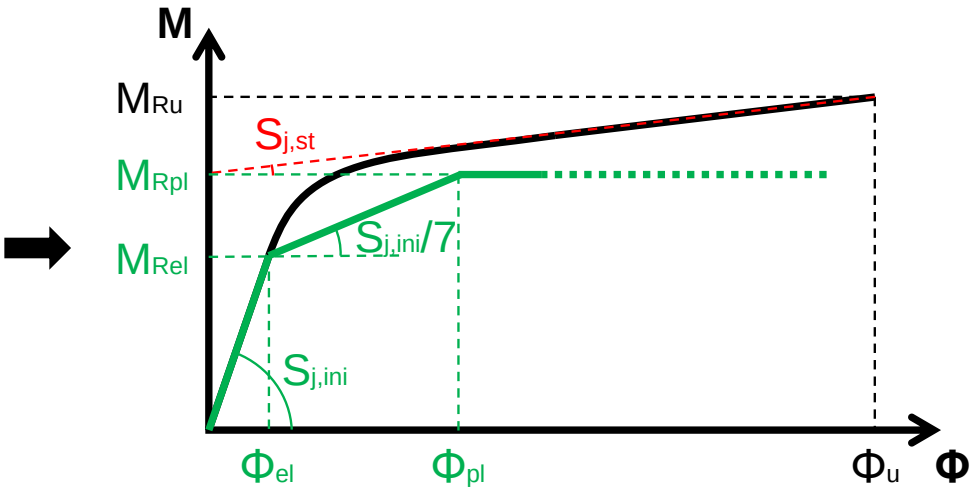


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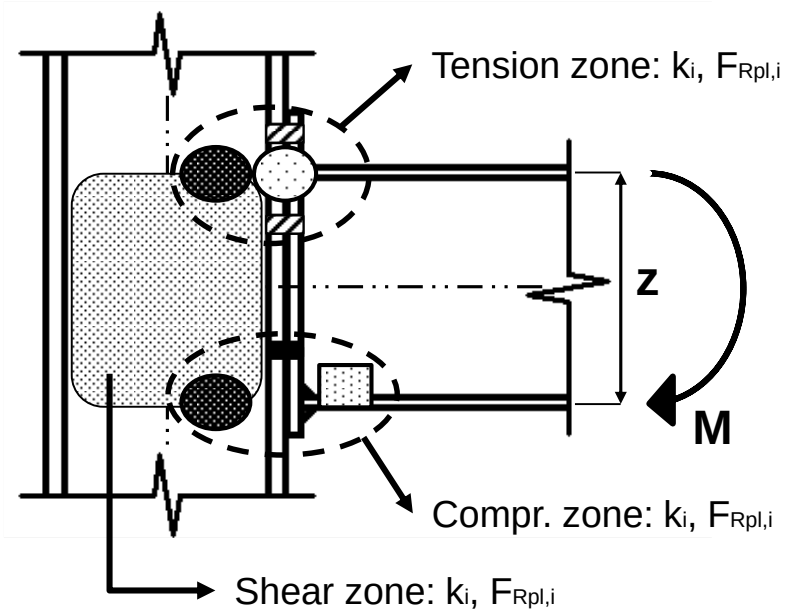
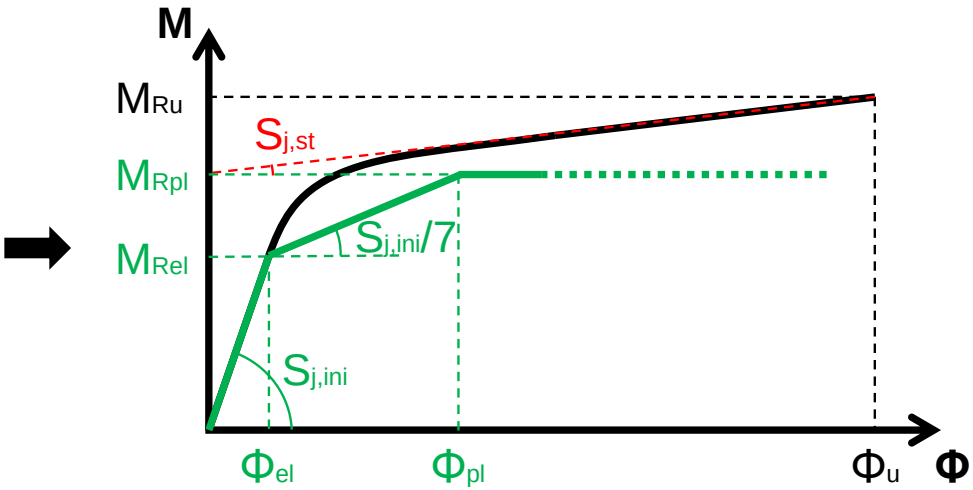
Elastic components

# Estimation of $S_{j,st}$

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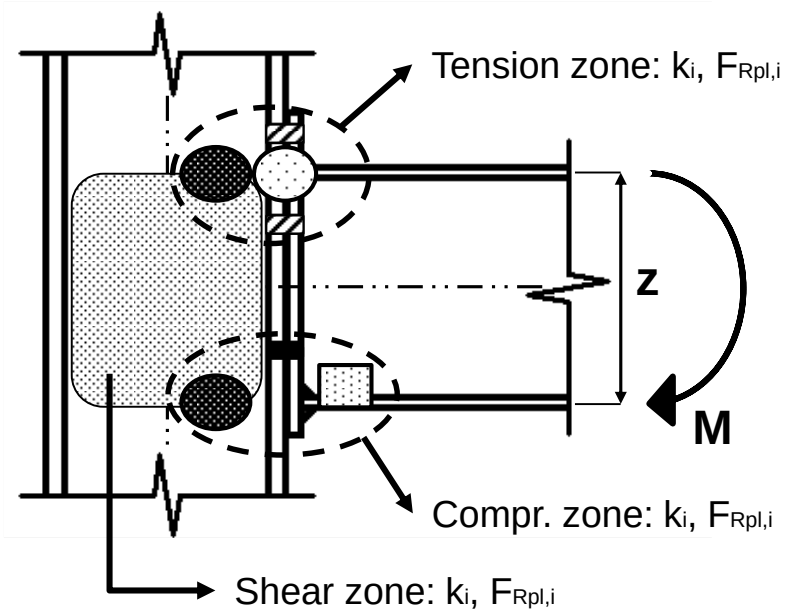
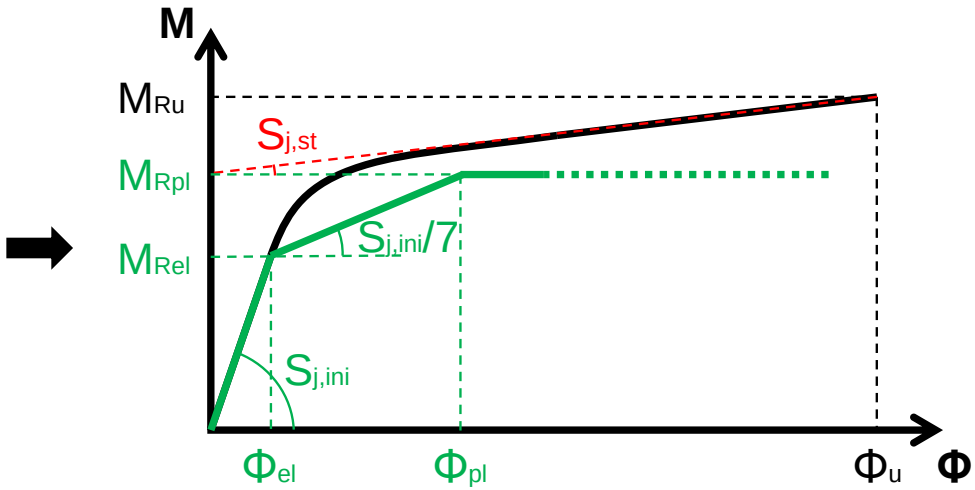
# Estimation of $S_{j,st}$

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$$M_{Rpl,lim} = 1{,}65 M_{Rpl}$$

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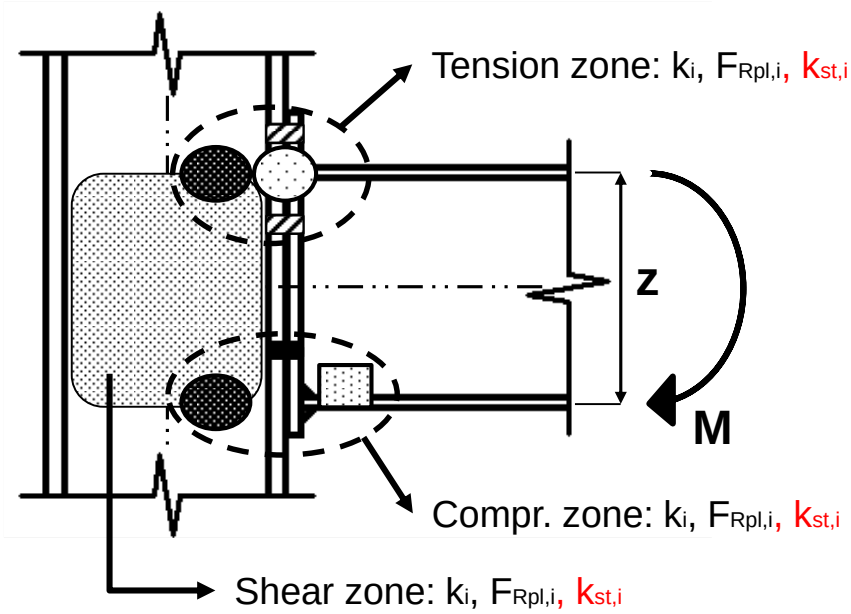


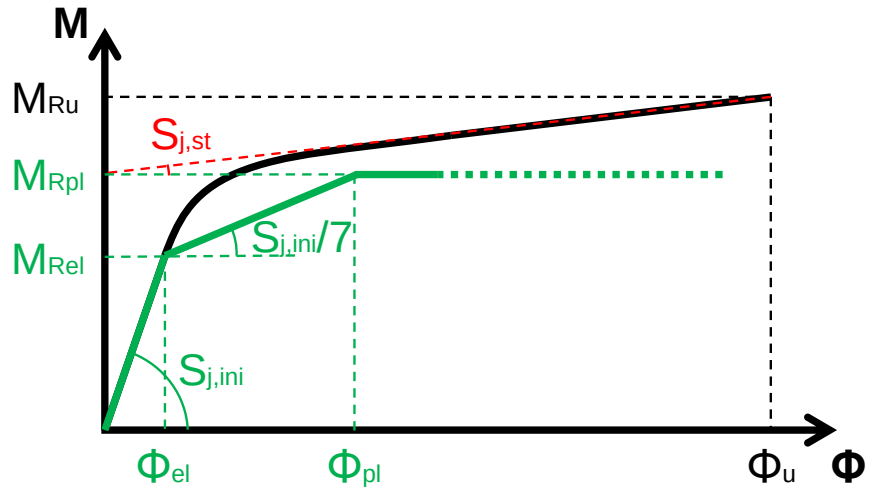


$$S_{j,st} = \frac{Ez^2}{\sum \frac{1}{k^*}}$$

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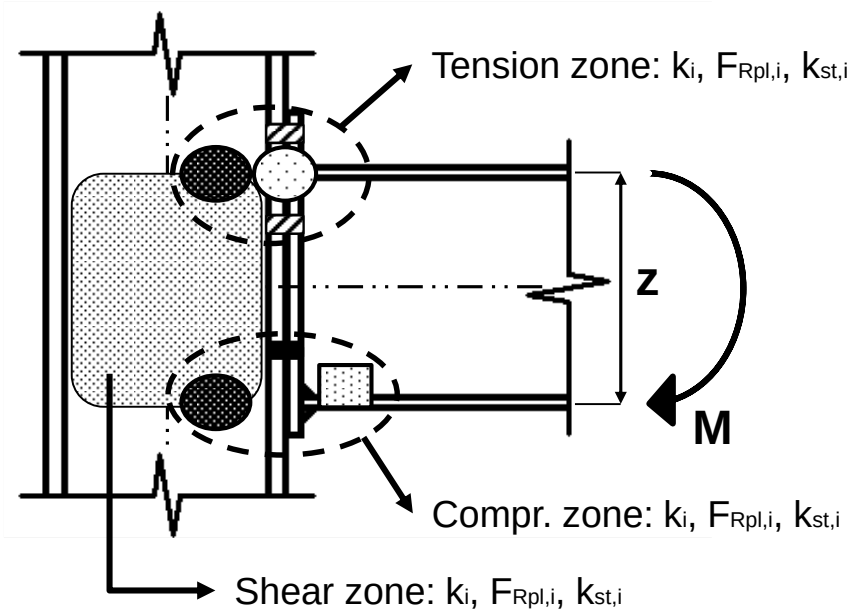
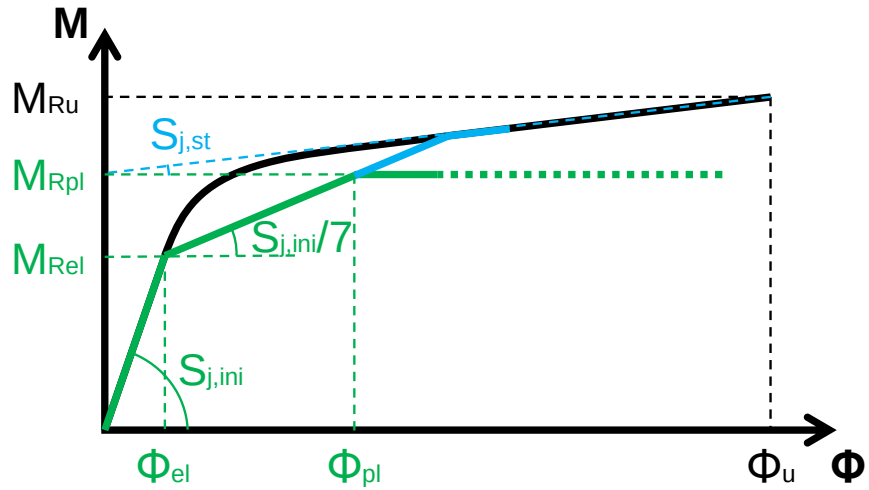
$$k_{st} = \begin{cases} \frac{E_{st}}{E} k_i & \rightarrow \text{components in tension/compression} \\ \frac{2(1+\upsilon)}{3} \frac{E_{st}}{E} k_i & \rightarrow \text{column web panel in shear} \end{cases}$$

# Estimation of $S_{j,st}$

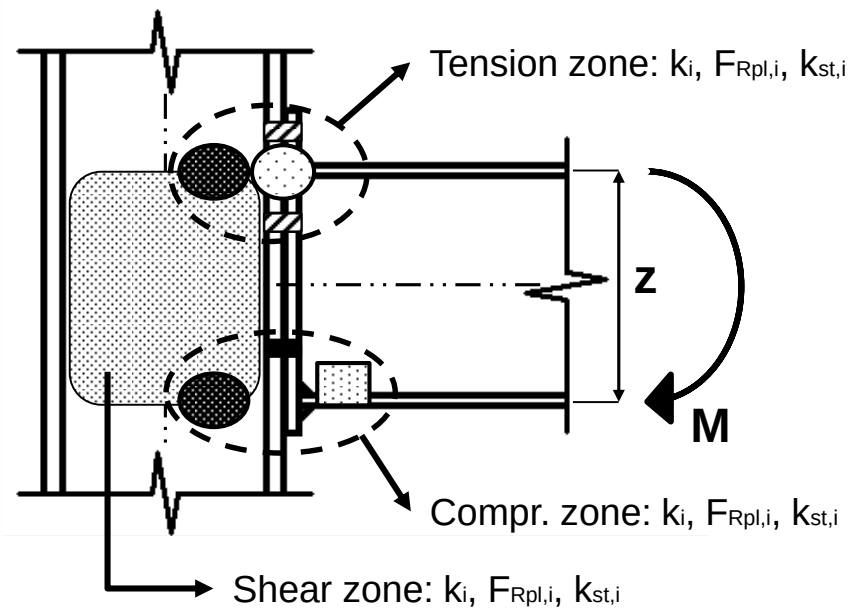


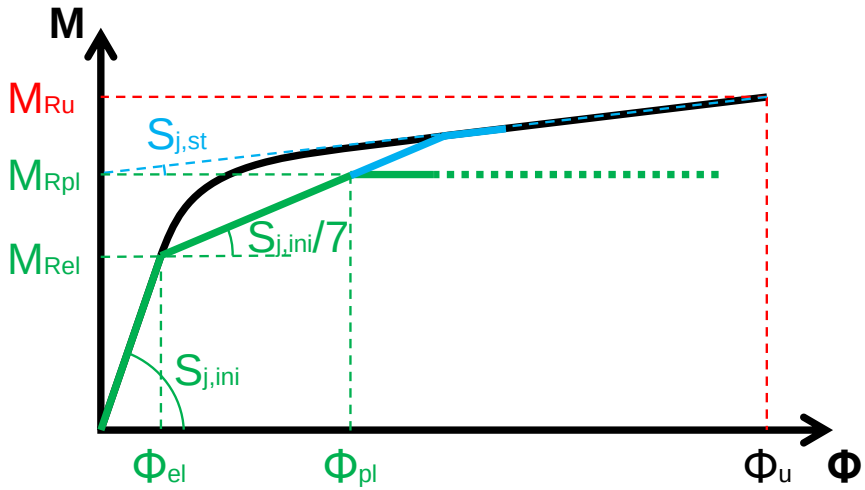




$$S_{j,st} = \frac{Ez^2}{\sum \frac{1}{k^*}}$$

$$\sum \frac{1}{k^*} = \sum_m \left(\frac{1}{k_{i,m}}\right)_{M_{Rpl,m} > M_{Rpl,lim}} + \sum_p \left(\frac{1}{k_{st,p}}\right)_{M_{Rpl,p} \leq M_{Rpl,lim}}$$

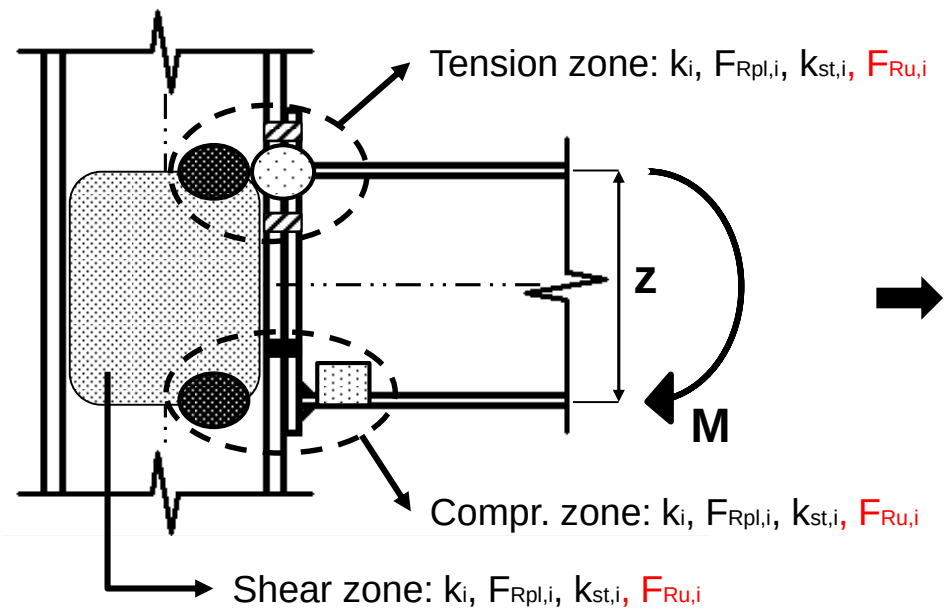
# Estimation of $M_{Ru}$

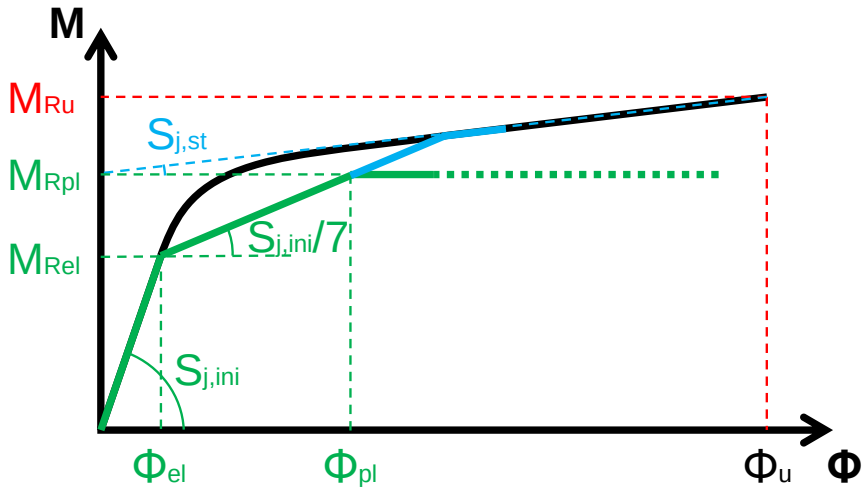



$$M_{Ru} = \min\left(F_{Ru,i}\right).z$$

# Estimation of $M_{Ru}$

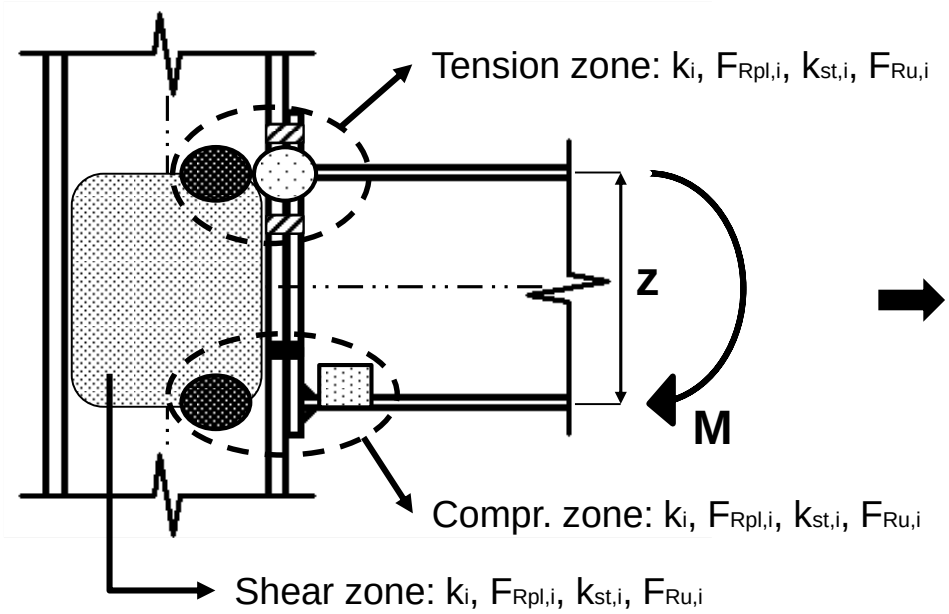


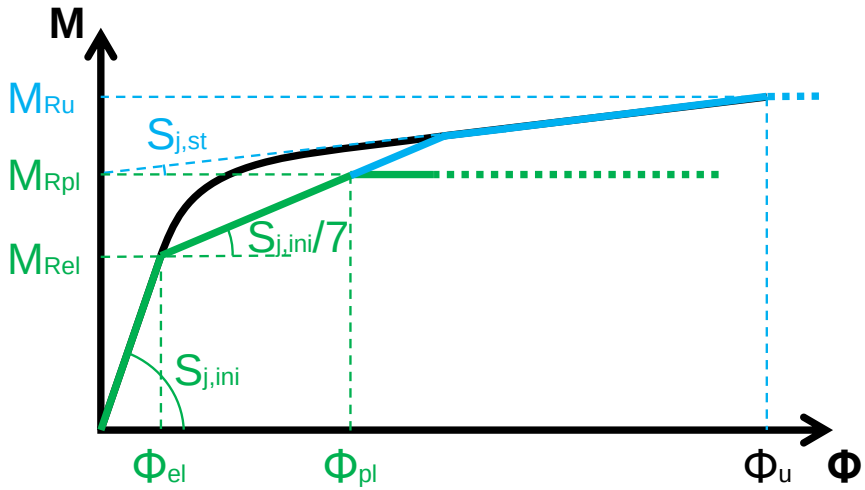




$$M_{Ru} = \min\left(F_{Ru,i}\right) . z$$

$F_{Rpl,i}$ ($f_y$) ↔ $F_{Ru,i}$ ($f_u$)

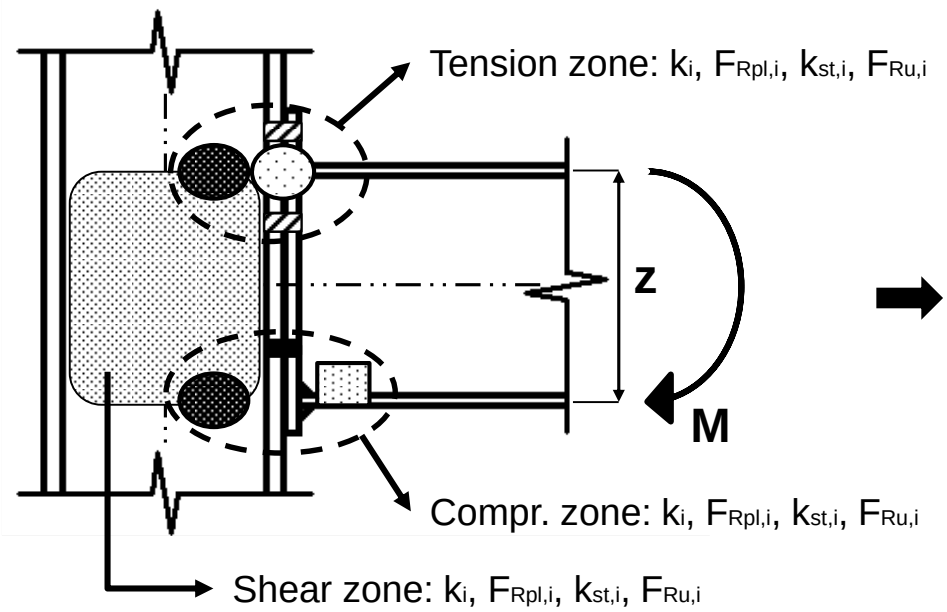
# Estimation of $M_{Ru}$

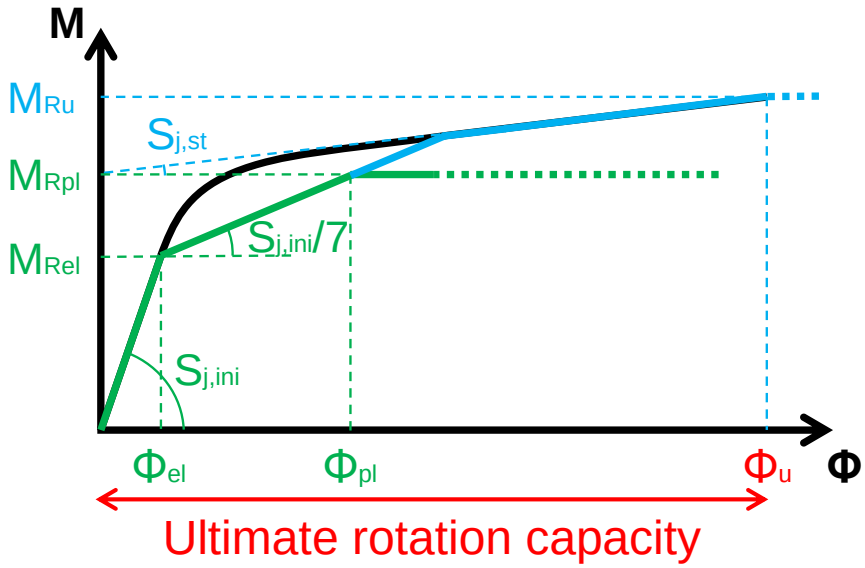



$$M_{Ru} = \min\left(F_{Ru,i}\right) . z$$

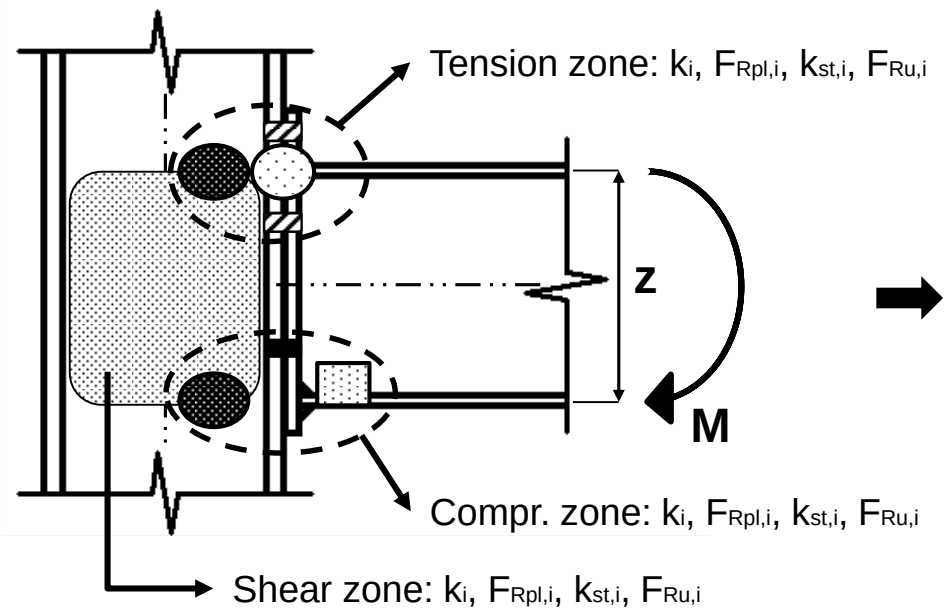
# Estimation of ductility

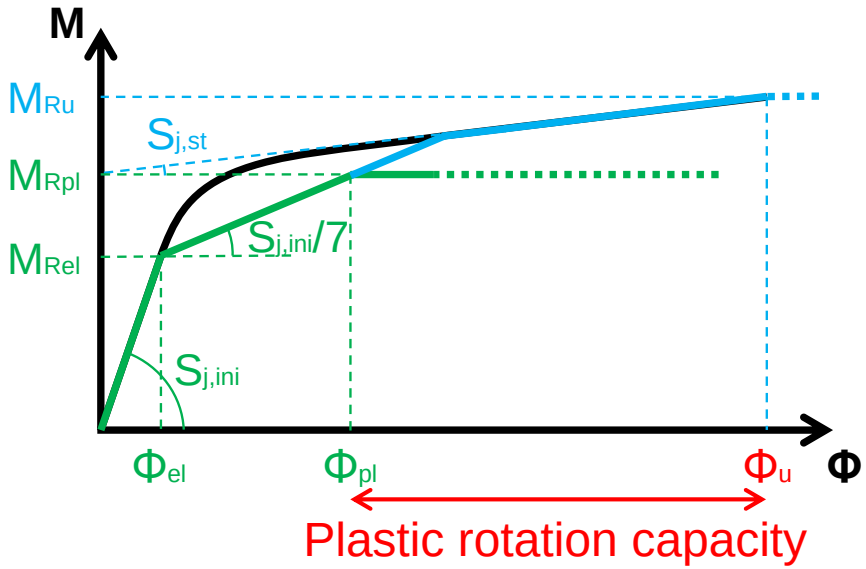



$$\Phi_u = \frac{M_{Ru} - M_{Rpl}}{S_{j,st}}$$

# Estimation of ductility

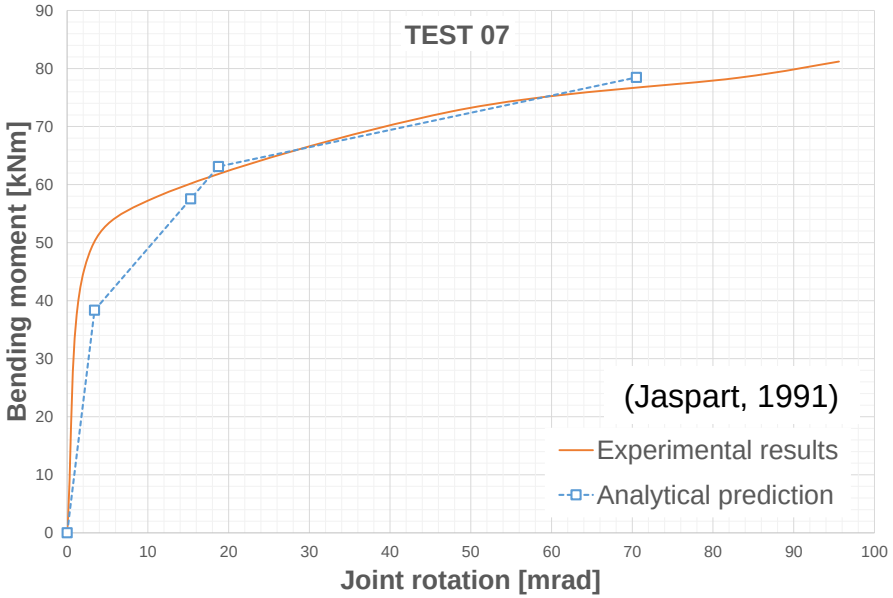


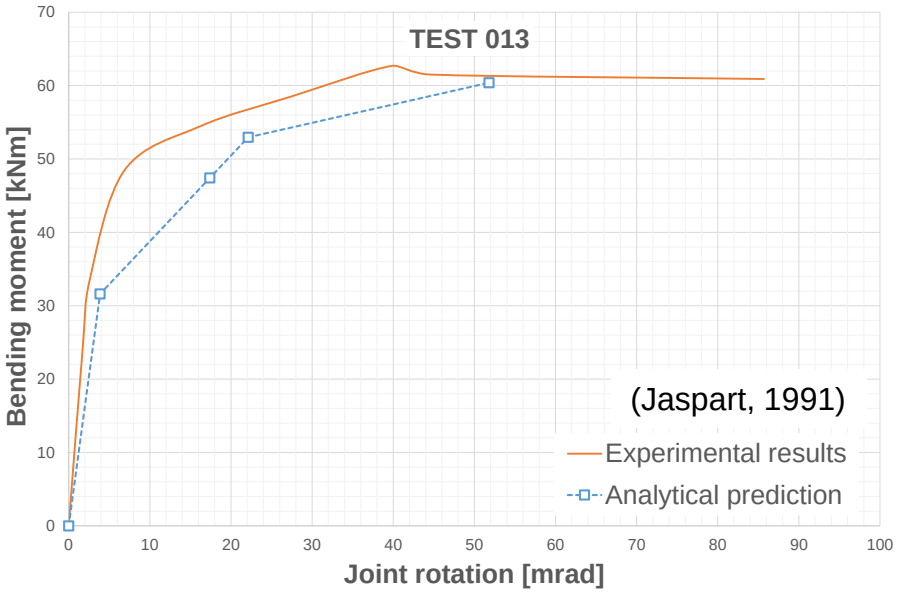



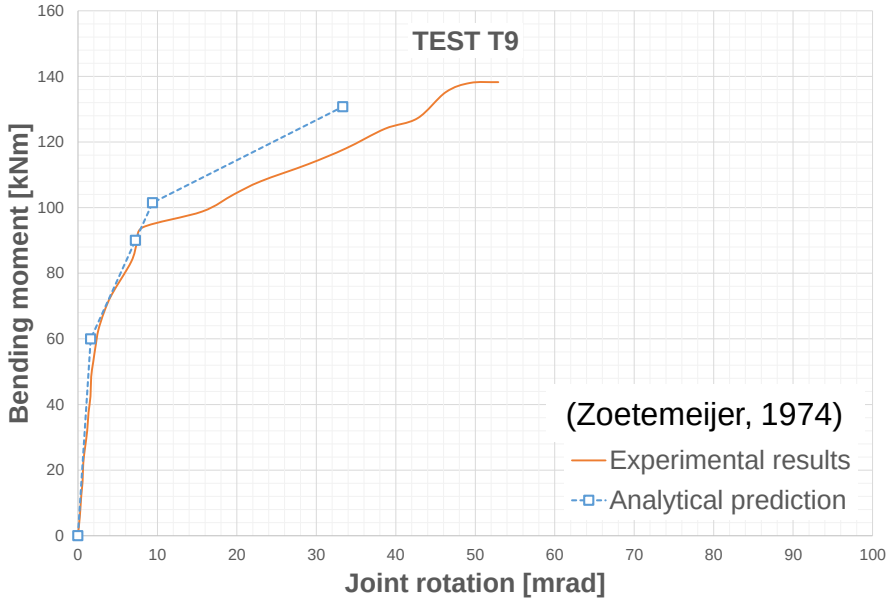

$$\Phi_u = \frac{M_{Ru} - M_{Rpl}}{S_{j,st}}$$

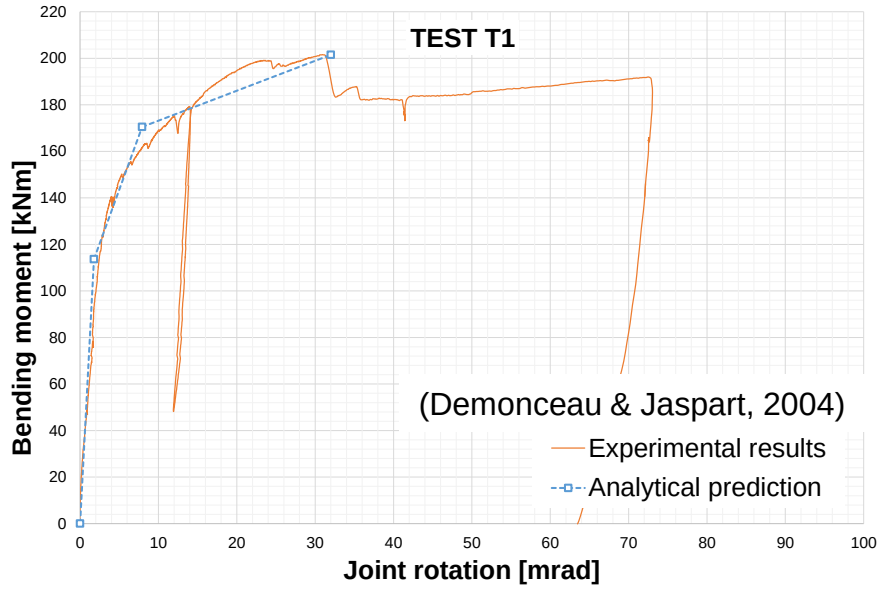
$$\Phi_u - \Phi_{pl} = \left(\frac{M_{Ru} - M_{Rpl}}{S_{j,st}}\right) - \left(\frac{M_{Rpl}}{S_{j,ini}/3}\right)$$

# Validation

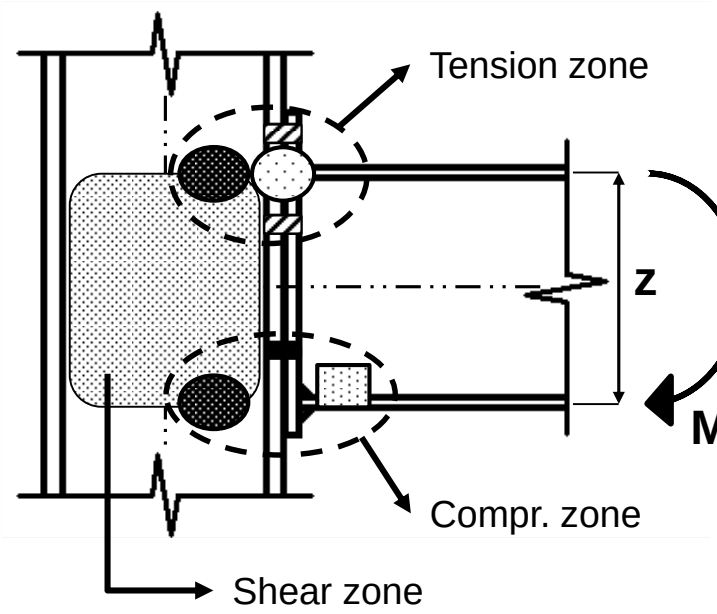

TEST 07
Bending moment [kNm]
Joint rotation [mrad]
(Jaspart, 1991)
Experimental results
Analytical prediction

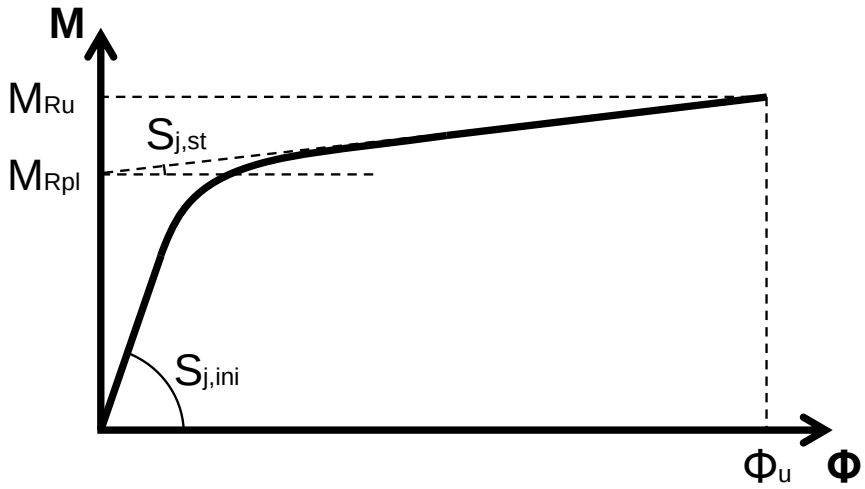

TEST 013
Bending moment [kNm]
Joint rotation [mrad]
(Jaspart, 1991)
Experimental results
Analytical prediction


TEST T9
Bending moment [kNm]
Joint rotation [mrad]
(Zoetemeijer, 1974)
Experimental results
Analytical prediction


TEST T1
Bending moment [kNm]
Joint rotation [mrad]
(Demonceau & Jaspart, 2004)
Experimental results
Analytical prediction

# Conclusions



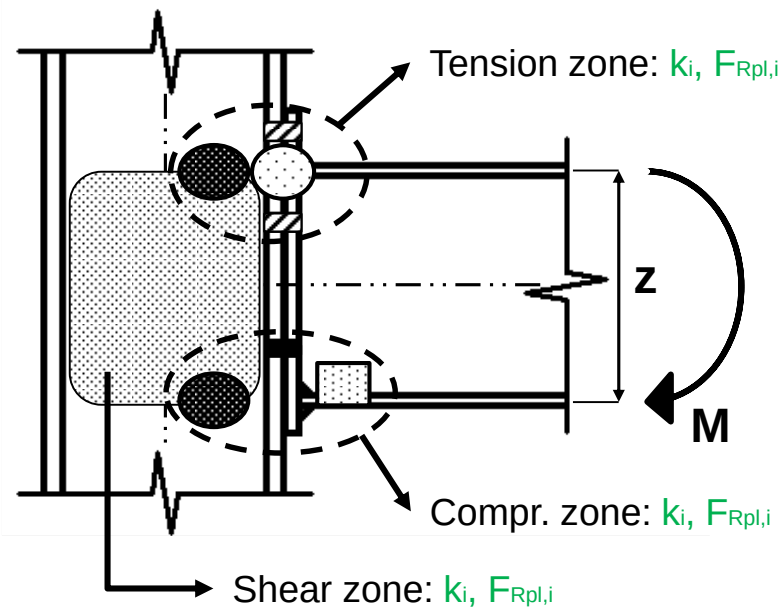



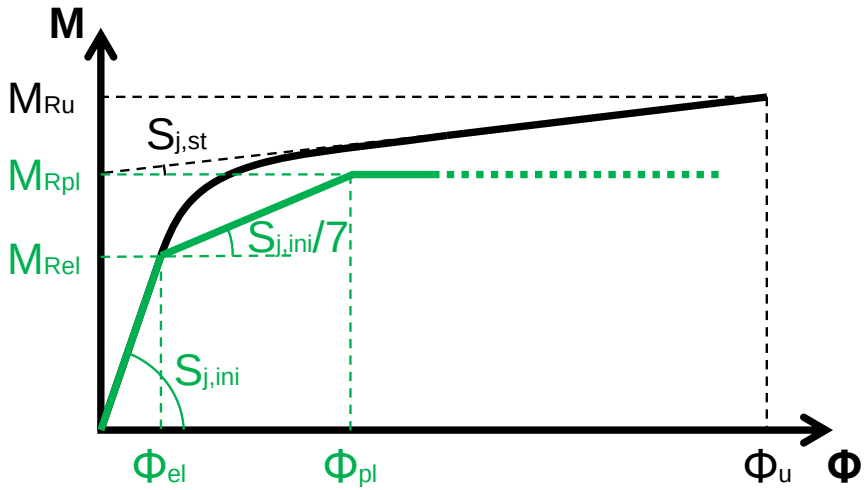

➔ 4 key parameters

- Initial stiffness
- Plastic bending resistance
- Post-plastic stiffness
- Ultimate bending resistance

# Conclusions

- **Eurocode 3, Part 1-8**



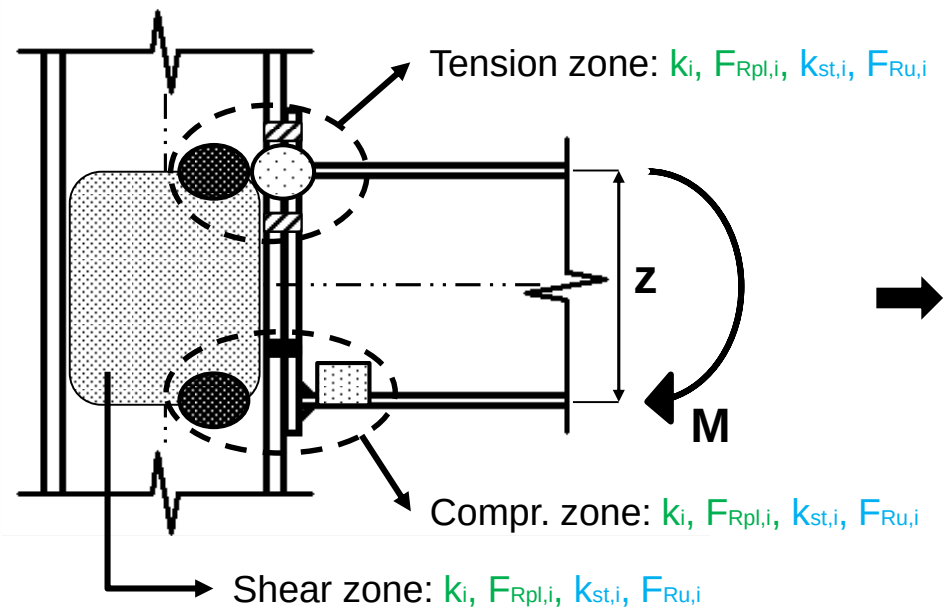



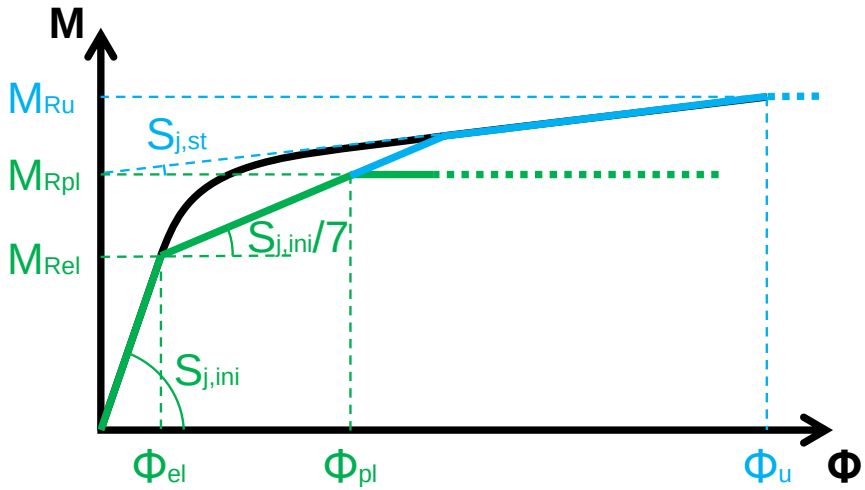

➔ 4 key parameters

- Initial stiffness $S_{j,ini} = \frac{Ez^2}{\sum_i 1/k_i}$
- Plastic bending resistance $M_{Rpl} = \min(F_{Rpl,i}) . z$
- Post-plastic stiffness
- Ultimate bending resistance

# Conclusions

- Eurocode 3, Part 1-8
- Present paper



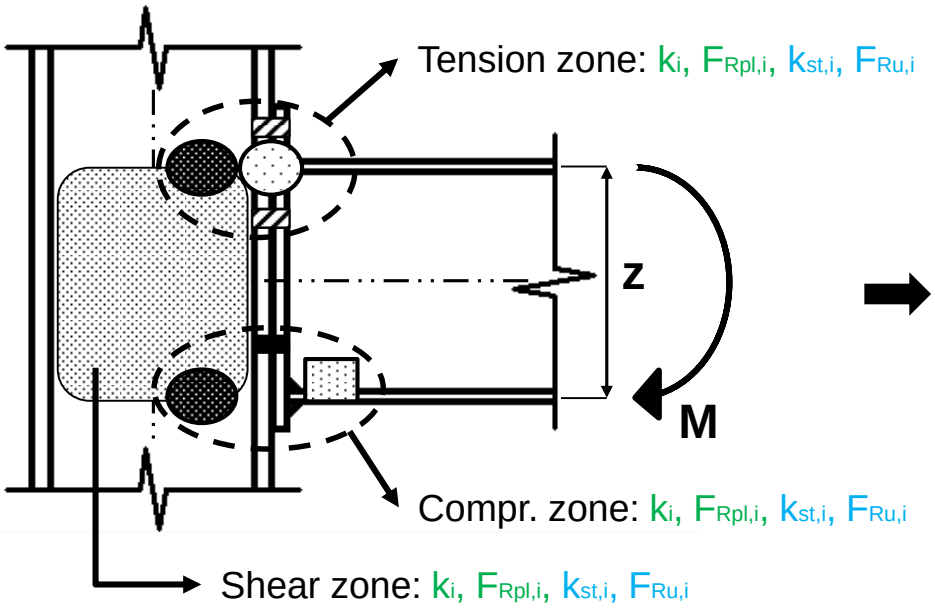



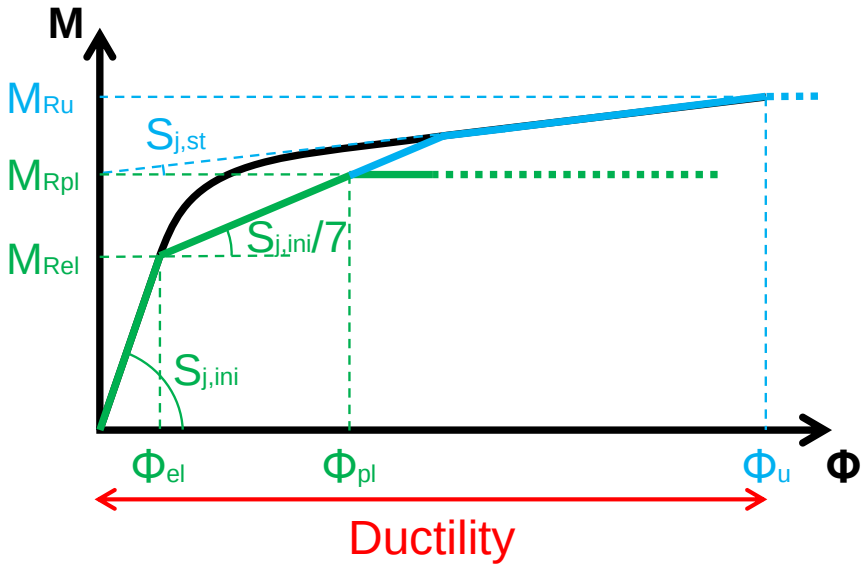

➔ 4 key parameters

- Initial stiffness $S_{j,ini} = \frac{Ez^2}{\sum_i 1/k_i}$
- Plastic bending resistance $M_{Rpl} = \min(F_{Rpl,i}) \cdot z$
- Post-plastic stiffness $S_{j,st} = \frac{Ez^2}{\sum_i 1/k^*}$
- Ultimate bending resistance $M_{Ru} = \min(F_{Ru,i}) \cdot z$

# Conclusions

- Eurocode 3, Part 1-8
- Present paper




➔ 4 key parameters

- Initial stiffness $S_{j,ini} = \frac{Ez^2}{\sum_i 1/k_i}$
- Plastic bending resistance $M_{Rpl} = \min(F_{Rpl,i}) \cdot z$
- Post-plastic stiffness $S_{j,st} = \frac{Ez^2}{\sum_i 1/k^*}$
- Ultimate bending resistance $M_{Ru} = \min(F_{Ru,i}) \cdot z$

➔ Ultimate rotation capacity: $\Phi_u = \frac{M_{Ru} - M_{Rpl}}{S_{j,st}}$

LIÈGE université
School of Engineering

# Thank you!
# Questions?

Jean-Pierre Jaspart
Adrien Corman
Jean-François Demonceau

SDSS 2019 Prague 11-13 September



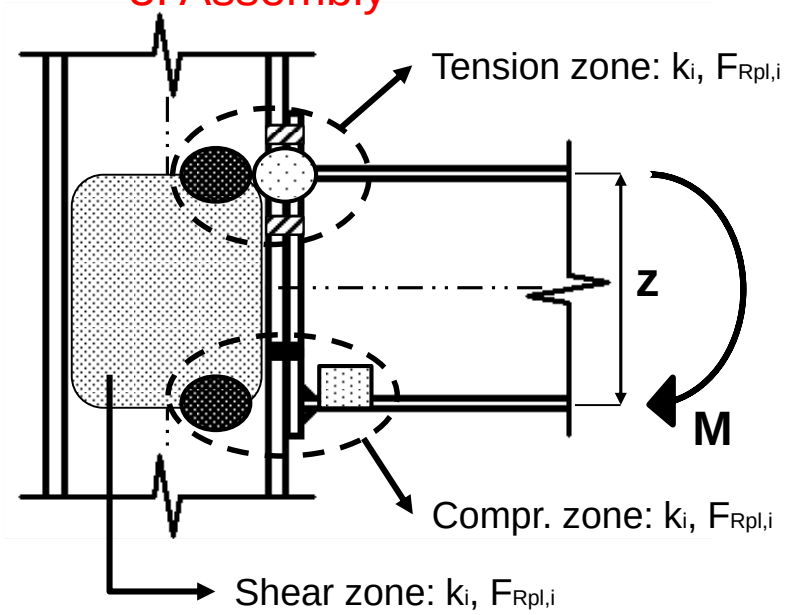
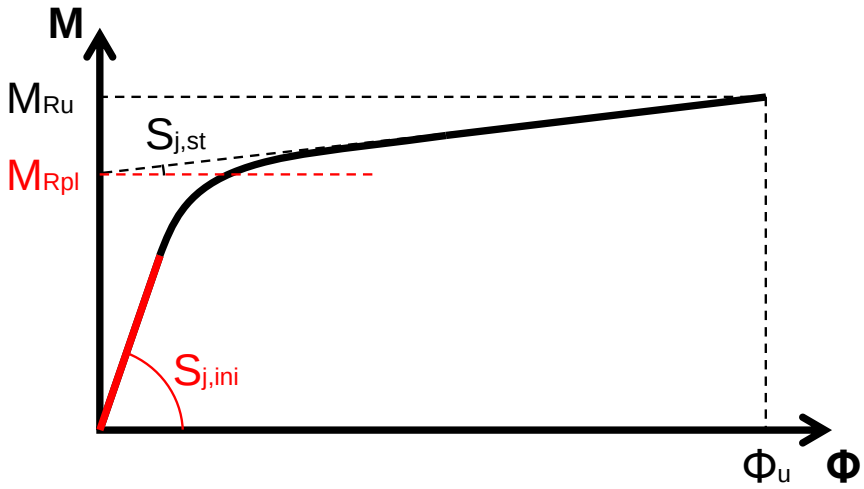
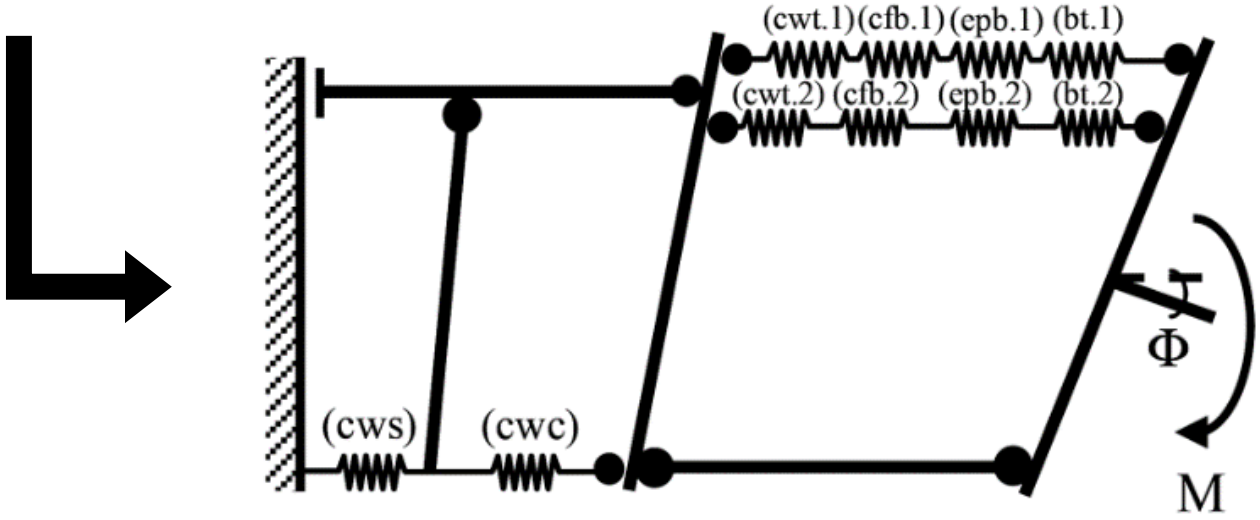
UEE
Urban & Environmental Engineering

# References


- Jaspart, J.-P., 1991. « *Etude de la semi-rigidité des nœuds poutre-colonne et son influence sur la résistance et la stabilité des ossatures en acier* », PhD dissertation , Liège University.

- Zoetemeijer, P., 1974. « *A design method for the tension side of statically loaded, bolted beam-to-column connections* ». Heron, Vol. 20, N°1, 1974)

- Demonceau, J.-F. & Jaspart, J.-P., 2004. « *Experimental and analytical investigations on single-sided composite joint configuration* », 5th International PhD Symposium in Civil Engineering, Balkema, pp. 341-349.

# Introduction: the component method

## 3. Assembly