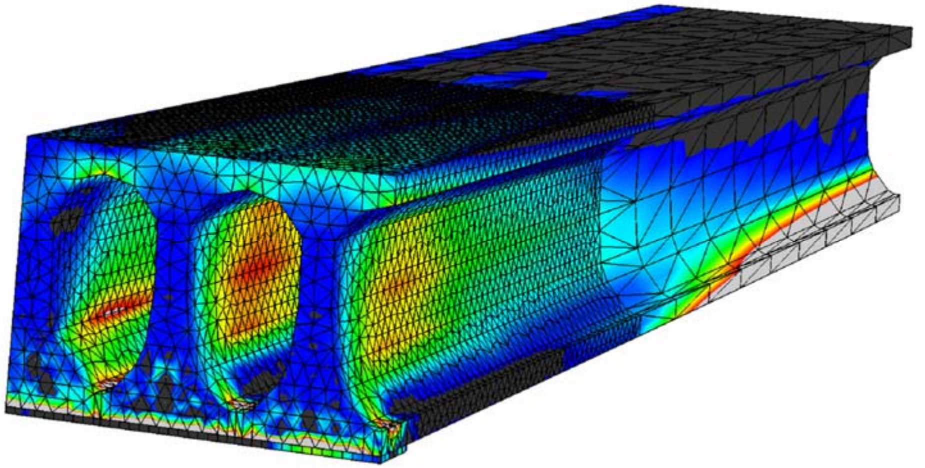
Parametric Study of Web Shear Cracking

Based on the Master's Project *"Improved Design Method for Web Shear Tension Failure in Hollow Core Units"* in the International Master's Programme Structural Engineering

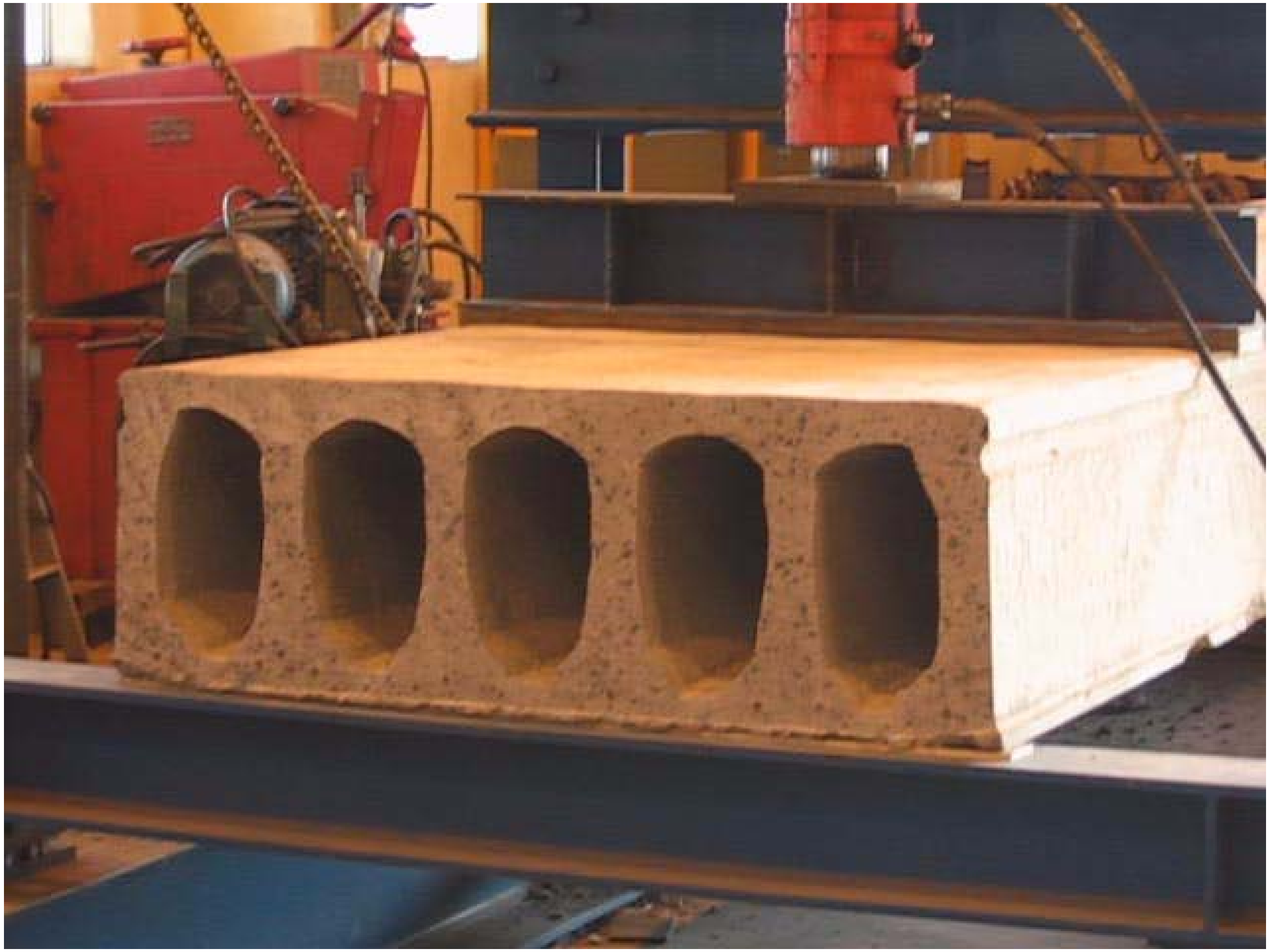


Lars Rettne

A COMPANY OF CONSOLIS

STRÄNGBETONG

Web Shear Tension Failure in Hollow Core Units



Problem Description

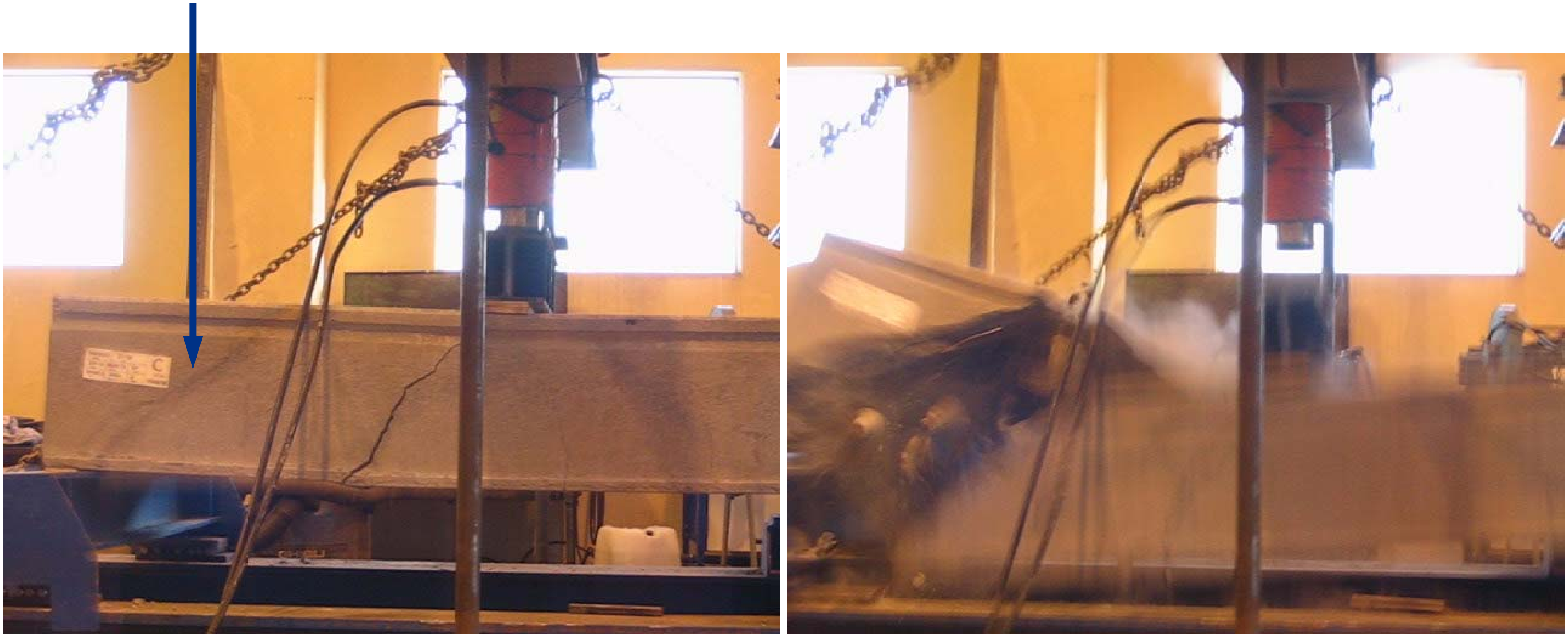
”In the present standard the guidance on how to calculate shear tension capacity is not detailed enough and a more precise method is needed”

Aim of the Project

- Create finite element (FE) models of single hollow core units
- Perform calculations using Yang's method of single hollow core units
- Compare the shear capacity and location of the critical point between the two methods

Critical Point

= The point where web shear cracking starts



Collaboration

- This project was initiated by Strängbetong, which is the largest hollow core unit producer in Sweden

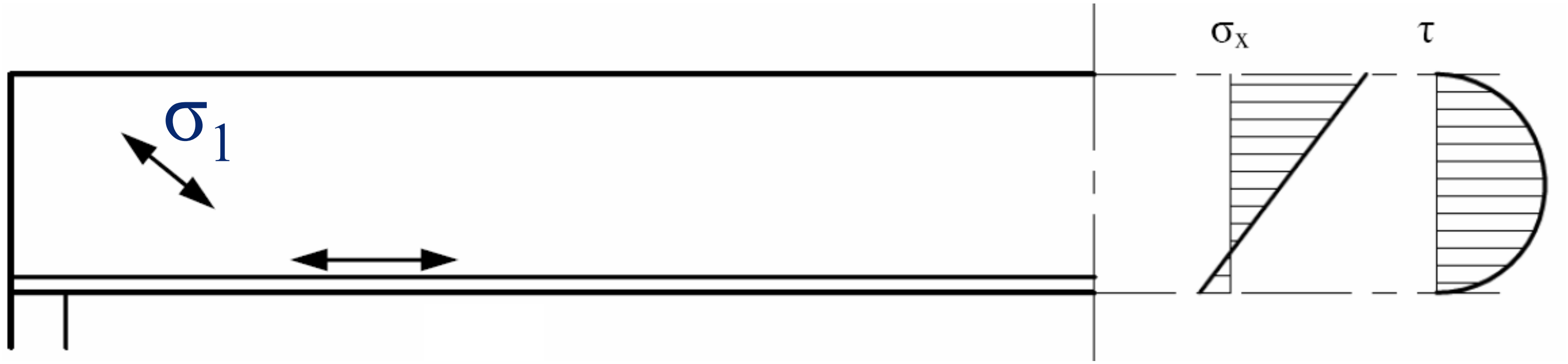
Hollow Core Floors

Hollow core floors consist of hollow core units

Hollow core unit

Web Shear Tension Failure in Hollow Core Units

Uncracked cross-section $\sigma_1 < f_{ctm}$

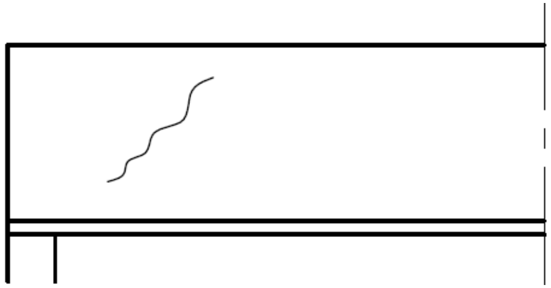


σ_1 = Principal stress

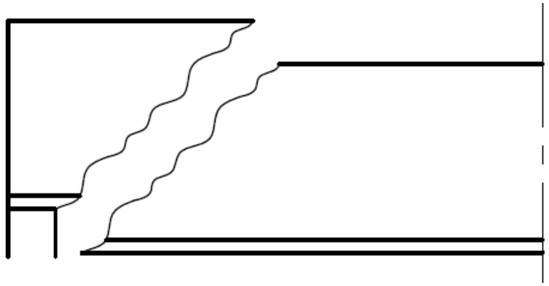
f_{ctm} = Mean tensile strength of concrete

Web Shear Tension Failure in Hollow Core Units

Web shear cracking $\sigma_1 = f_{ctm}$



Immediately failure (brittle)

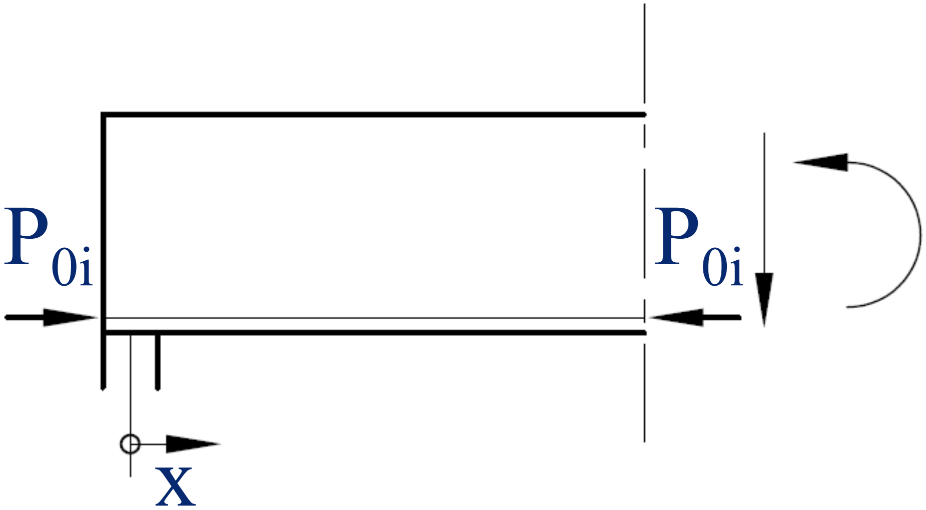


Shear Capacity with Respect to Web Shear Tension Failure

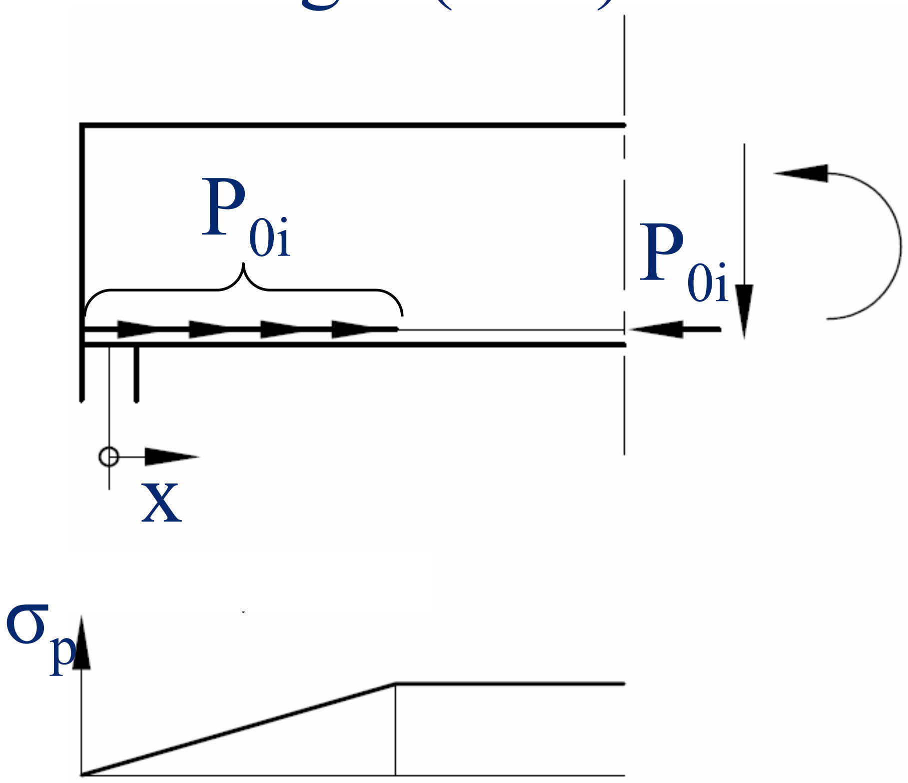
- Failure when the concrete tensile strength is reached, $\sigma_1 = f_{ctm}$
- The principal stresses are dependent of the shear and normal stresses, $\sigma_1 = \sigma_1(\sigma_x, \tau)$

Shear Stress Calculations in Prestressed Members

Traditional (present)



Yang's (new)



Shear Stress Calculations in Prestressed Members

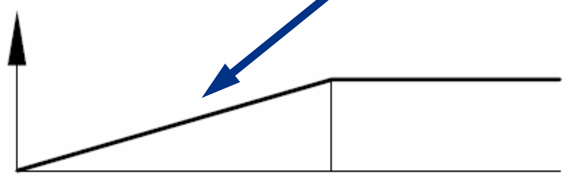
Traditional (present)

$$\tau(x_{cp}, z_{cp}) = \frac{S(z_{cp})V(x_{cp})}{I_{\mathrm{I}} b_w(z_{cp})}$$

Yang's (new)

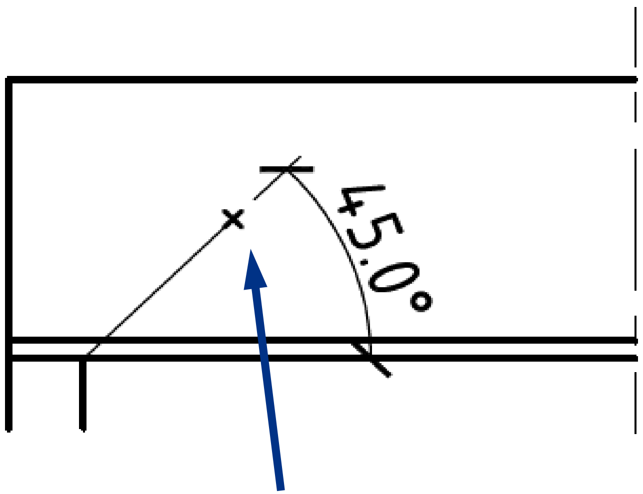
$$\tau(x_{cp}, z_{cp}) = \frac{S(z_{cp})V(x_{cp})}{I_{\mathrm{I}} b_w(z_{cp})} + f\left(\frac{dP_{0i}}{dx}\right)$$

The shape is taken into account



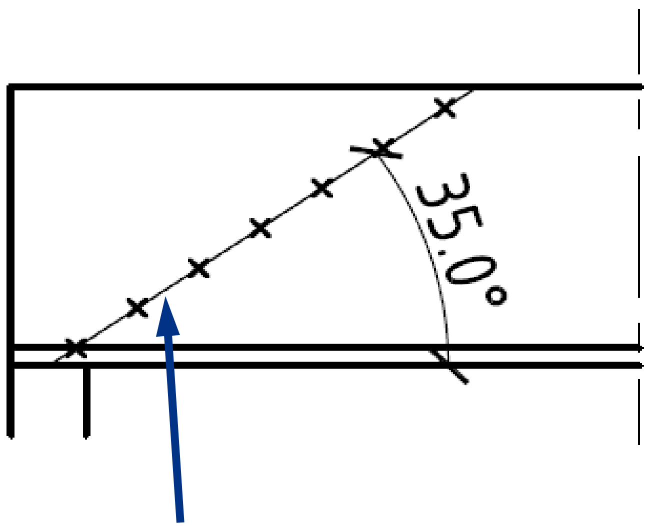
Shear Capacity Calculations in Prestressed Members

Traditional (present)



Assumed location of critical point

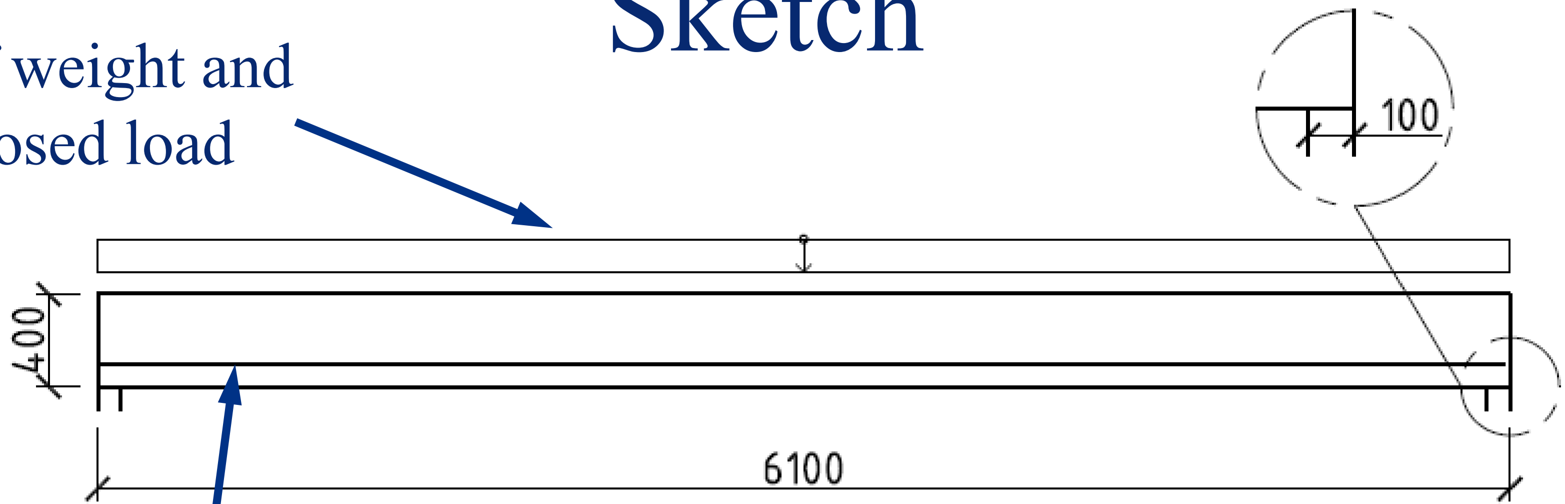
Yang's (new)



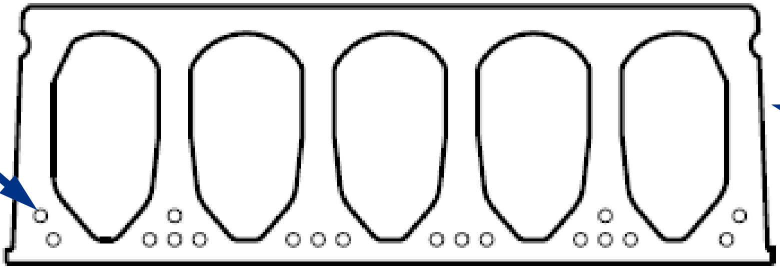
Assumed location of critical point somewhere along line

Reference Case – Principal Sketch

Self weight and imposed load



Prestressing strand



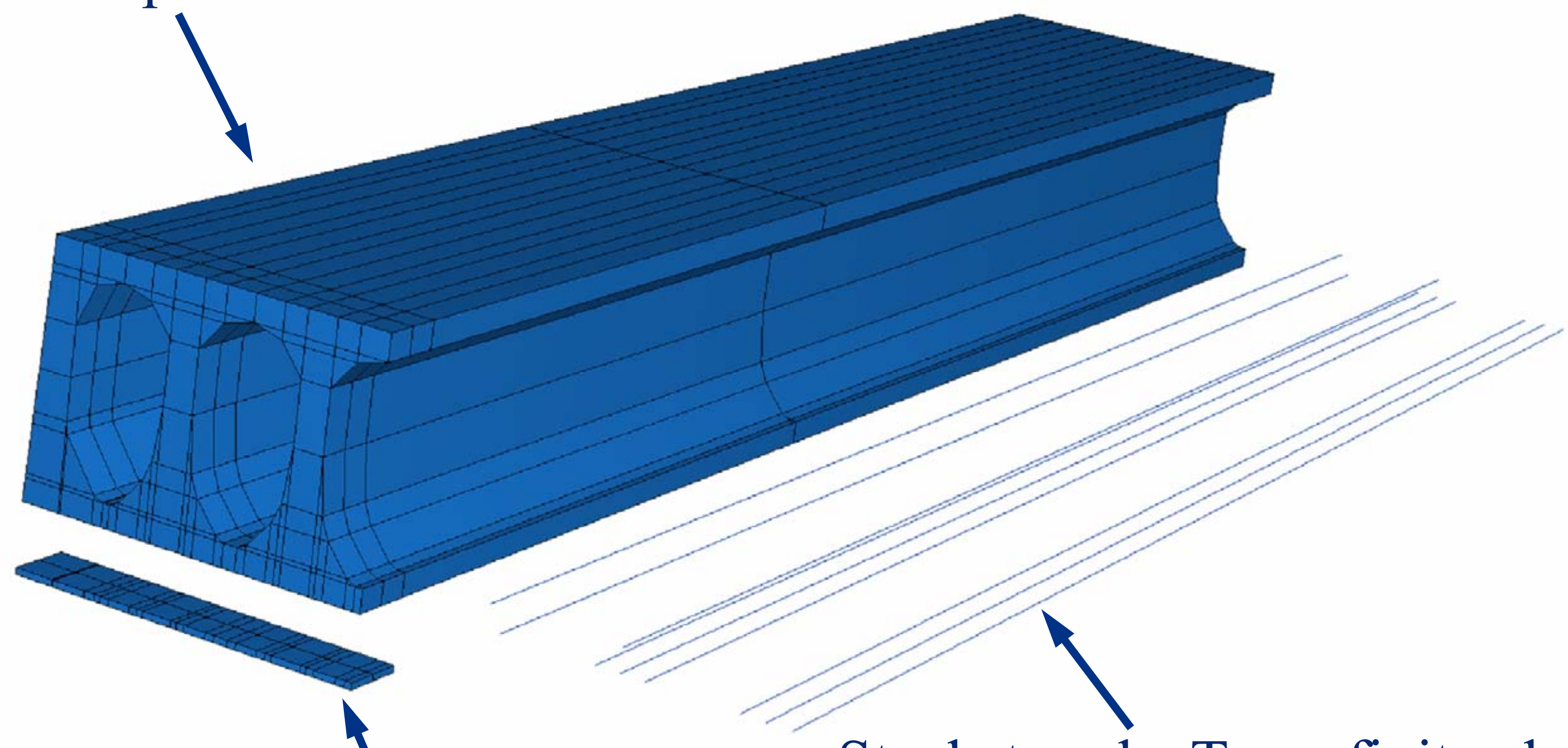
Cross-section

Parametric Study

- Prestressing strand arrangement
- Prestressing strand amount
- Prestress
- Concrete strength class
- Concrete strength at strand release
- Prestress transfer function
- Type of cross-section

FE Model

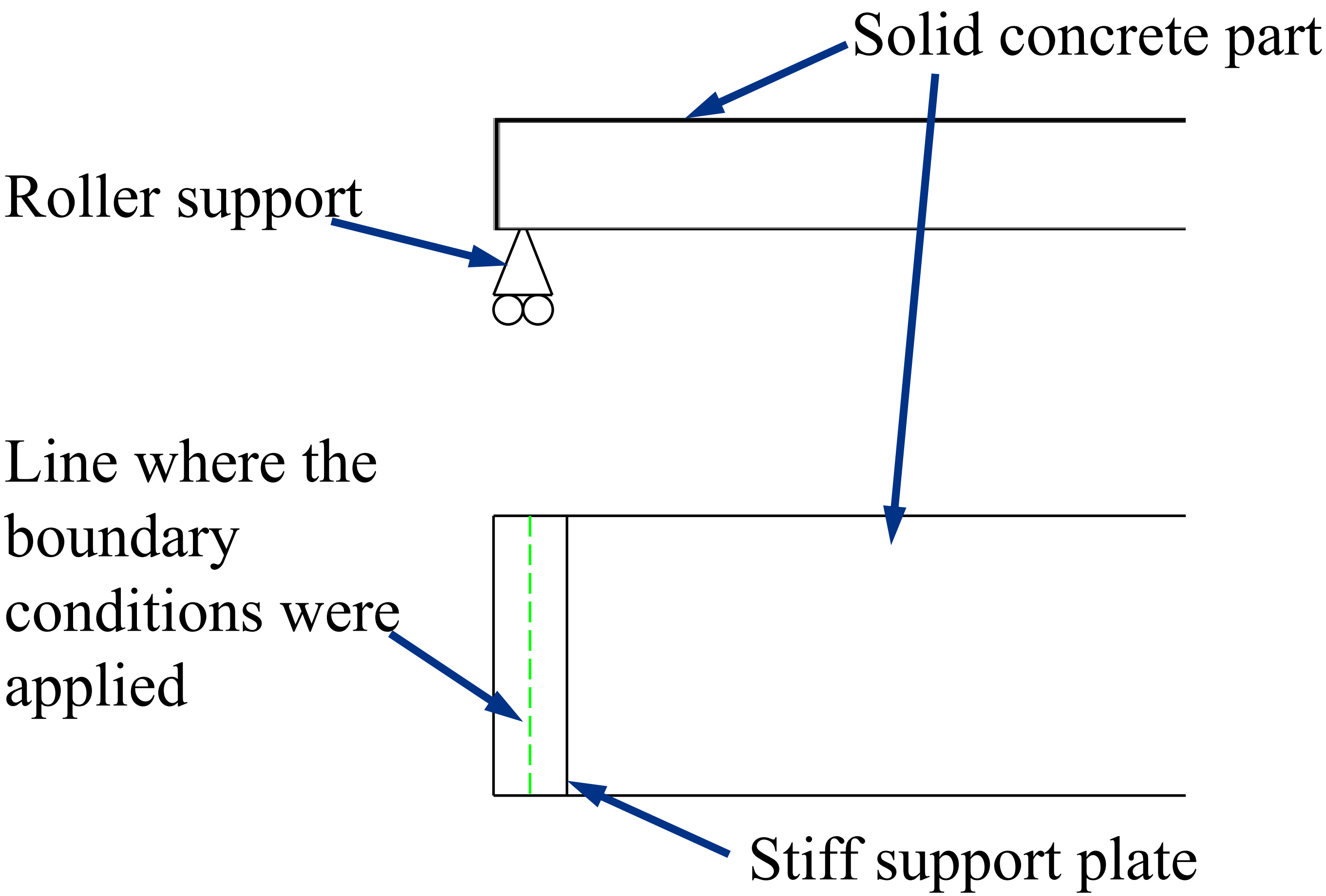
Concrete part: Solid finite elements



Steel strands: Truss finite elements

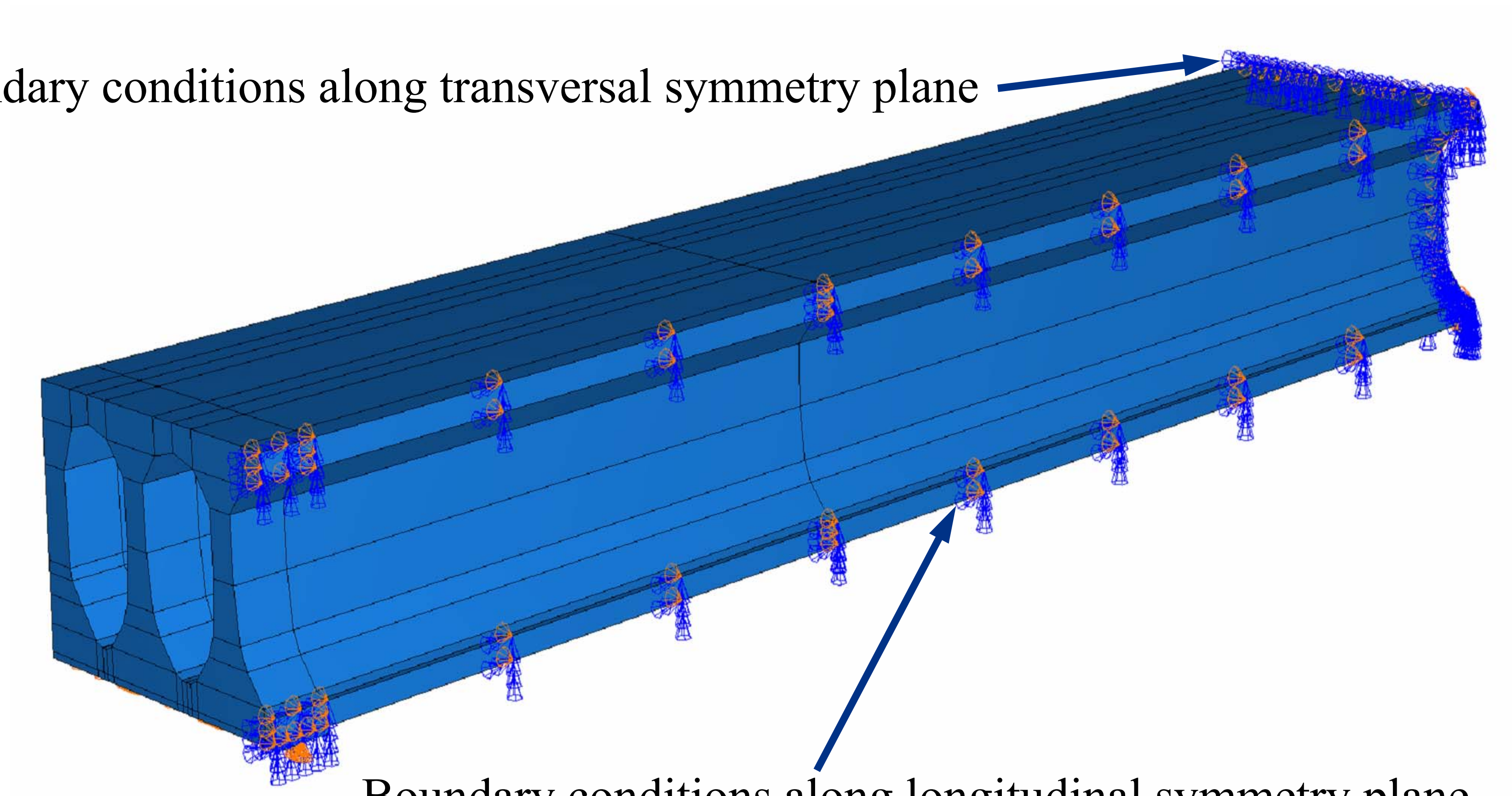
Stiff steel support plate: Solid finite elements

FE Model - Boundary Conditions



FE Model - Boundary Conditions: Symmetry Planes

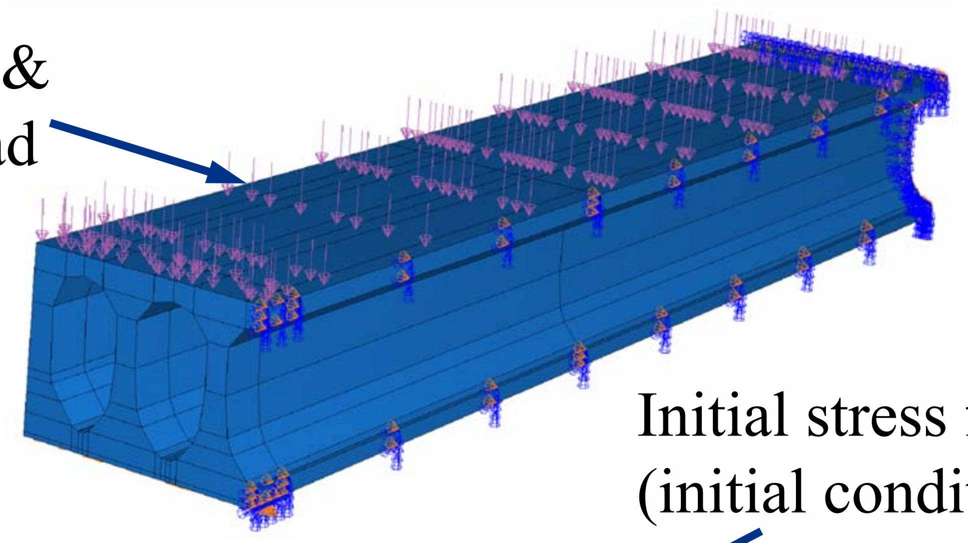
Boundary conditions along transversal symmetry plane



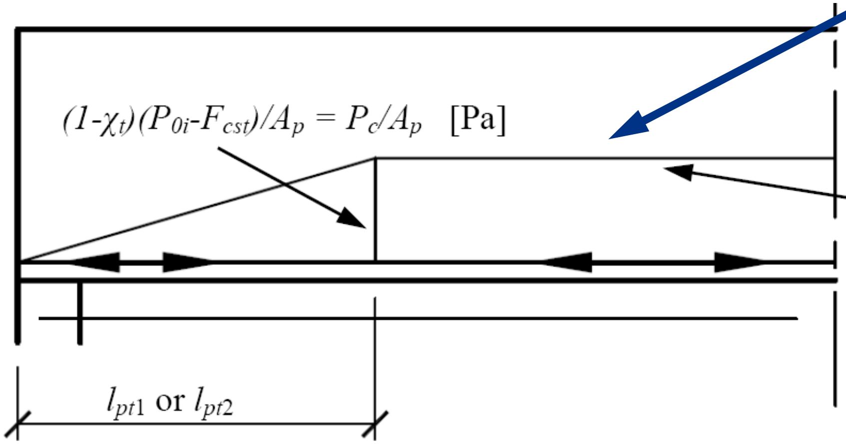
Boundary conditions along longitudinal symmetry plane

FE Model - Loads

Self weight & Imposed load (pressure)

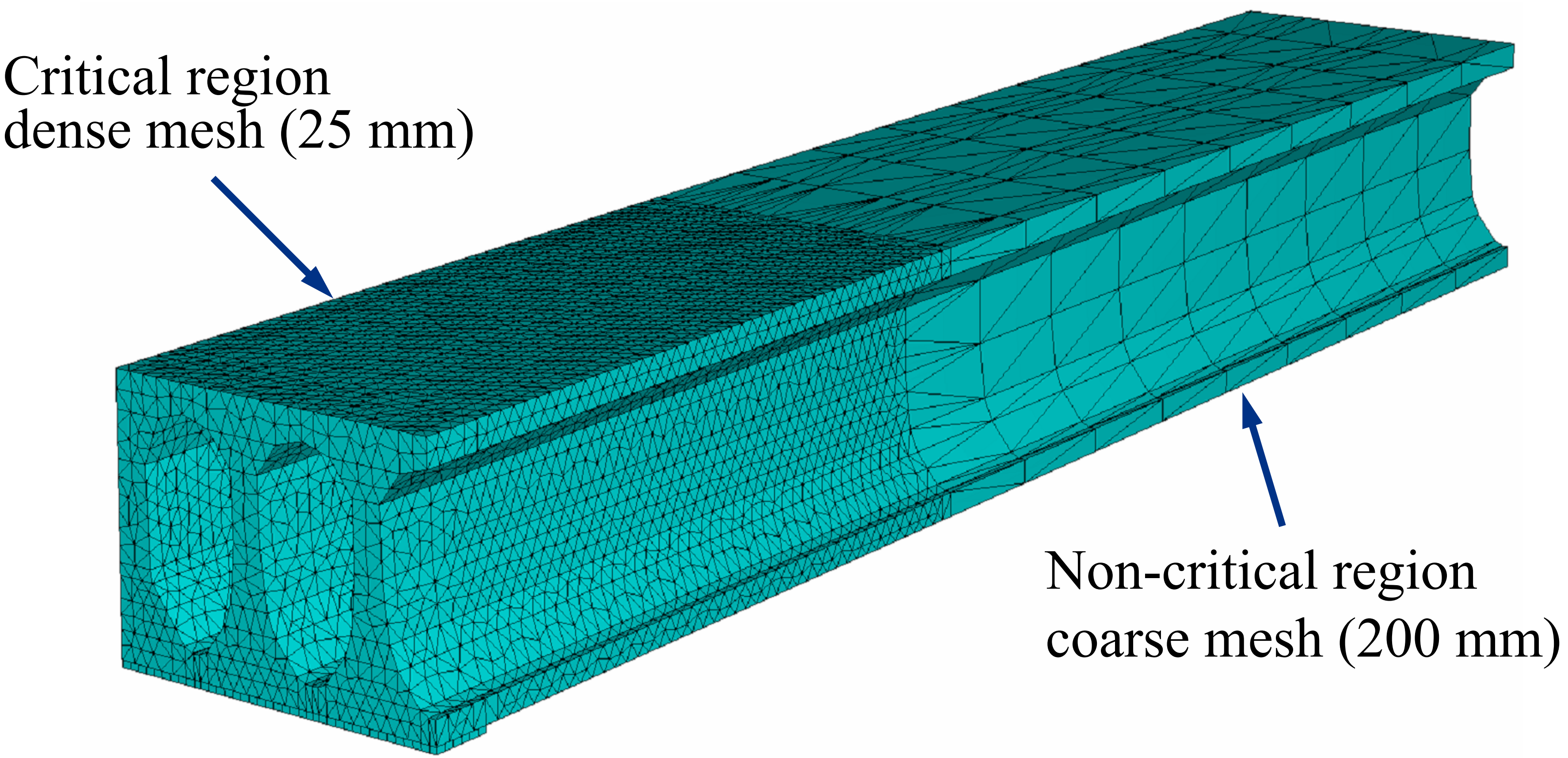


Initial stress from prestressing (initial condition)



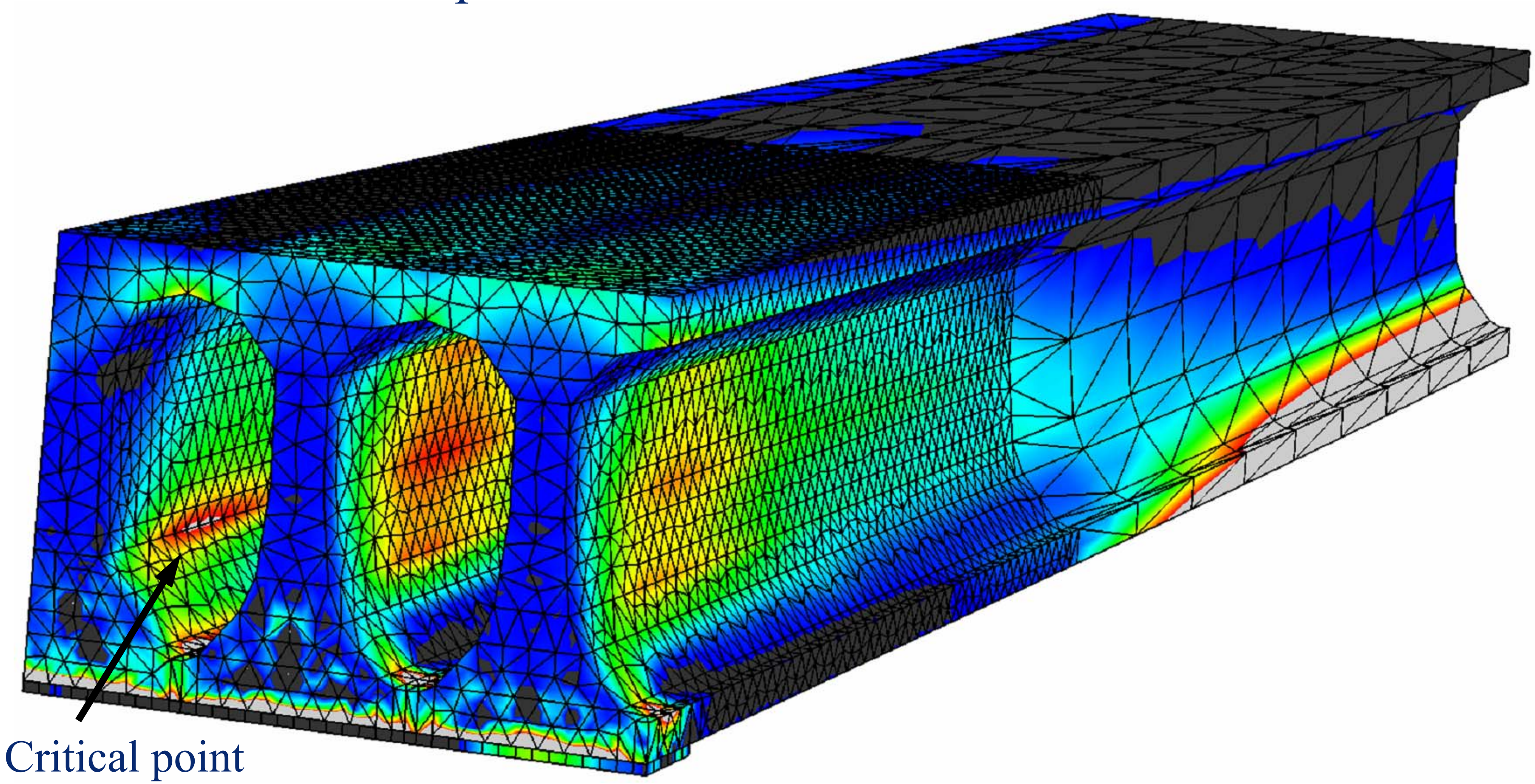
Note that this is the stress distribution in the prestressing strands before "release", i.e. before interacting with the concrete in the model.

FE Model - Mesh



Results – FE Method

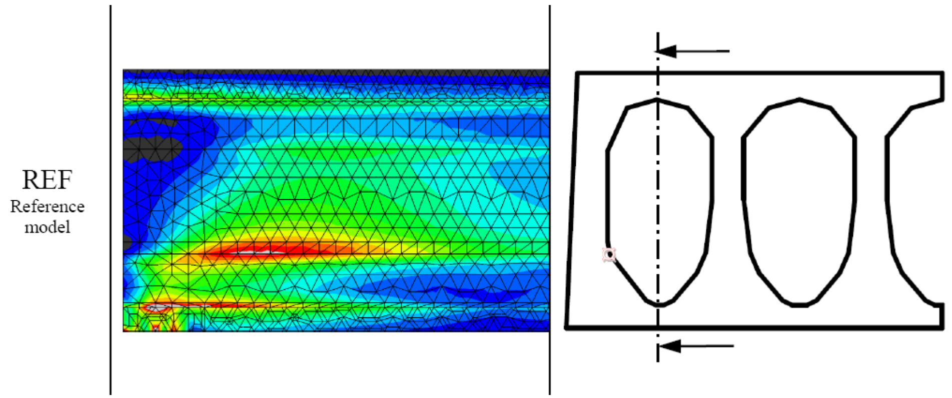
Principal Stresses in the Reference case



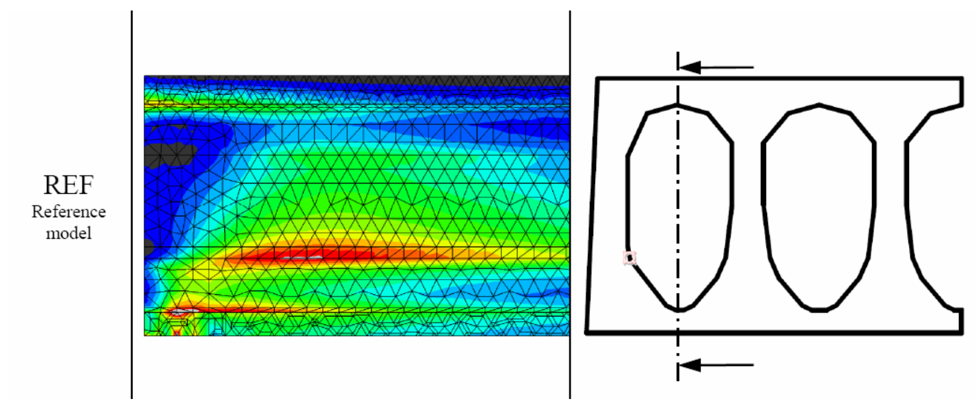
Results – FE Method

Stress Field in the Reference Case

Short term response
(28 days age)



Long term response
(57 years age)



Results – FE Method

Stress Field in the Reference Case

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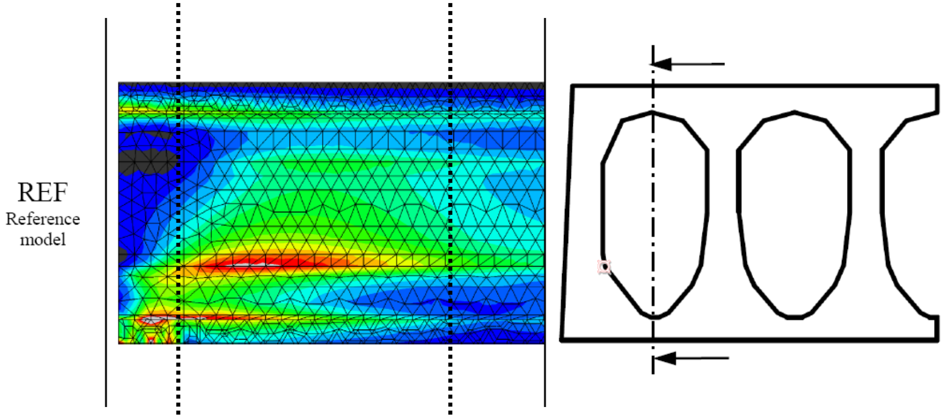

Long term response
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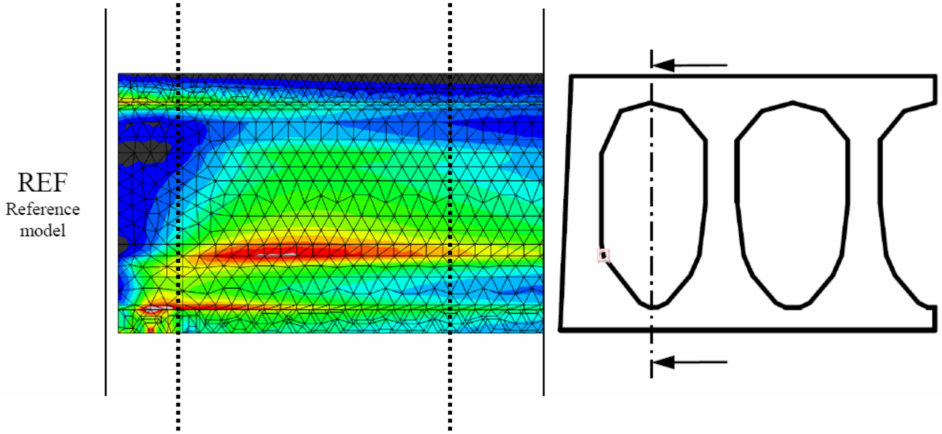
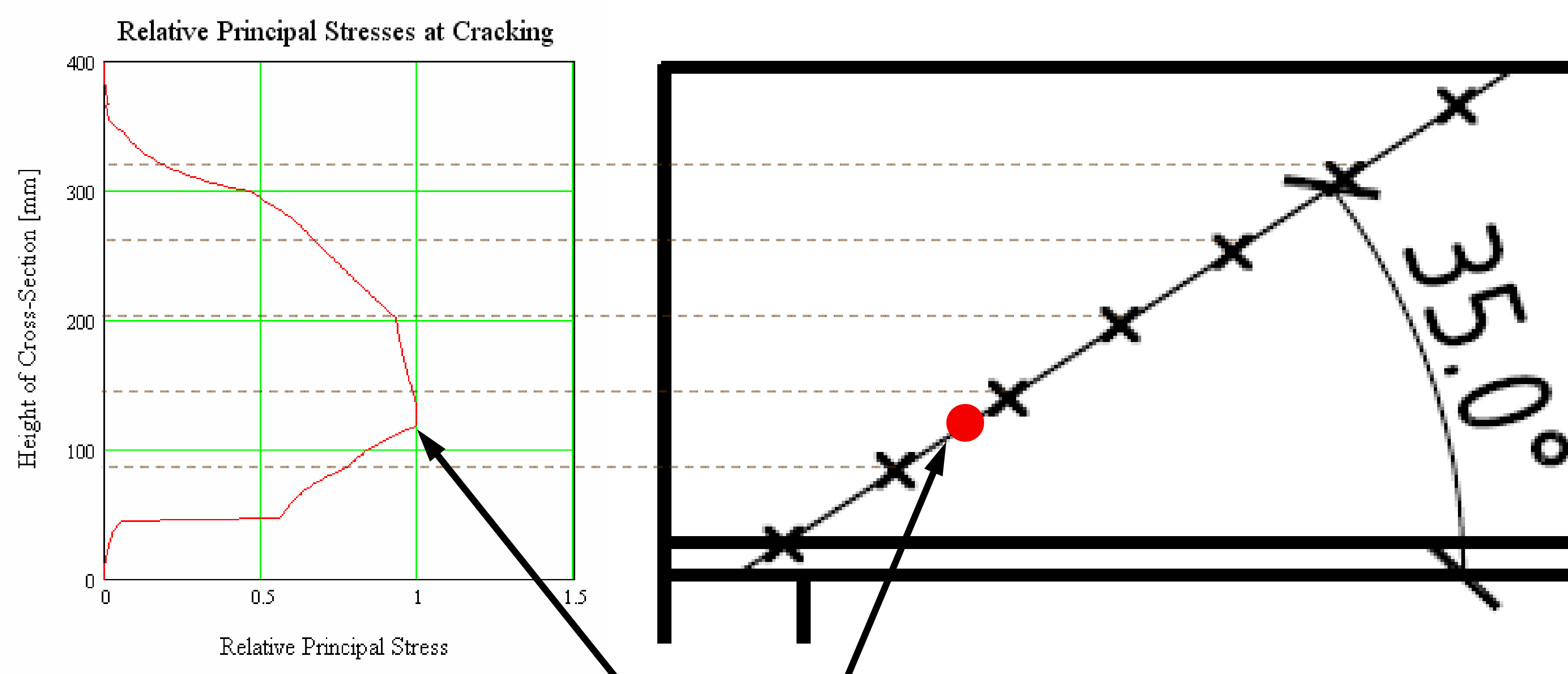


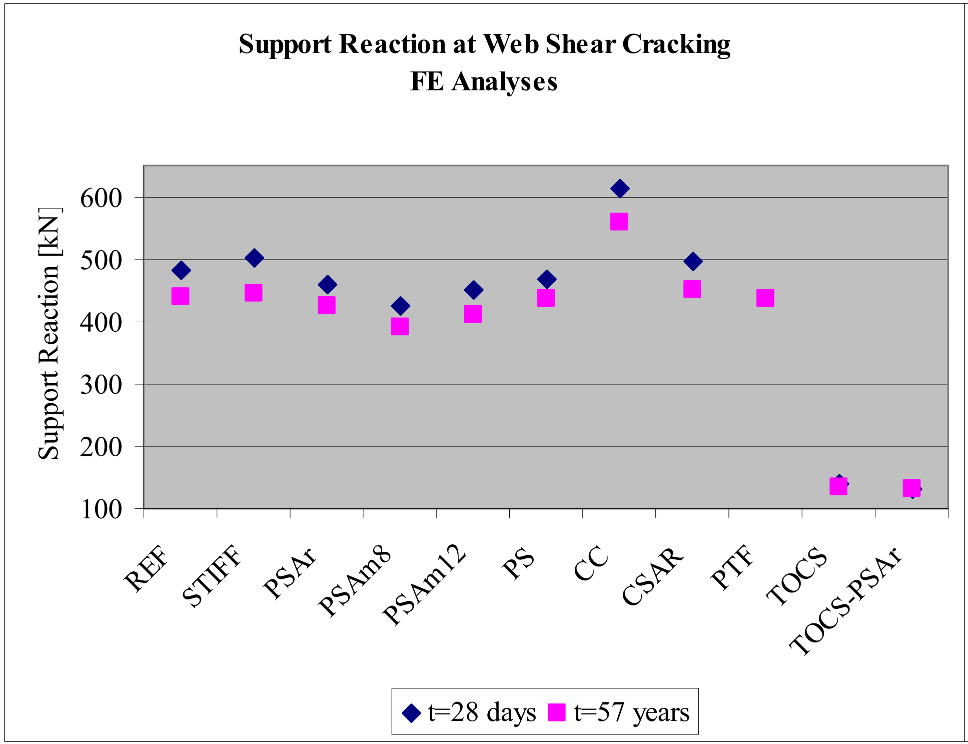
Results – Yang's Method

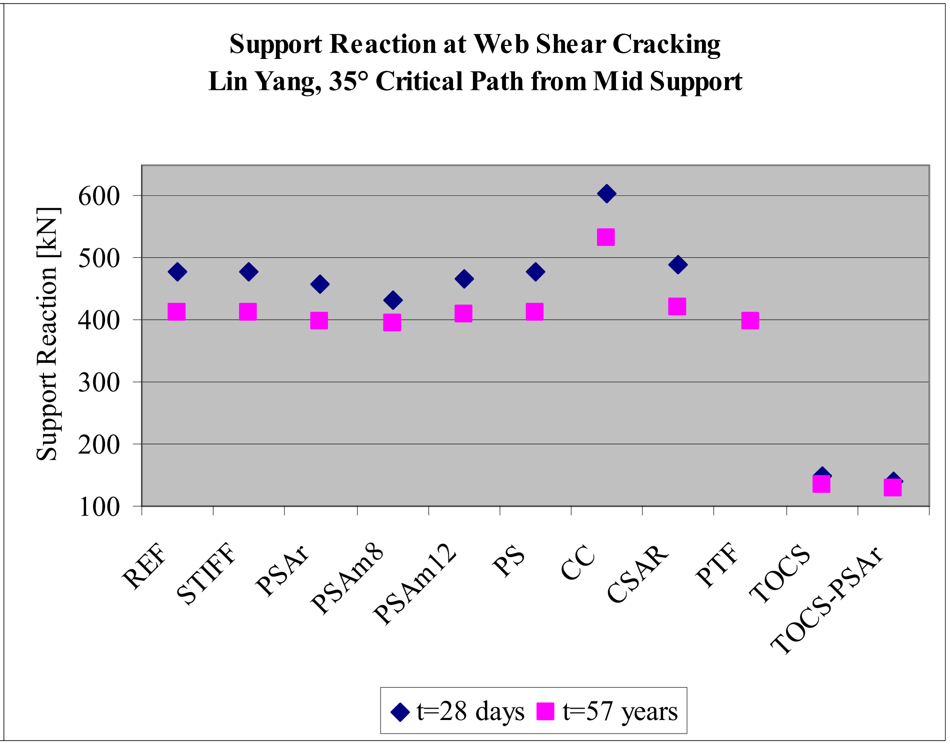
Principal Stresses in the Reference Case



Critical point

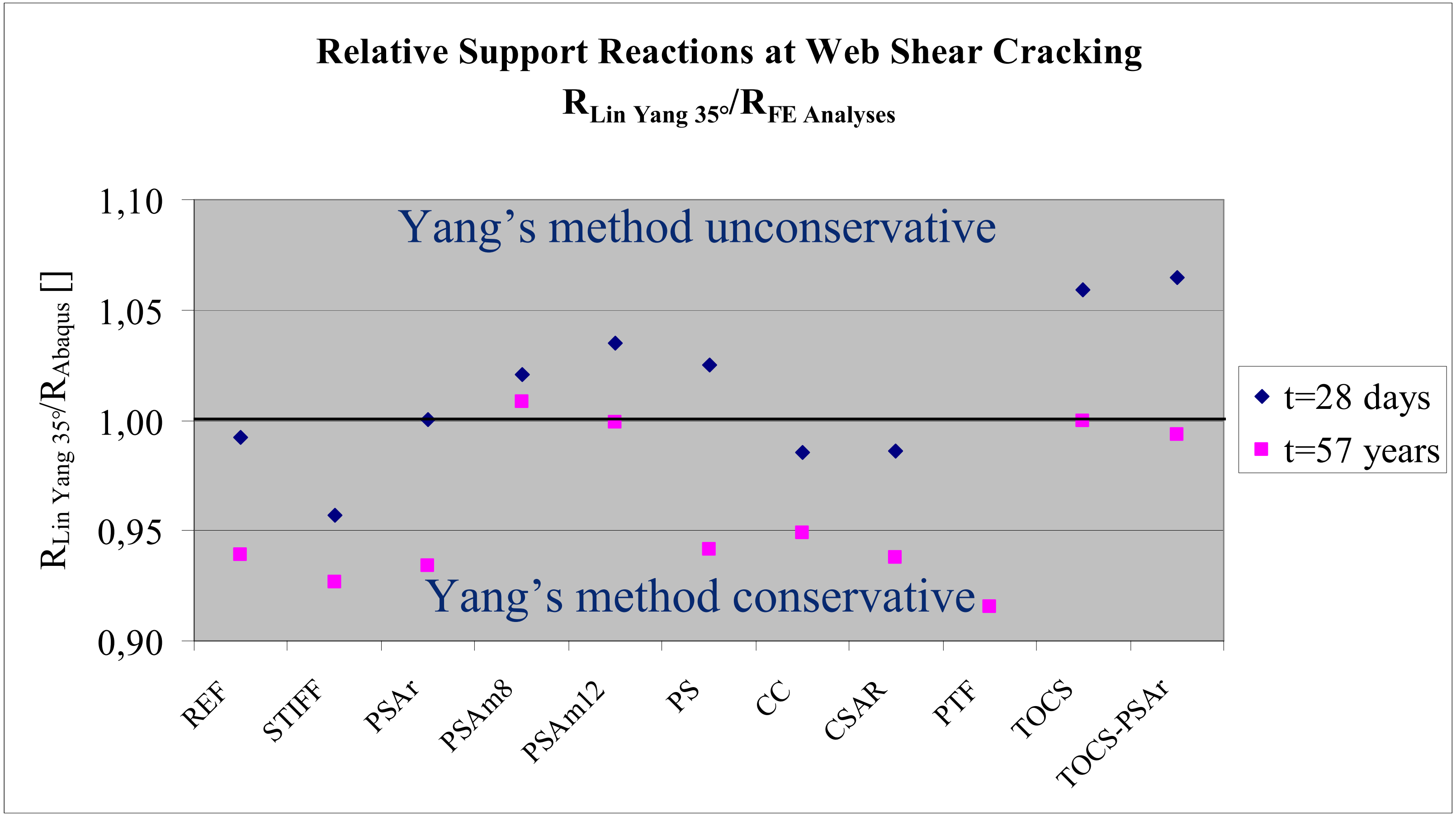
Shear Capacity



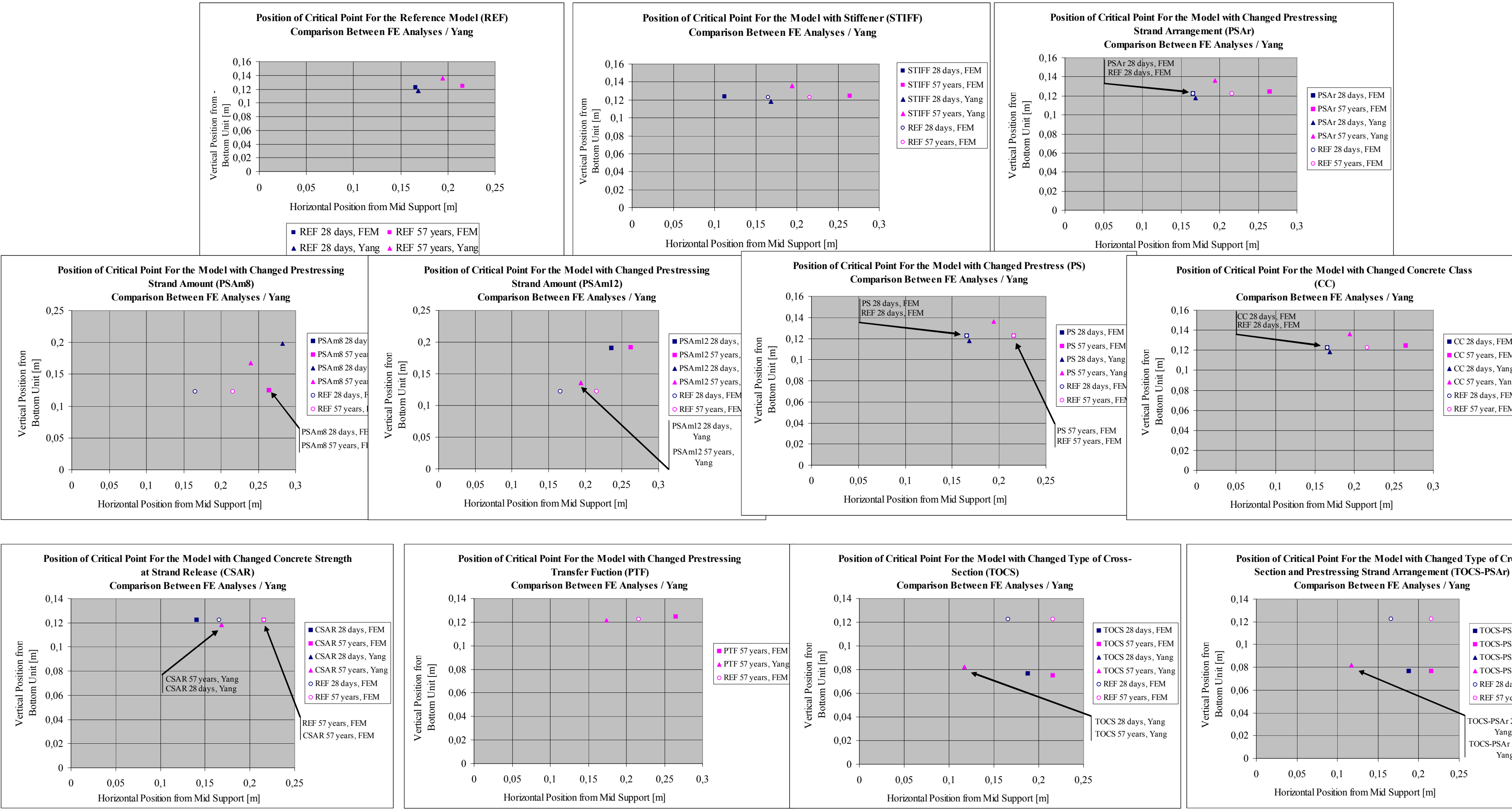


Shear Capacity

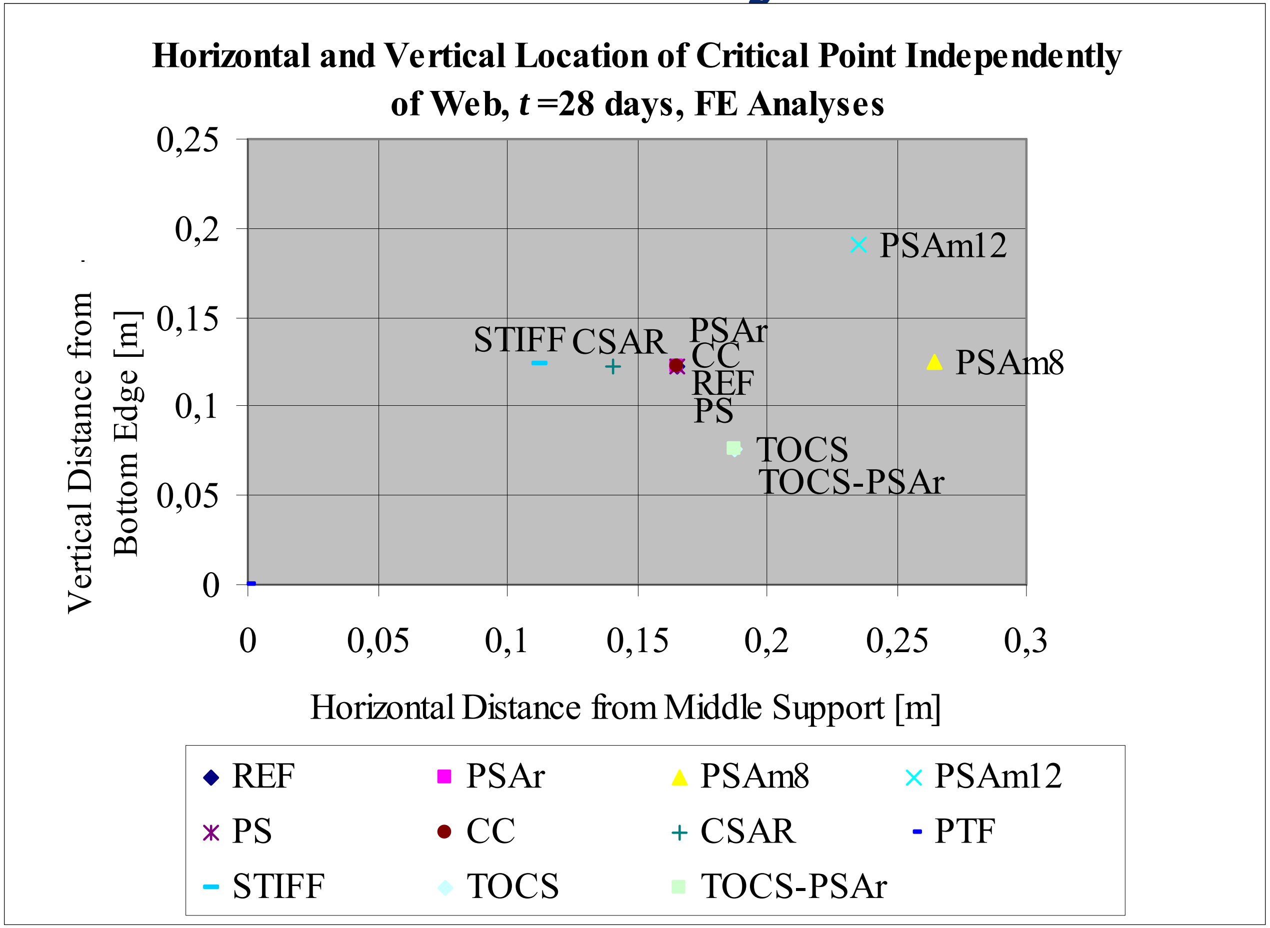
Comparison between FEM and Yang's Method



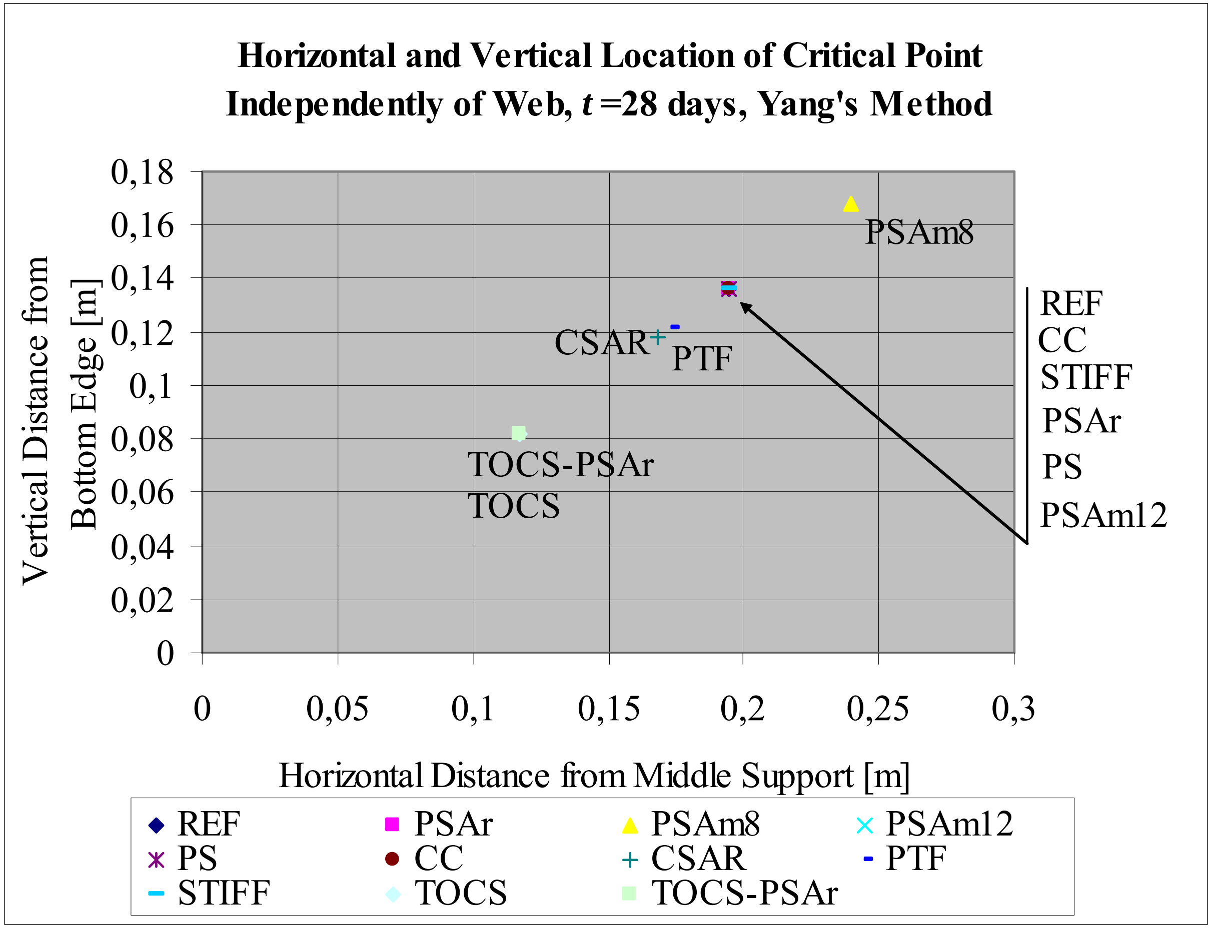
Location of Critical Point



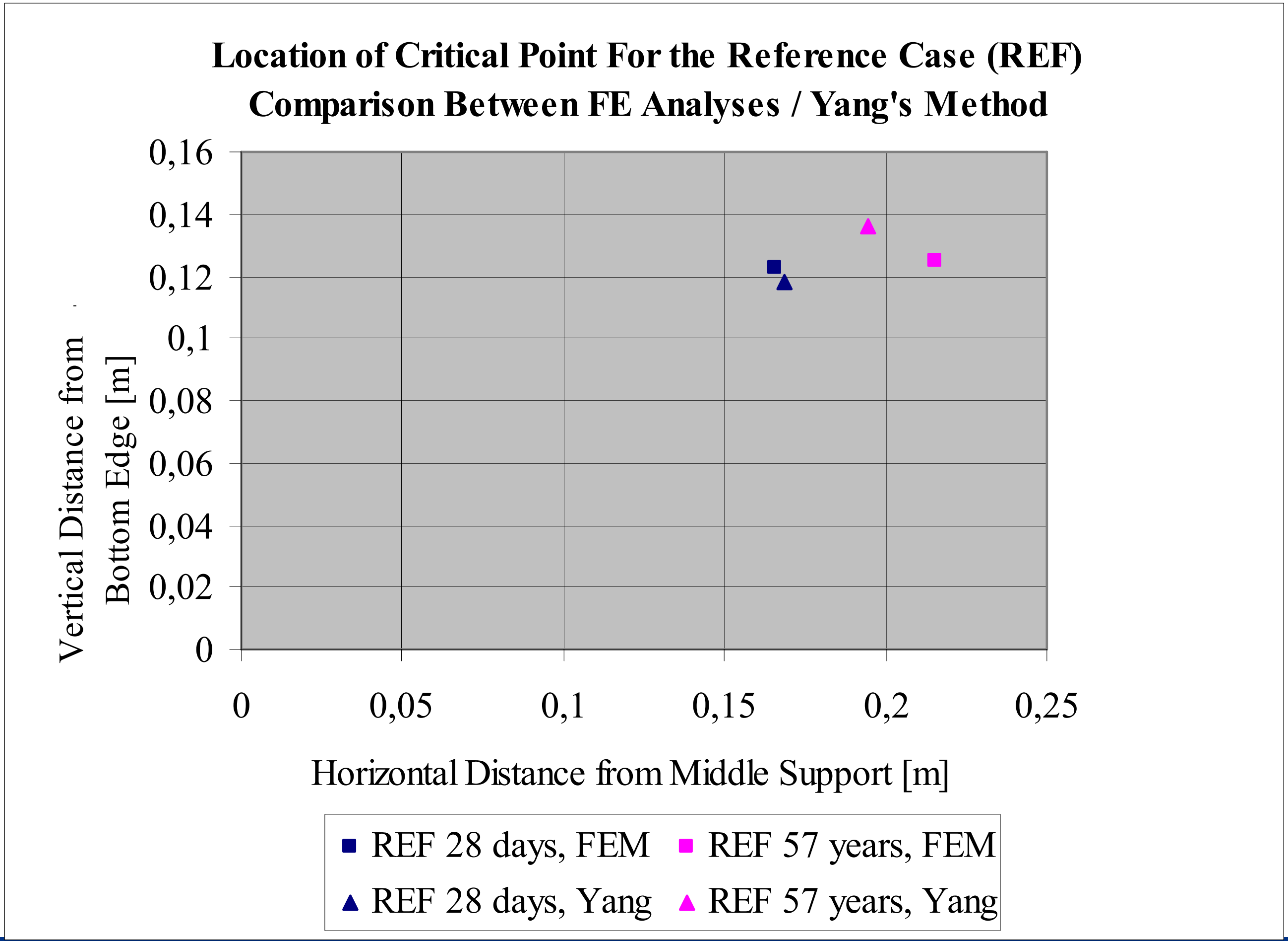
Location of Critical Point FE Analyses



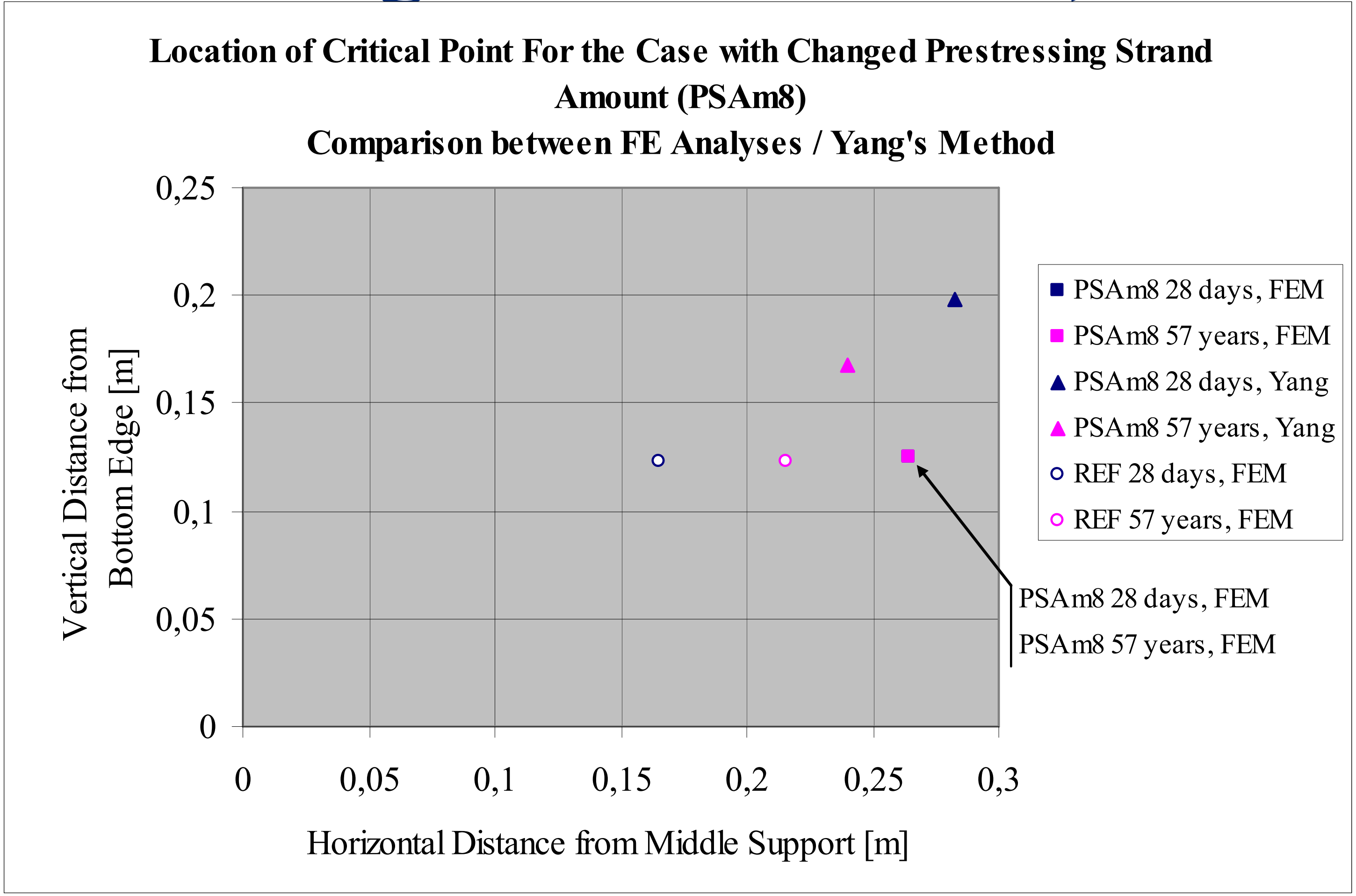
Location of Critical Point
Yang's Method



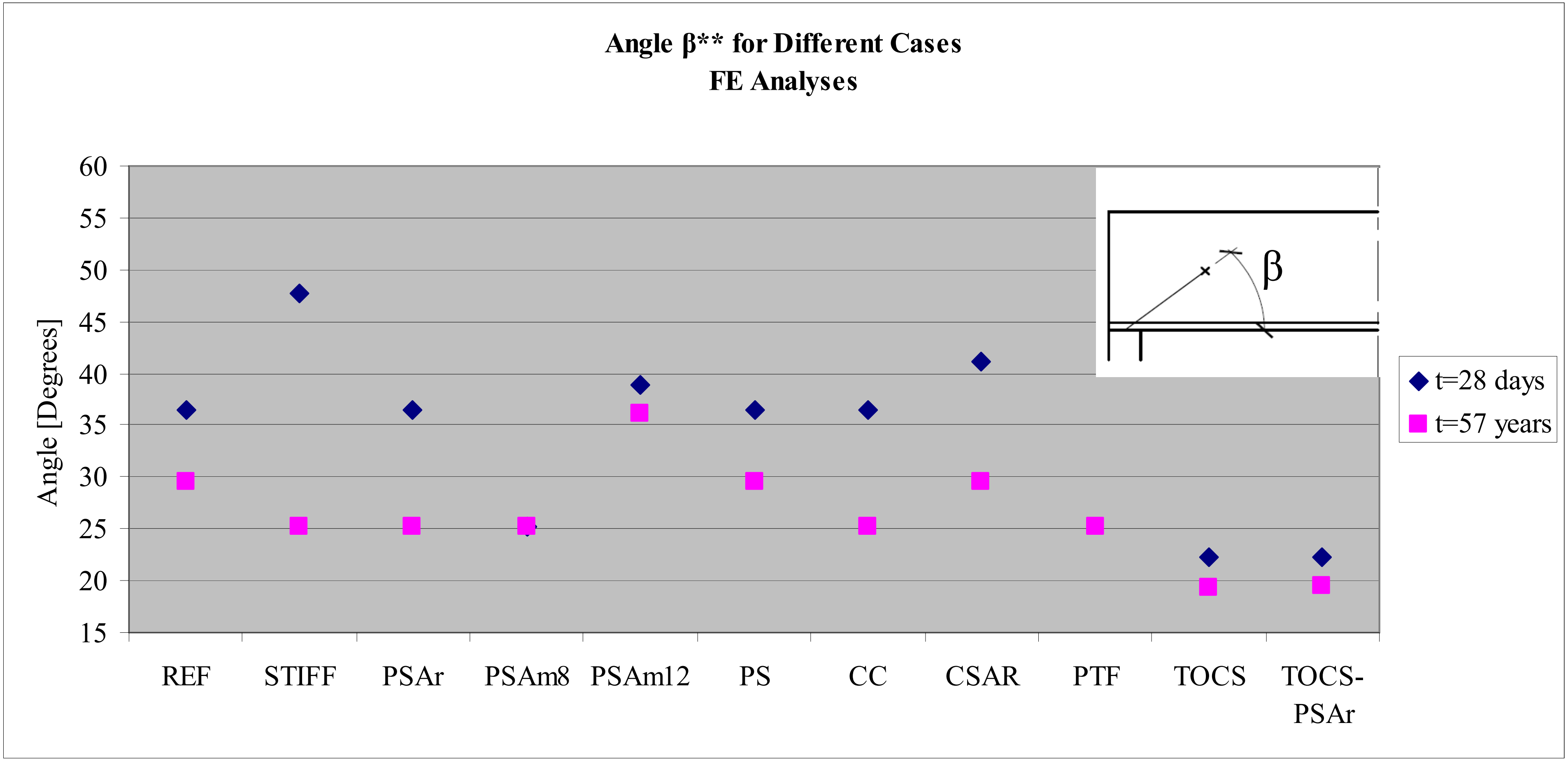
Location of Critical Point: Reference Case



Location of Critical Point: Prestressing Strand Amount, PSAm8

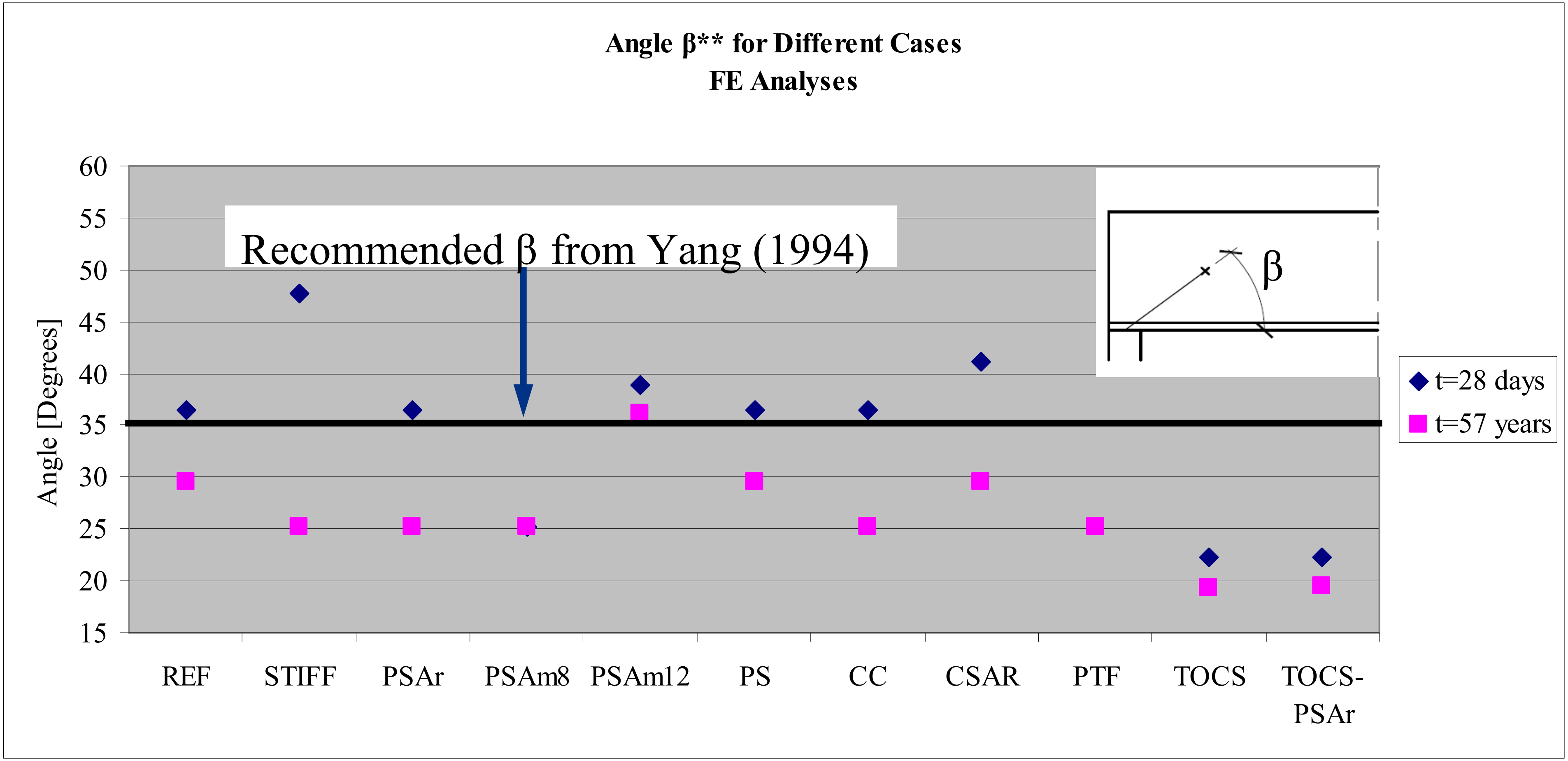


Angle β for Different Cases



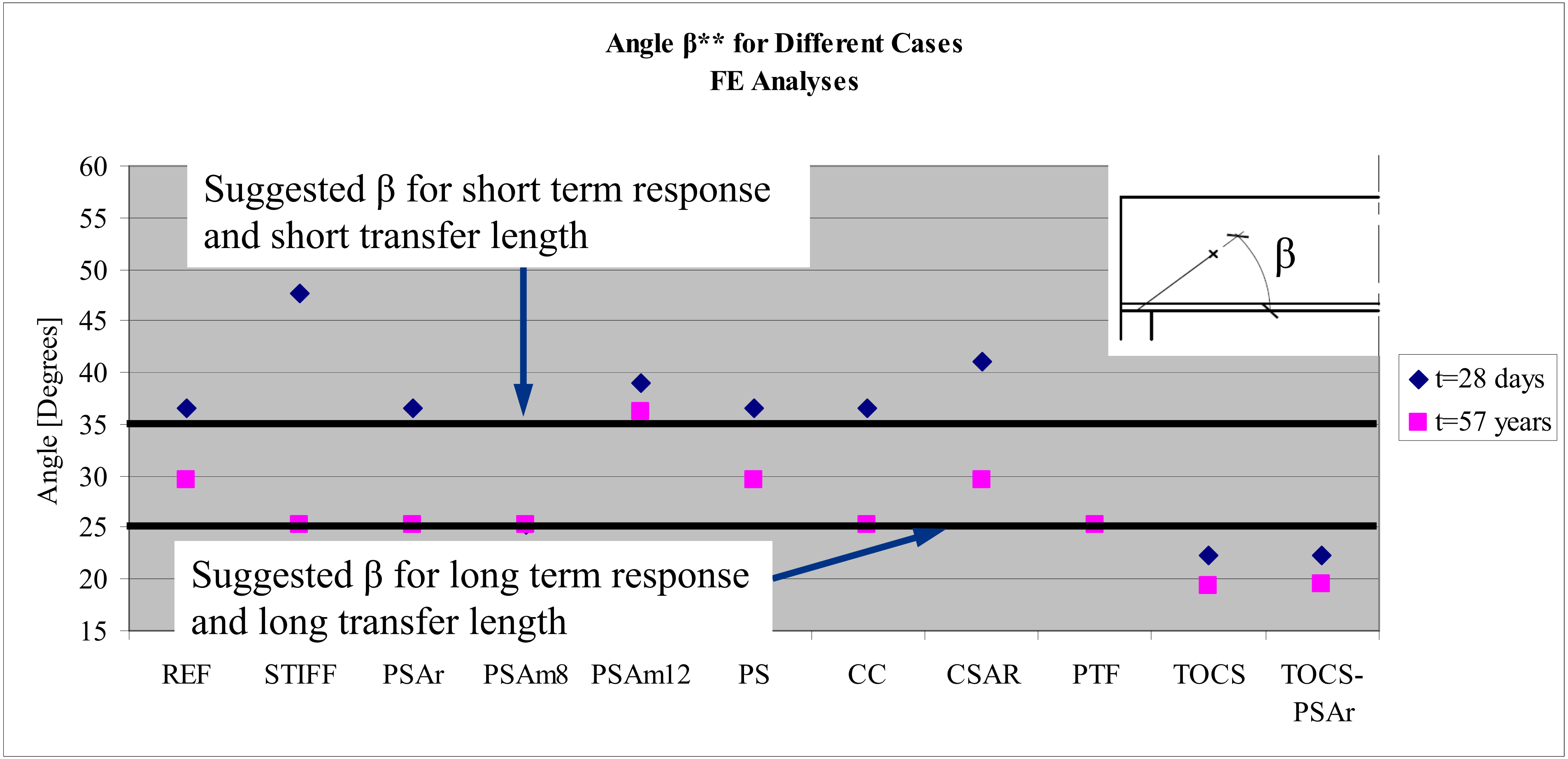
Angle β for Different Cases

Comparison between FEM and Yang's Method

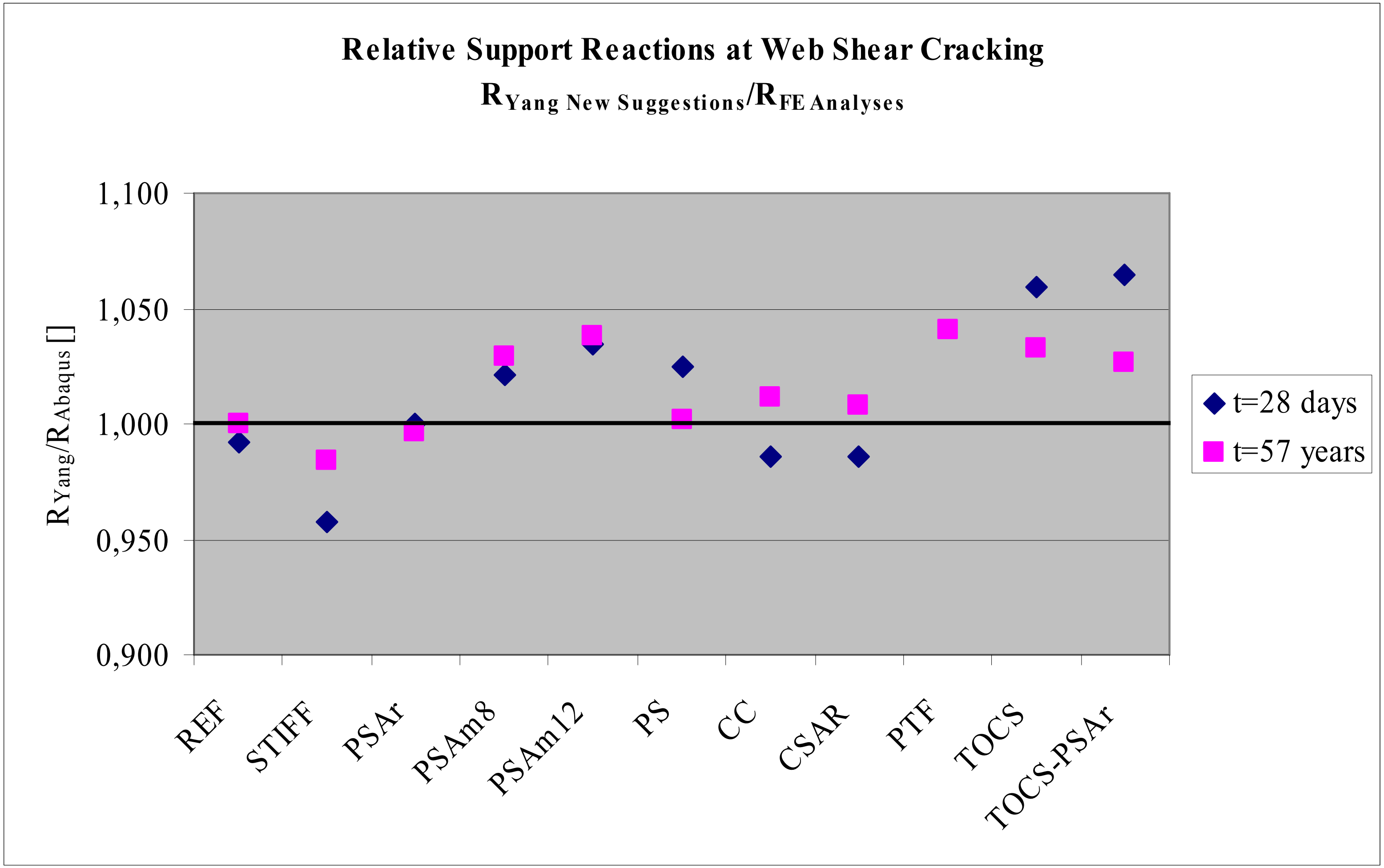


Angle β for Different Cases

Recommendations of New Angle



Relative Shear Capacity
New Recommended Angle is Used



Conclusions

General from FE Analyses

- For long term response and long transfer length, the critical point was found along a path with a smaller inclination than 35° proposed by Yang (1994).
- For long term response and long transfer length, the capacity of web shear tension failure was reduced.

Conclusions

Specific from FE Analyses

- Decreased reinforcement amount had a great influence on the position of the critical point; the horizontal distance from the support to the critical point was increased. The capacity in web shear tension failure is reduced.
- Increased prestress from 1000 MPa to 1200 MPa did not affect the location of the critical point, but reduced the shear capacity.

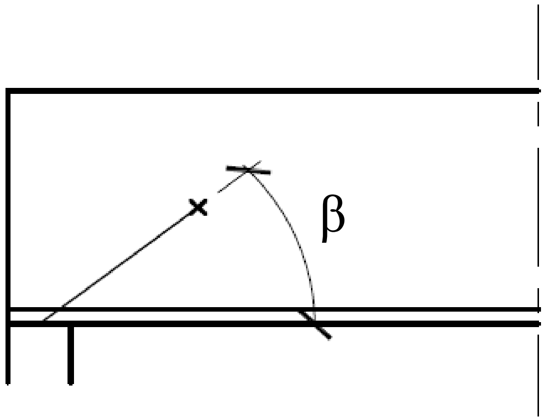
Conclusions

General from Comparison FEM – Yang's Method

- The agreement between Yang's method and FEM regarding the location of the critical point was, with some exceptions, good for short term response and short transfer length and less good for long term response and long transfer length.
- The agreement between Yang's method and FEM regarding the web shear tension capacity was, with some exceptions, good for short term response and short transfer length and less good for long term response and long transfer length.

Recommendation

- Use β=35° for short term response and short transfer length with Yang's method.
- Use β=25° for long term response and long transfer length with Yang's method.



Thanks for your attention!