A priori schatten van de scheurbandbreedte binnen het 'uitgesmeerde scheurenconcept'

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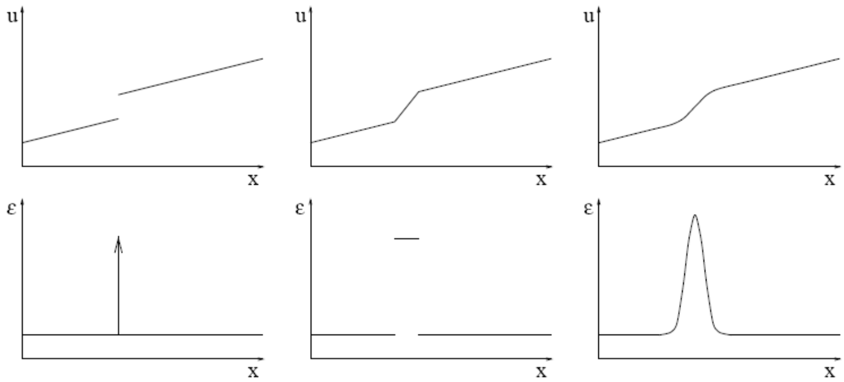
DOV lezingenavond 2011

24 November, Nieuwegein

TU Delft Delft University of Technology

Achtergrond

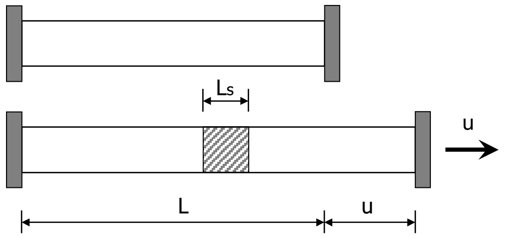
Classificatie modellen voor beschrijving scheurgedrag

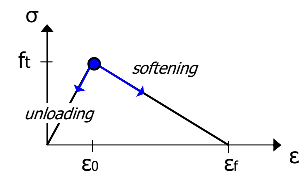


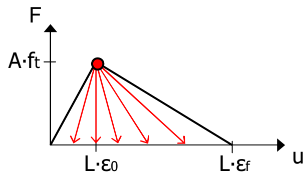
* **Jirasek, M.** (2002)
Objective modeling of strain localization

Achtergrond

'Mesh-size sensitivity'







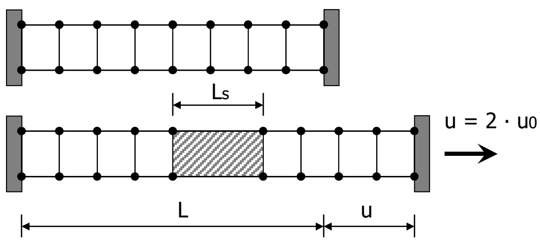
Volledig ontwikkelde scheur in 'softening' zone:

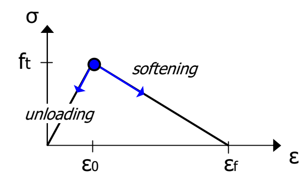
$$u = L_s \cdot \varepsilon_s + L_u \cdot \varepsilon_u = L_s \cdot \varepsilon_f$$

* **Jirasek, M.** (2002)
Objective modeling of strain localization

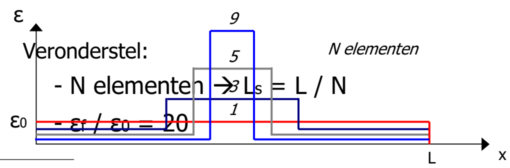
Achtergrond

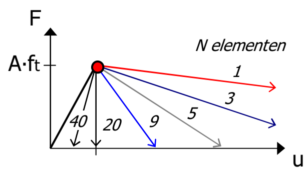
'Mesh-size sensitivity'





Veronderstel:
- N elementen → $L_s = L / N$
- $\varepsilon_f / \varepsilon_0 = 20$

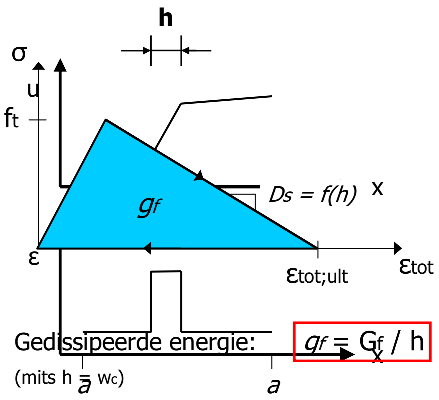


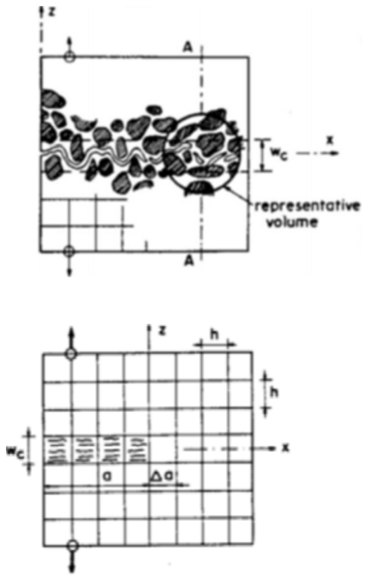


* **Jirasek, M.** (2002)
Objective modeling of strain localization

Achtergrond

Scheurband model





* **Bazant, Z.P., Oh, B.H.** (1983)
Crack band theory for fracture of concrete

A priori schatting van *h*

- Als $h \neq w_c$ → Totale gedissipeerde energie $g_{f\ totaal}$ is incorrect!
- Negatieve invloed op correcte predicties voor bezwijklast en bezwijkmode!

Methodieken voor a priori schattingen van *h* :

- DIANA
- Volgens J. Oliver (1989)
- Volgens S. Govindjee en anderen (1995)
- Additionele factor van Cervenka (1995)

A priori schatting van *h*

DIANA

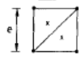
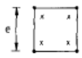
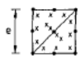
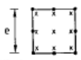
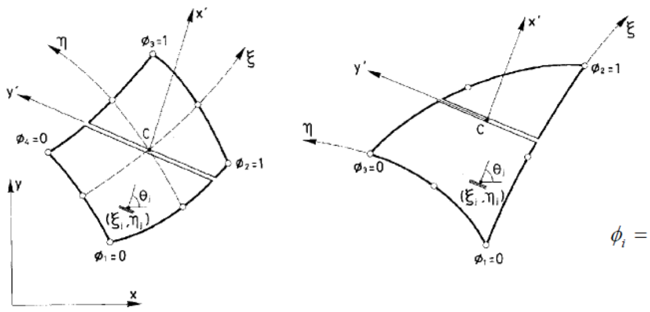
element type and integration	effective band width h for zig-zag fracture propagation through regular mesh (found by trial-and-error for present problem)
	e
	$e\sqrt{2}$
	$\frac{1}{2}e\sqrt{2}$
	e

Table. 4.I. Recommendations for estimating the crack band width.

* **Rots, J.G.** (1988)
Computational modeling of concrete fracture

A priori schatting van *h*

Volgens Oliver*



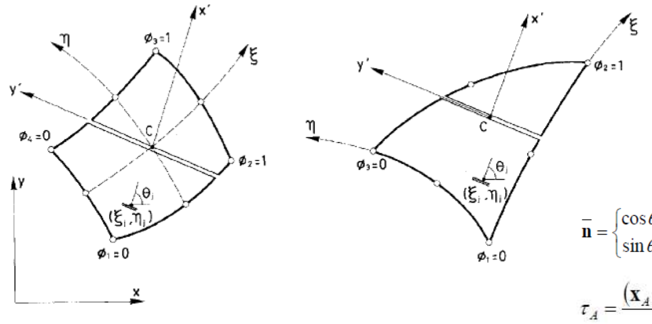
$$\phi_i = \begin{cases} 1 \rightarrow x_i' \geq 0 \\ 0 \rightarrow x_i' < 0 \end{cases}$$

$$l^*(\xi_j,\eta_j) = \left(\sum_{i=1}^{n} \left[\frac{\partial N_i^*(\xi_j,\eta_j)}{\partial x} \cdot \cos(\theta_j) + \frac{\partial N_i^*(\xi_j,\eta_j)}{\partial y} \cdot \sin(\theta_j) \right] \cdot \phi_i \right)^{-1}$$

* **Oliver, J.** (1989)
A consistent characteristic length for smeared cracking models

A priori schatting van *h*

Volgens Govindjee (e.a.)*



$$\bar{\mathbf{n}} = \begin{Bmatrix}\cos\theta\\ \sin\theta\end{Bmatrix} \quad \text{in 2D-cases}$$

$$\tau_A = \frac{(\mathbf{x}_A - \mathbf{x}_c)\bullet \mathbf{n}(\mathbf{x}) - \tau^{\min}}{\tau^{\max} - \tau^{\min}}$$

$$(l^*)^{-1} = \partial_x \tau \bullet \mathbf{n} = \left\|(\partial_x \xi)\ \mathbf{n}\right\| \sum_{A=1}^{Nnodes} \tau_A \partial_\xi N_A(\xi) \bullet \bar{\mathbf{n}}$$

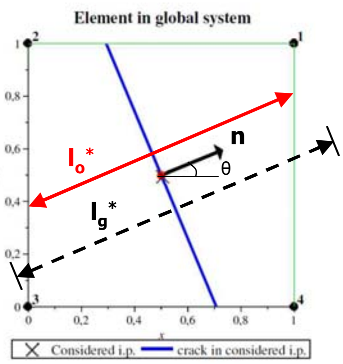
$$\tau^{\min} = \min_{A=1,Nnodes} \{(\mathbf{x}_A - \mathbf{x}_c)\bullet \mathbf{n}(\mathbf{x})\}$$

$$\tau^{\max} = \max_{A=1,Nnodes} \{(\mathbf{x}_A - \mathbf{x}_c)\bullet \mathbf{n}(\mathbf{x})\}$$

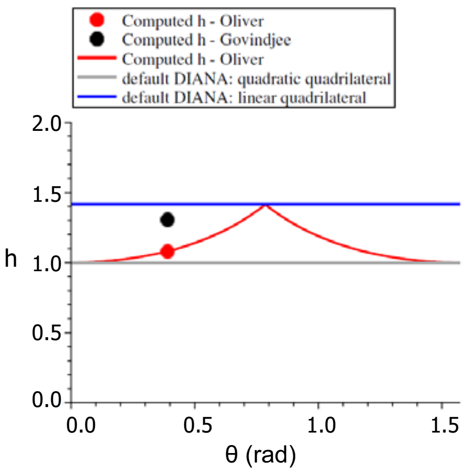
* **Govindjee, S., Kay, J.C., Simo, J.C.** (1995)
Anisotropic modeling and numerical simulation of brittle damage in concrete

A priori schatting van *h*

Verschillen Oliver en Govindjee (e.a.)

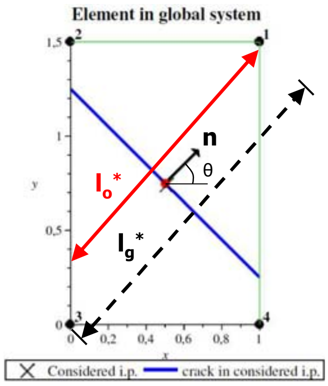


θ = 1/8 · π rad

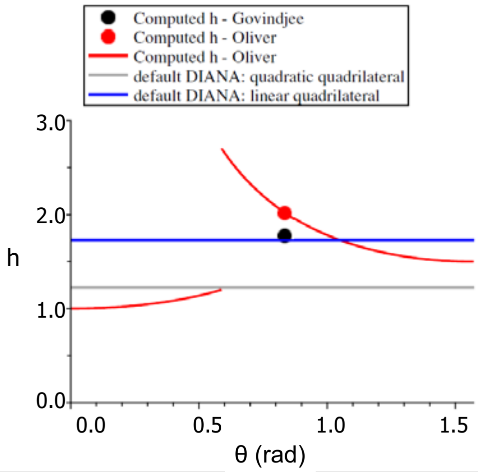


A priori schatting van *h*

Verschillen Oliver en Govindjee (e.a.)



θ = 1/4 · π rad



A priori schatting van *h*

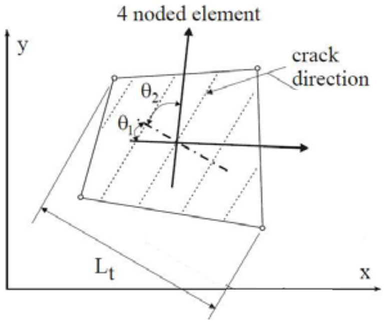
Additionele factor Cervenka

$$L_t^{'} = \gamma L_t$$

$$\gamma(\theta_j) = 1 + (\gamma_{\max} - 1)\cdot\frac{\theta_j}{\pi/4}, \qquad \theta_j \in \langle 0, \pi/4 \rangle$$

γ_{max} = 1.5

θ_j = min (θ_1 , θ_2) in radialen



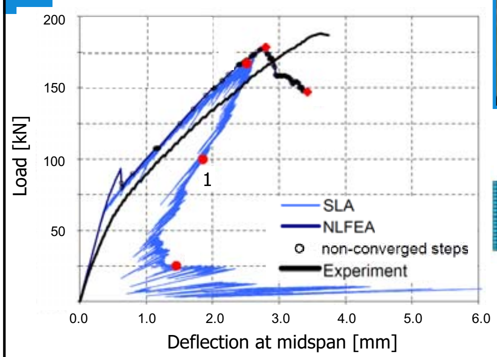
γ = 1.0 (scheur parallel aan element randen)

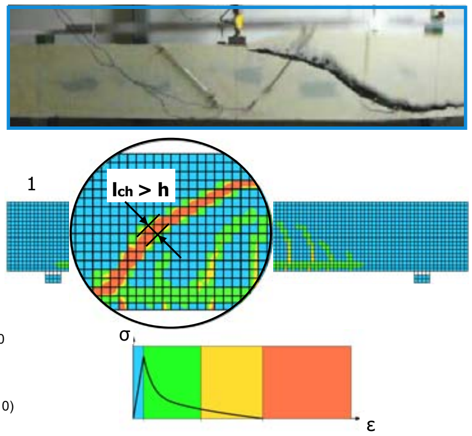
γ = 1.5 (scheur onder 45° tot element randen)

* **Cervenka, J., Cervenka, V.** (2010)
On the uniqueness of numerical solutions of shear failure of deep concrete beams: Comparison of smeared and discrete crack approaches

Numeriek voorbeeld (1)

A priori schatting *h* volgens DIANA



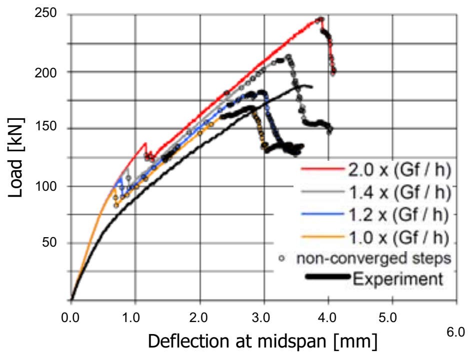


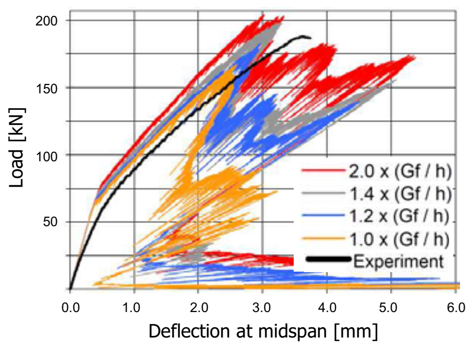
* **Sarkhosh, R., den Uijl, J.A., Braam, C.R., Walraven, J.C.** (2010)
Shear Capacity of Concrete Beams without Shear Reinforcement
under Sustained Loads - Experimental Results

Numeriek voorbeeld (1)

A priori schatting *h* (handmatig)

Invloed van *h* op bezwijklast & bezwijkmode → niet altijd, zie Hendriks (e.a.) * !

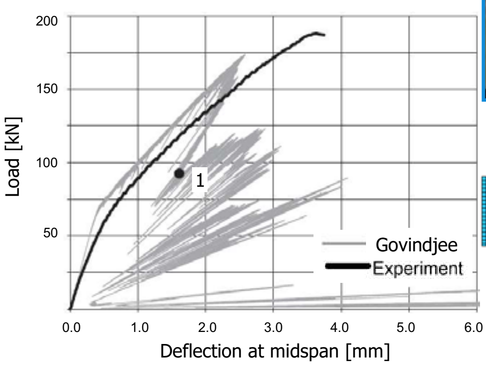


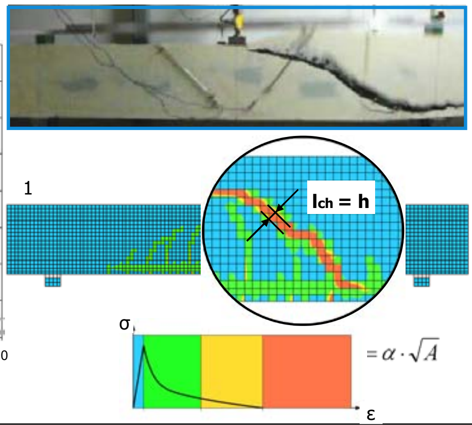


* **Hendriks, M.A.N., Damoni, C., Belletti, B.** (2010)
Guidelines for non-linear finite element analysis of concrete structures – Crack bandwidth

Numeriek voorbeeld (1)

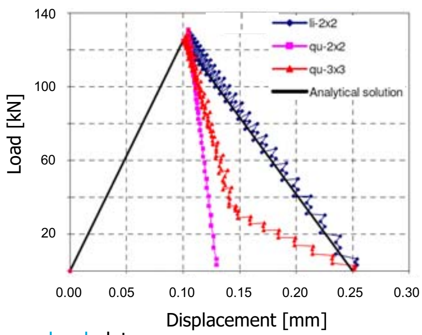
A priori schatting *h* volgens Govindjee (e.a.)





Numeriek voorbeeld (2)

A priori schatting *h* volgens Govindjee (e.a.)



Additionele factor (1) : $h = \alpha \cdot h^{*}$

- **quadratic 2x2** → $\alpha = 1/2$
- **quadratic 3x3** → $\alpha = 13/18$

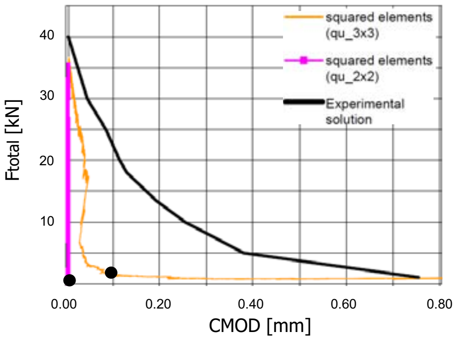
h^{*}

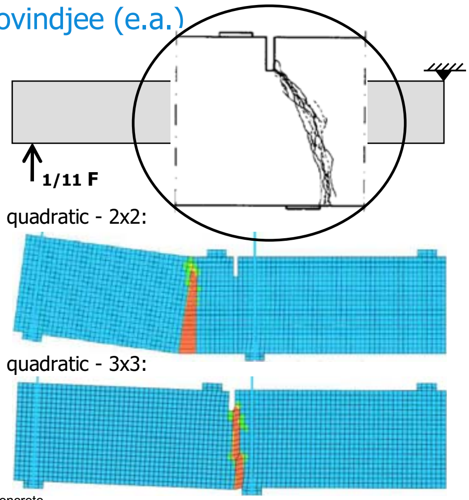
Damage level plots:

linear – 2x2 *quadratic – 2x2* *quadratic – 3x3*

Numeriek voorbeeld (3)

A priori schatting *h* volgens Govindjee (e.a.)





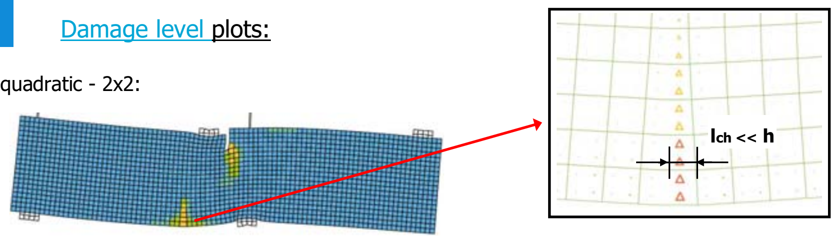
* **Schlangen, E.** (1993)
Experimental and Numerical Analyses of Fracture Processes in Concrete

Numeriek voorbeeld (3)

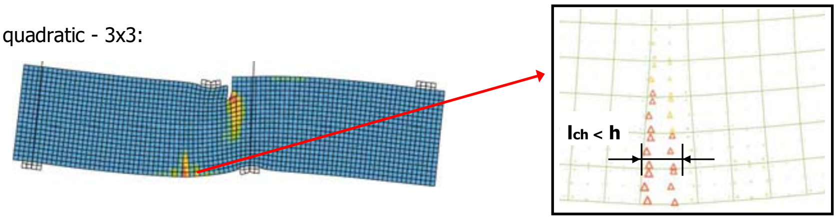
A priori schatting *h* volgens Govindjee (e.a.)

Damage level plots:

quadratic - 2x2:

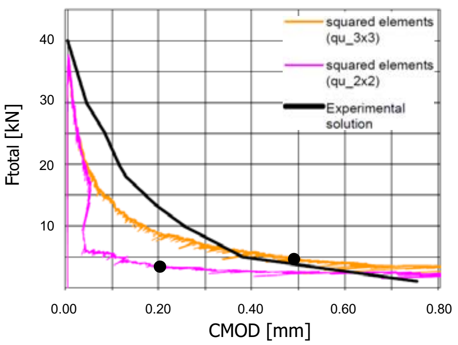


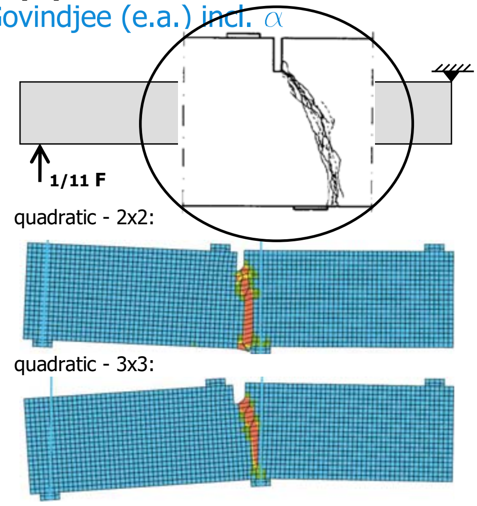
quadratic - 3x3:



Numeriek voorbeeld (3)

A priori schatting *h* volgens Govindjee (e.a.) incl. α





Huidig onderzoek

<u>Samenvattend:</u>

- Verschillende methodieken voor a priori schatten van *h.*
- Belang van een goede schatting (verificatie a posteriori!)
- Naast scheur oriëntatie binnen het element zijn ook het integratieschema en de orde van het element van belang voor een goede schatting.

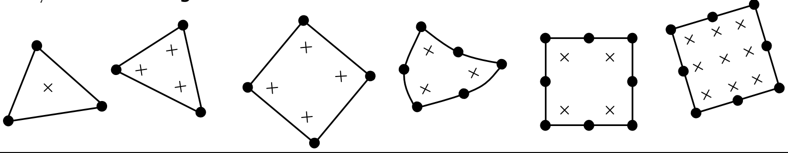
<u>Verbeterde schatting voor *h* :</u>

$$\boxed{h = \alpha \cdot \gamma \cdot h^*}$$

h* = de a priori schatting van de scheurbandbreedte volgens Govindjee (e.a.)

α = 'integratie schema – factor'

γ = 'alignment – factor'



Huidig onderzoek

Nieuwe testserie:

- Gebruik van periodieke randvoorwaarden.
- Sequentieel Lineaire Analyse – methode als numerieke oplossingsprocedure.