Dredging Processes

Dr.ir. Sape A. Miedema

6. Rock Cutting

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Dredging A Way Of Life

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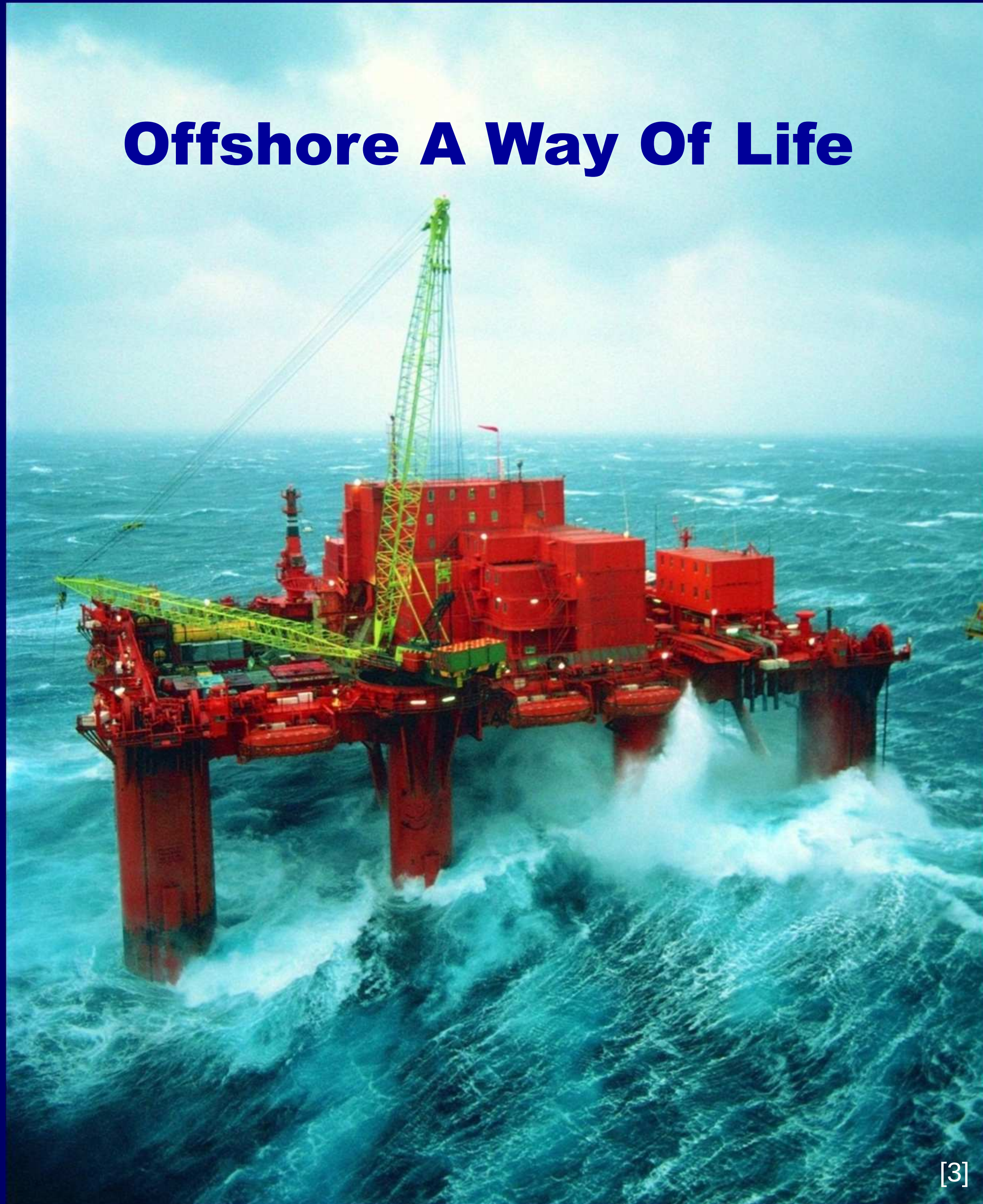
Offshore A Way Of Life



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Offshore & Dredging Engineering

Dr.ir. Sape A. Miedema
Educational Director

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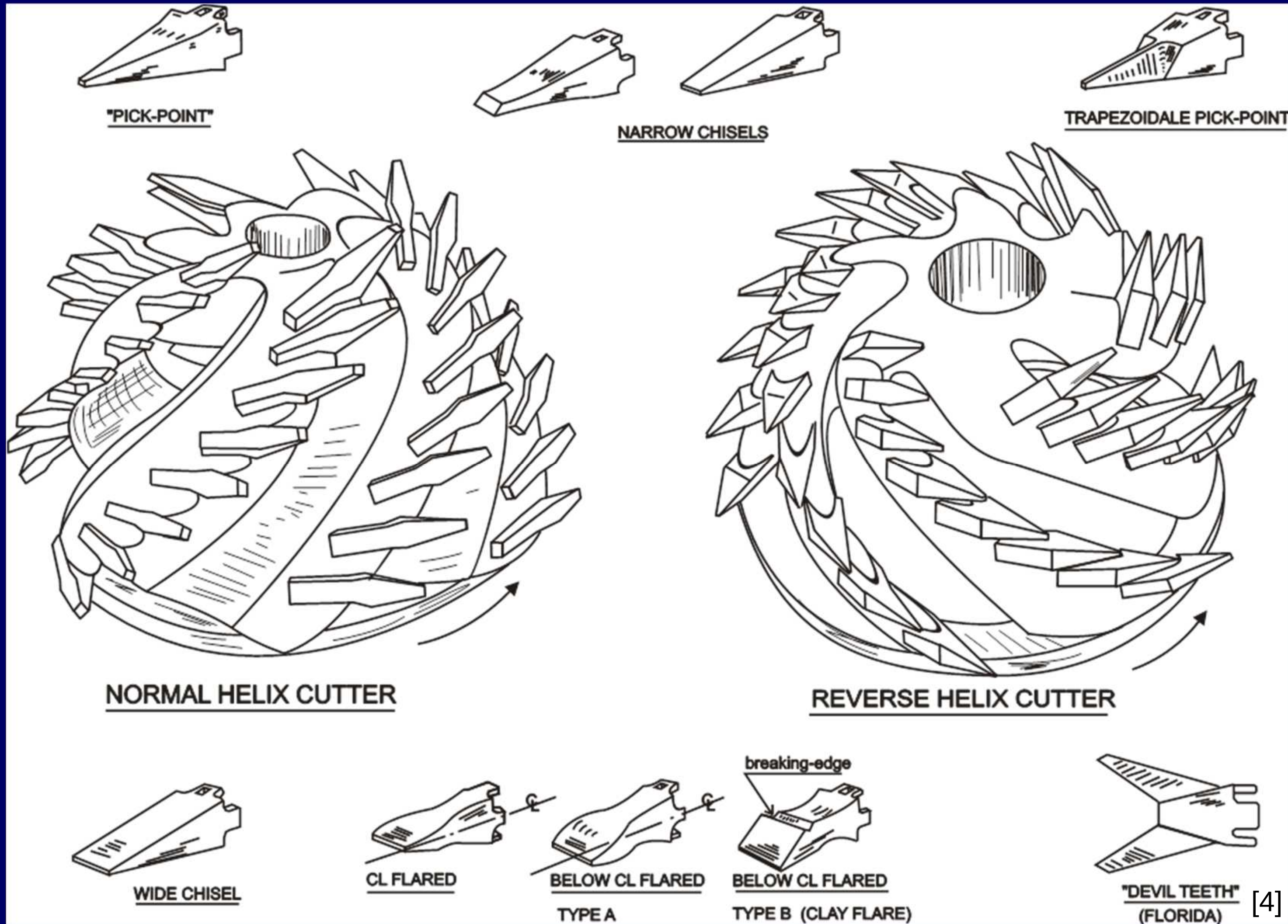
Rock Cutting

Rock Cutterheads



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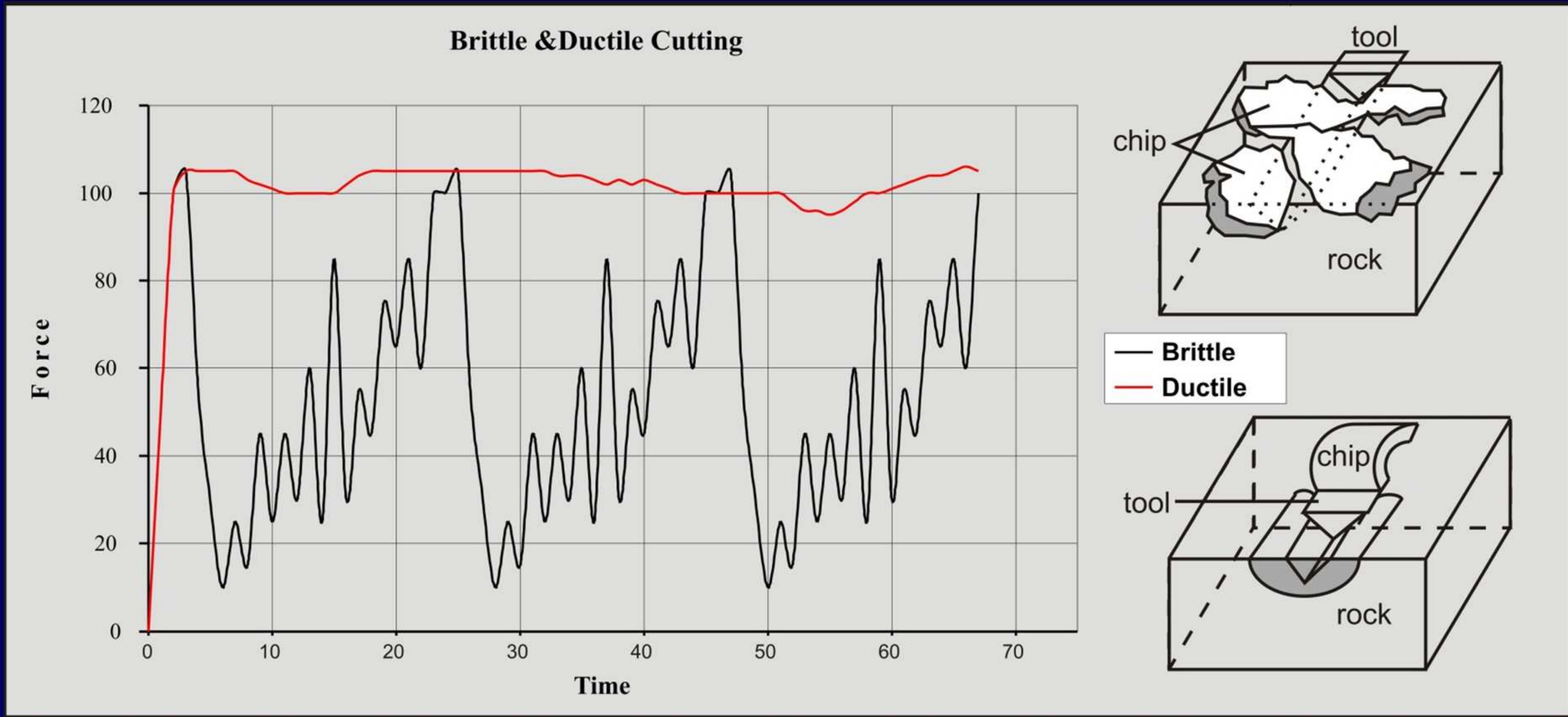
Brittle versus Ductile



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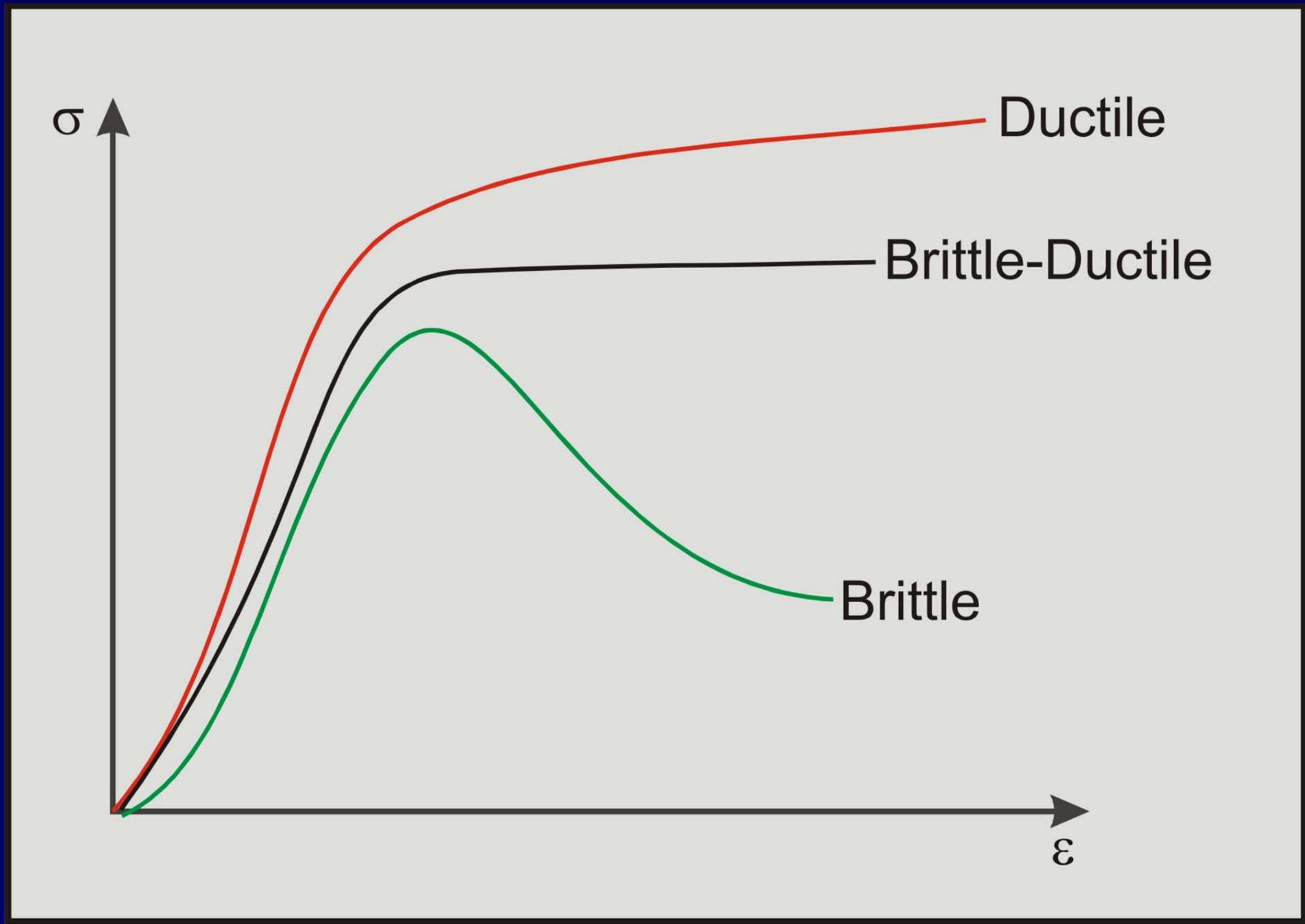
Brittle versus Ductile



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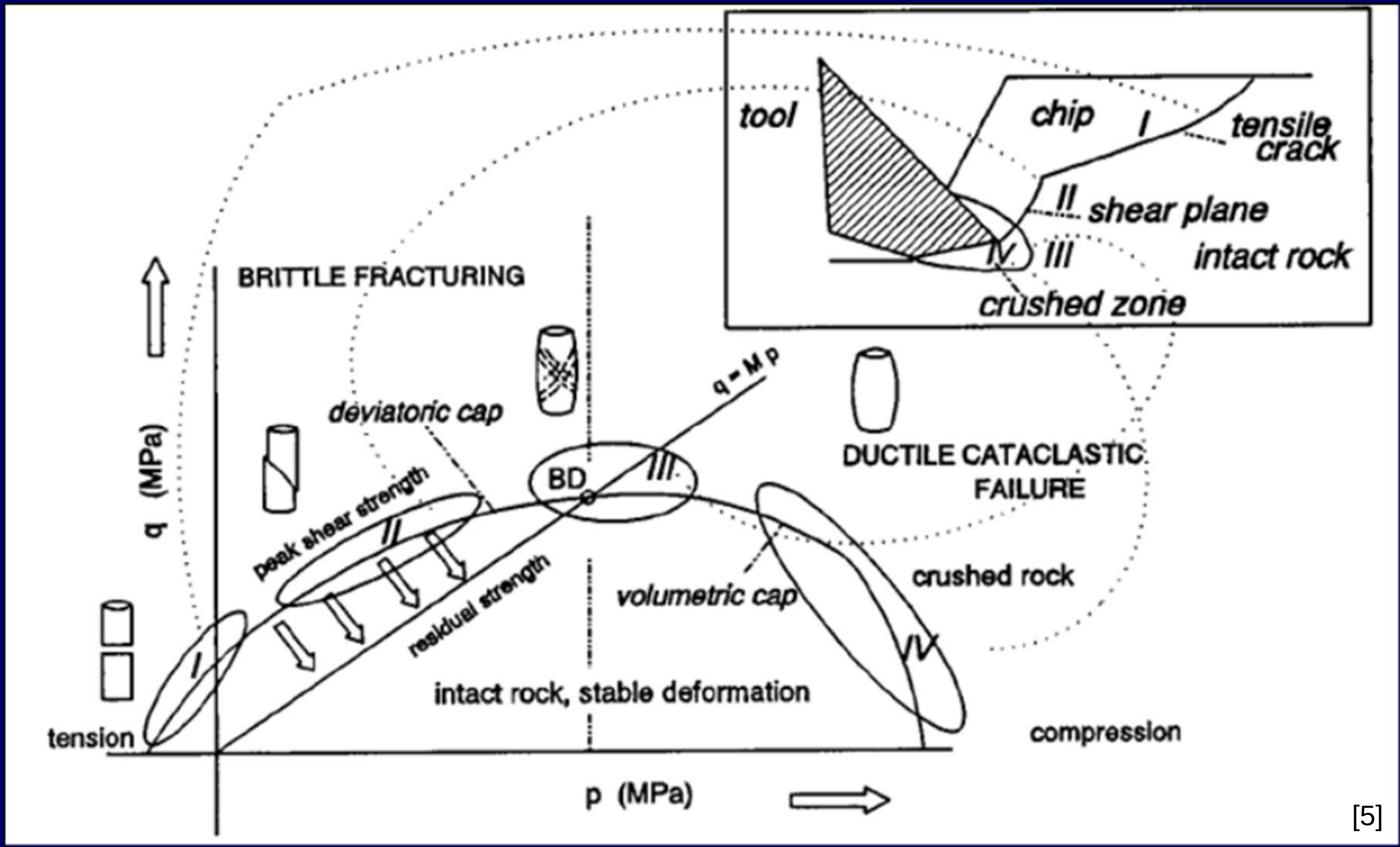
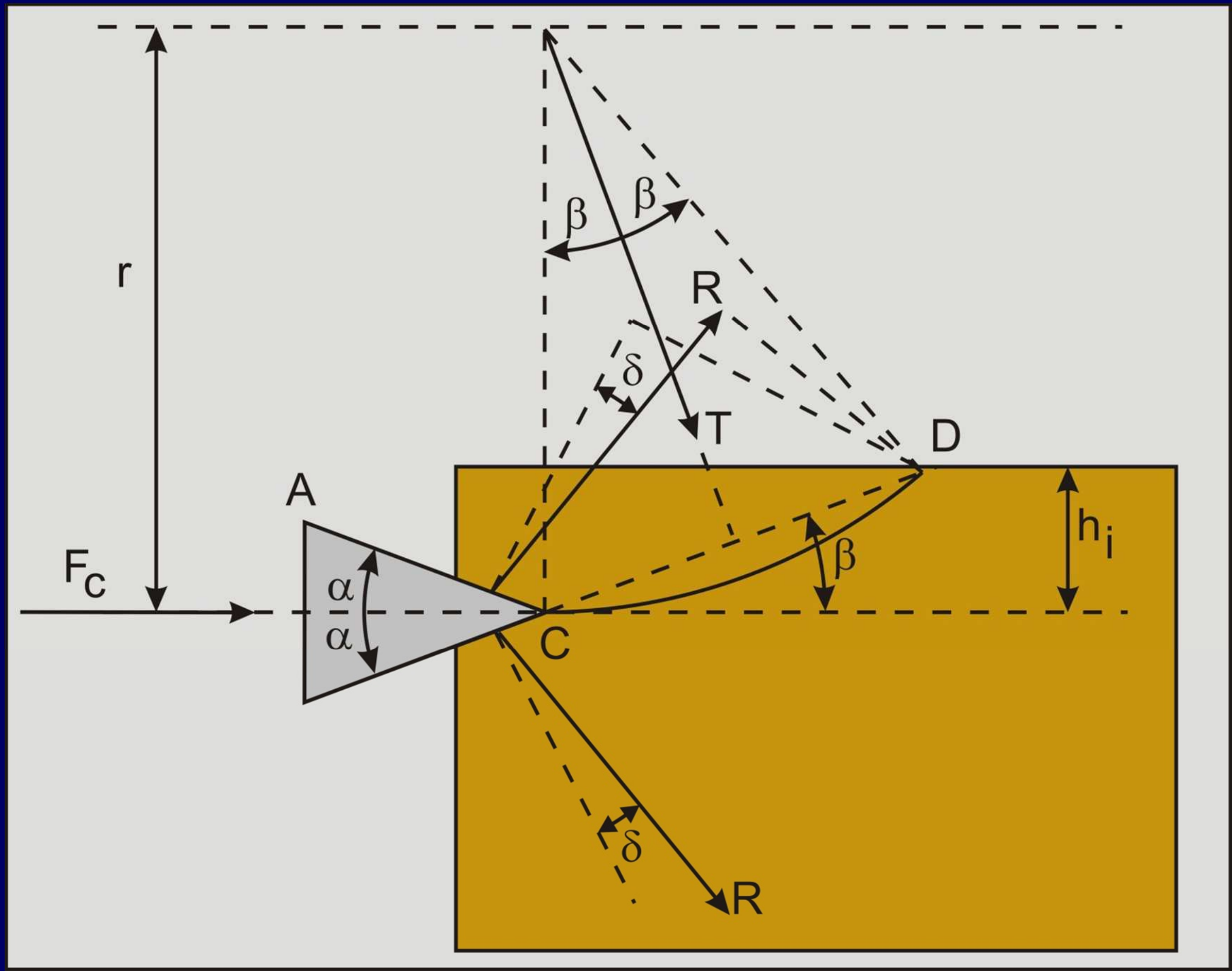
Rock Cutting



Evans Basic



Evans Basic

$$F_c = \sigma_T \cdot h_i \cdot w \cdot \frac{2 \cdot \sin(\alpha+\delta)}{1-\sin(\alpha+\delta)}$$

$$F_{ch} = F_c$$

$$F_{cv} = 0$$

$$E_{sp} = \frac{F_{ch} \cdot v_c}{h_i \cdot w \cdot v_c} = \sigma_T \cdot \frac{2 \cdot \sin(\alpha+\delta)}{1-\sin(\alpha+\delta)}$$

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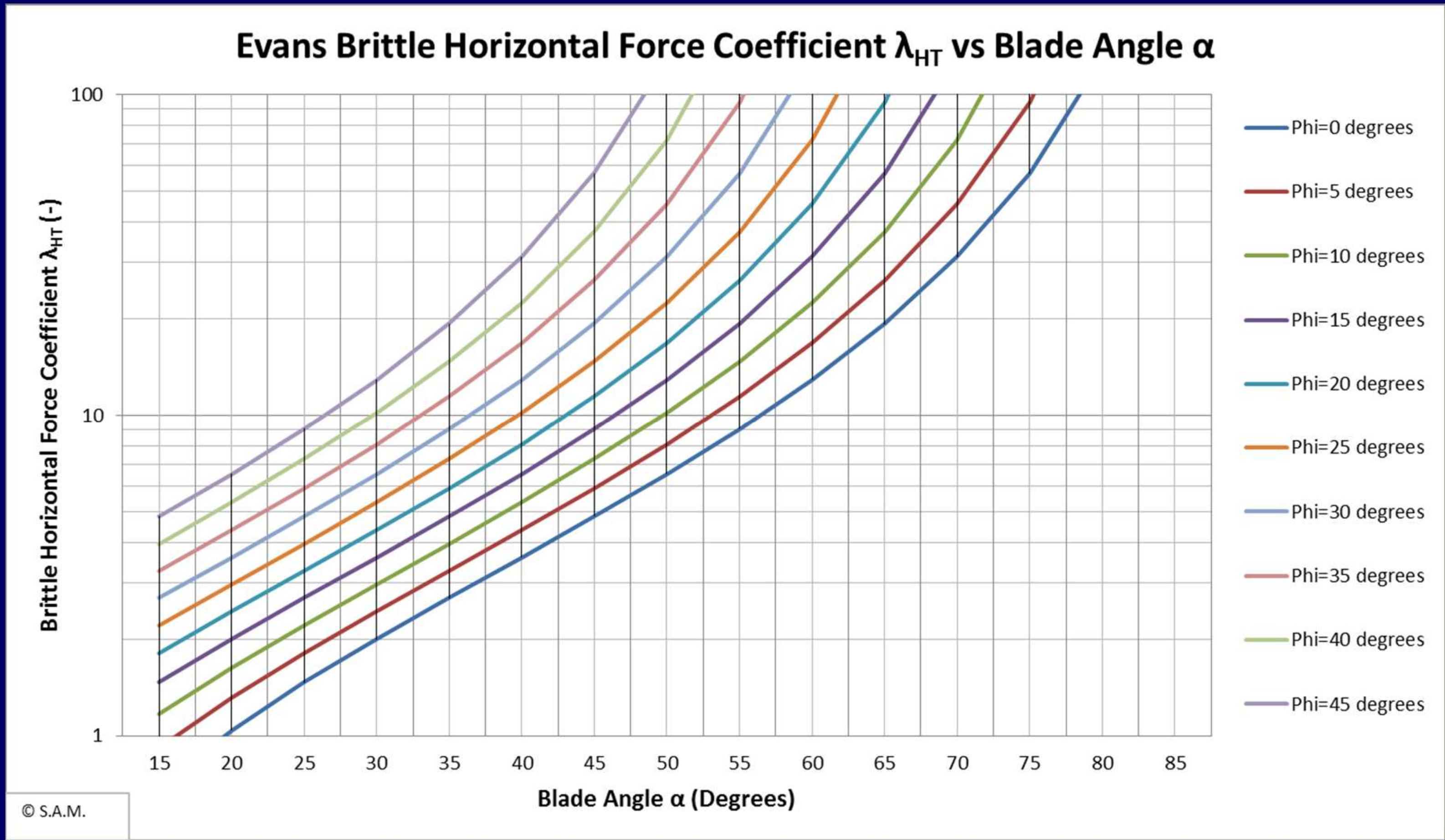
Evans Brittle Horizontal Force Coefficient



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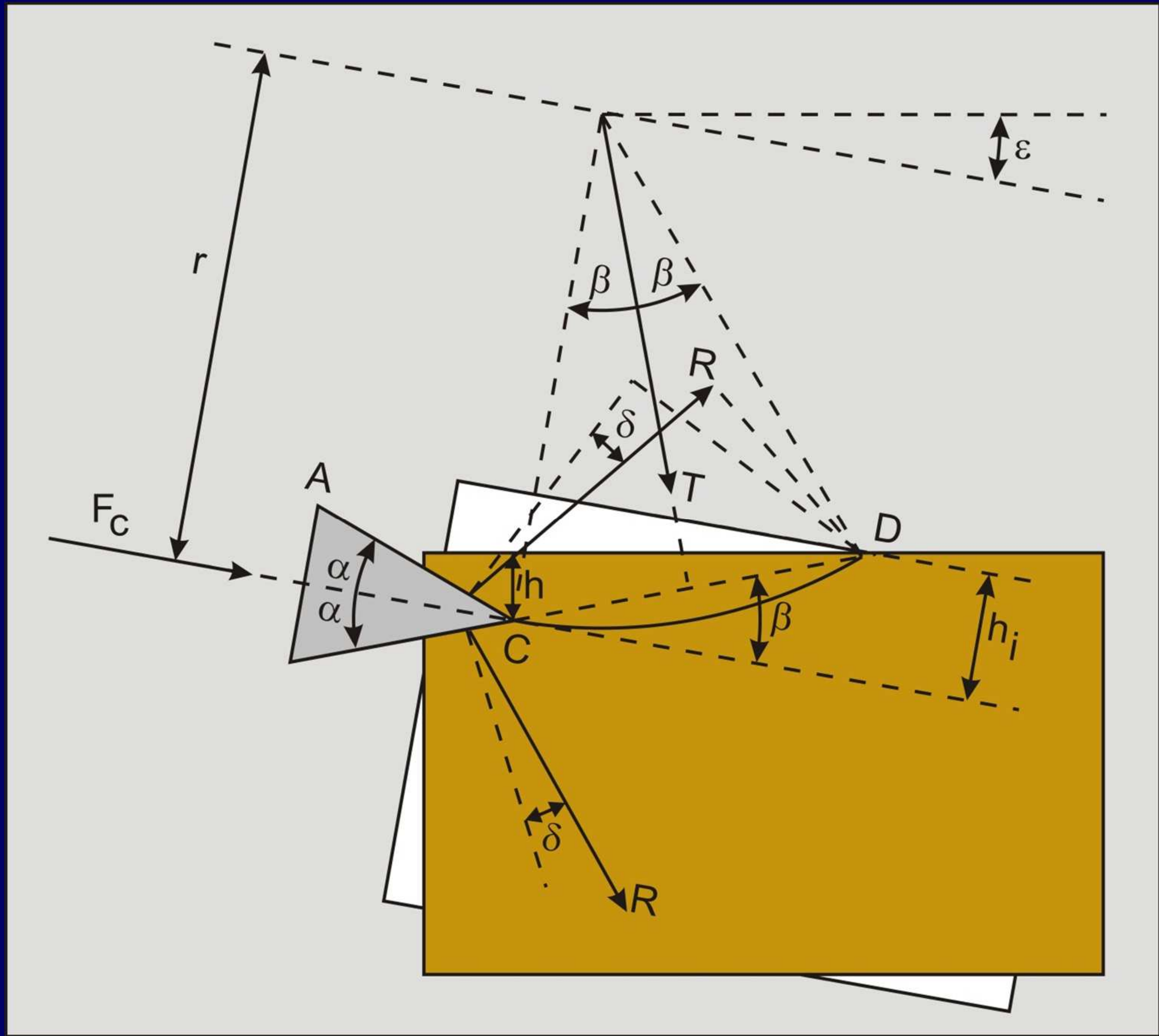
Evans under an Angle



Evans under an Angle

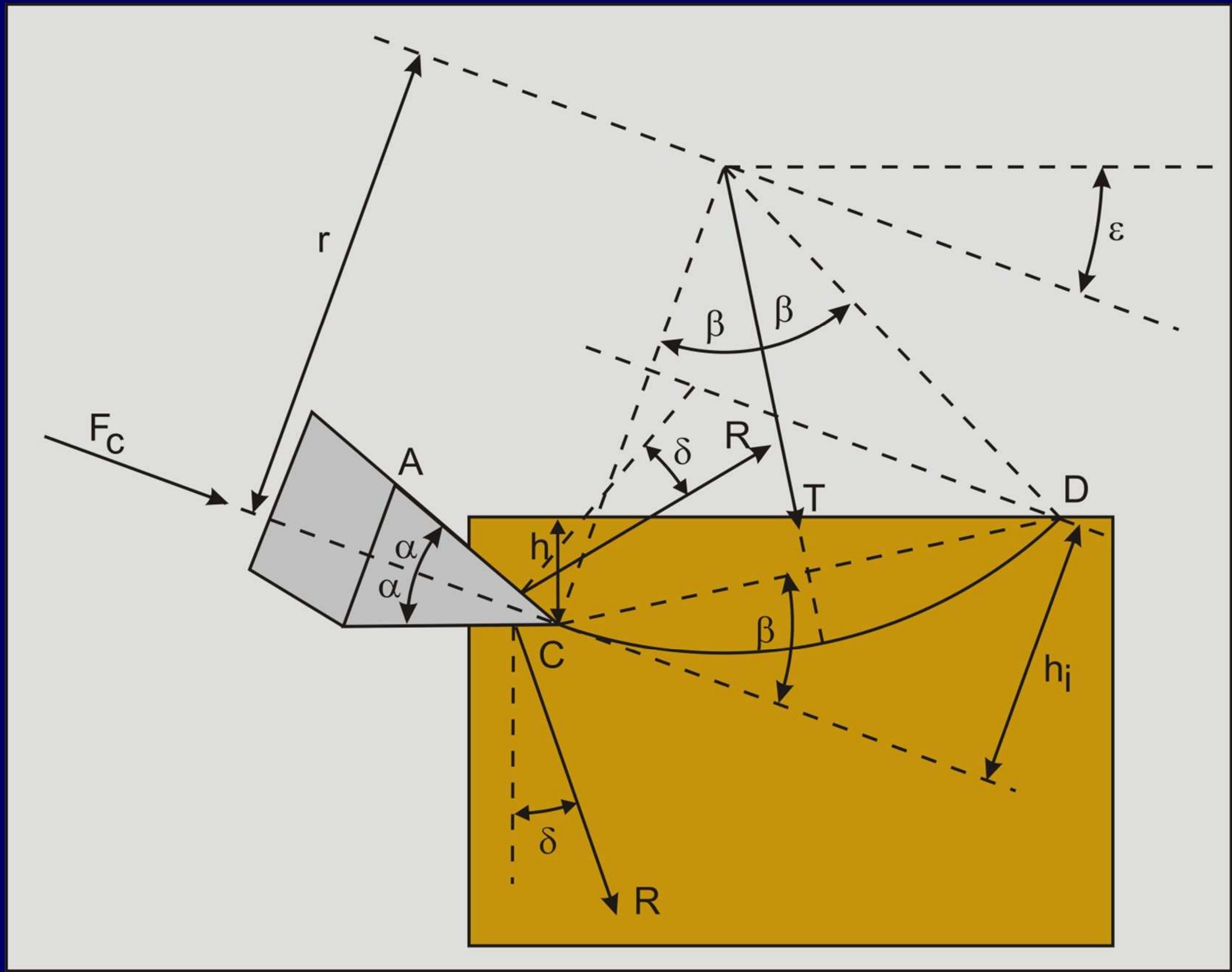
$$F_c = \sigma_T \cdot h \cdot w \cdot \frac{2 \cdot \sin(\alpha+\delta)}{1-\sin(\alpha+\delta+\varepsilon)}$$

$$F_{ch} = F_c \cdot \cos(\varepsilon)$$

$$F_{cv} = F_c \cdot \sin(\varepsilon)$$

$$E_{sp} = \frac{F_{ch} \cdot v_c}{h_i \cdot w \cdot v_c} = \sigma_T \cdot \frac{2 \cdot \sin(\alpha+\delta)}{1-\sin(\alpha+\delta+\varepsilon)} \cdot \cos(\varepsilon)$$

Evans Pick Point



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Evans Pick Point

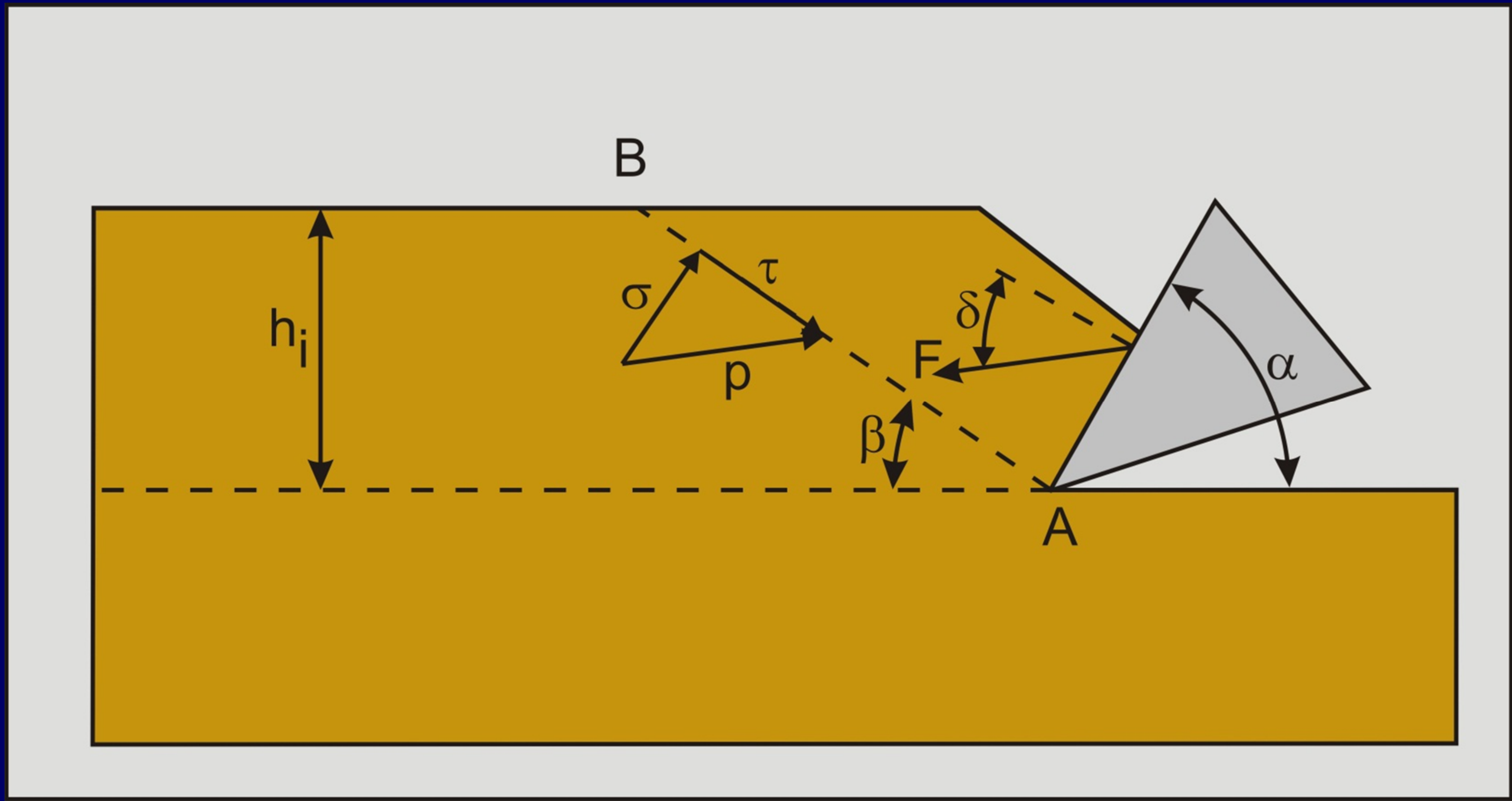
$$F_c = \sigma_T \cdot h \cdot w \cdot \frac{2 \cdot \sin(\alpha + \delta)}{1 - \sin(2 \cdot \alpha + \delta)}$$

$$F_{ch} = F_c \cdot \cos(\alpha)$$

$$F_{cv} = F_c \cdot \sin(\alpha)$$

$$E_{sp} = \frac{F_{ch} \cdot v_c}{h_i \cdot w \cdot v_c} = \sigma_T \cdot \frac{2 \cdot \sin(\alpha + \delta)}{1 - \sin(2 \cdot \alpha + \delta)} \cdot \cos(\alpha)$$

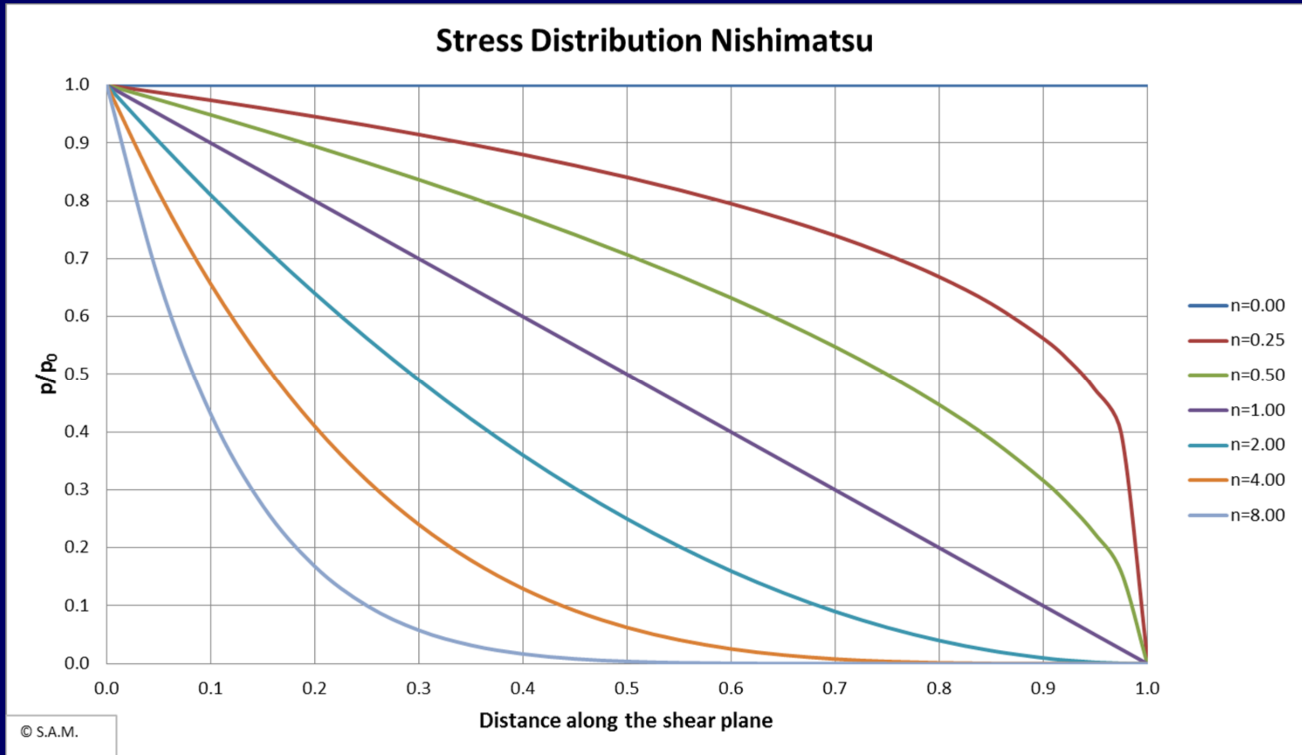
Nishimatsu



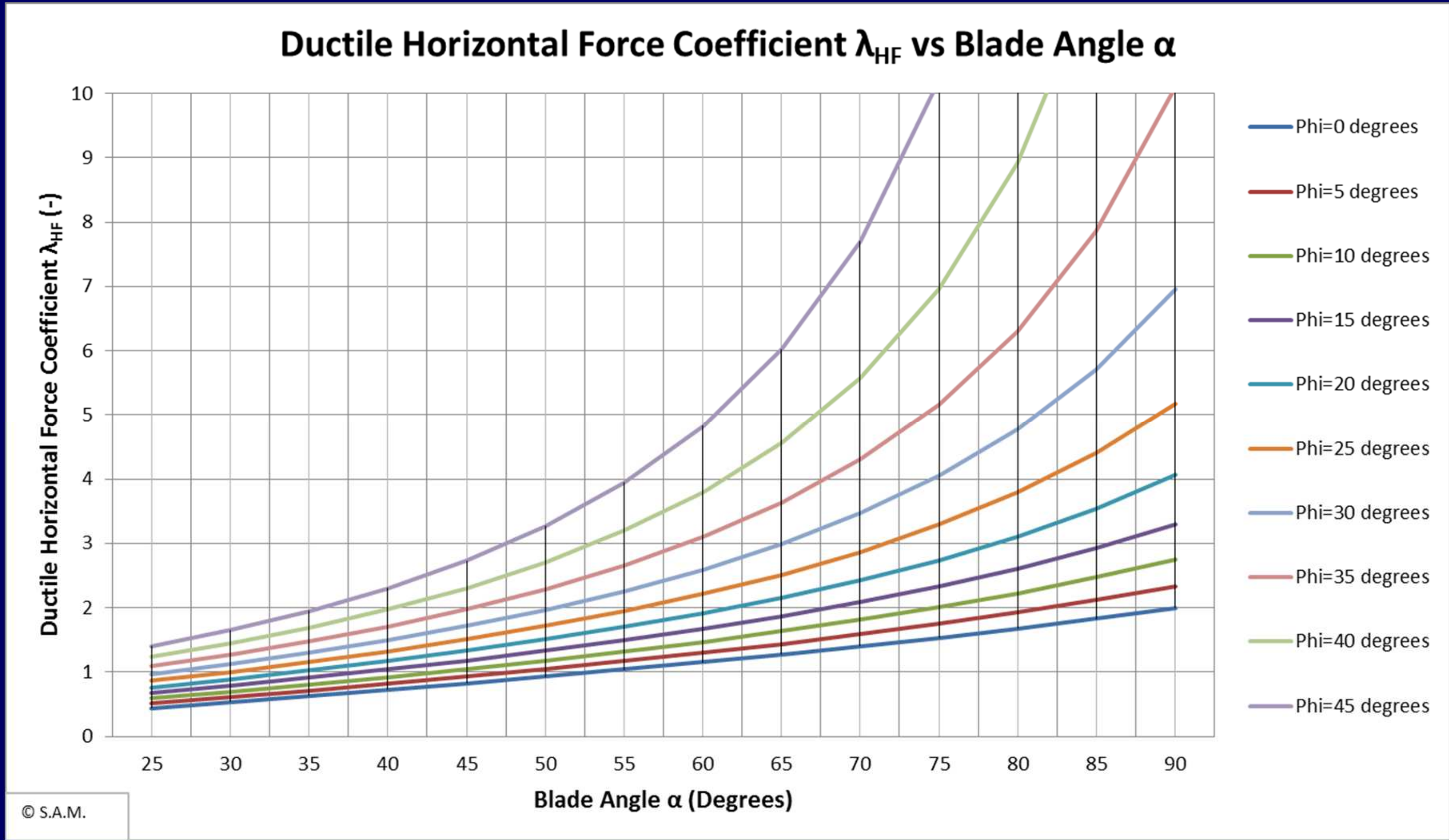
Nishimatsu

$$F_h = \frac{1}{(n+1)} \cdot \frac{2 \cdot c \cdot h_i \cdot w \cdot \cos(\varphi) \cdot \sin(\alpha+\delta)}{1+\cos(\alpha+\delta+\varphi)} = \frac{1}{(n+1)} \cdot \lambda_{HF} \cdot c \cdot h_i \cdot w$$

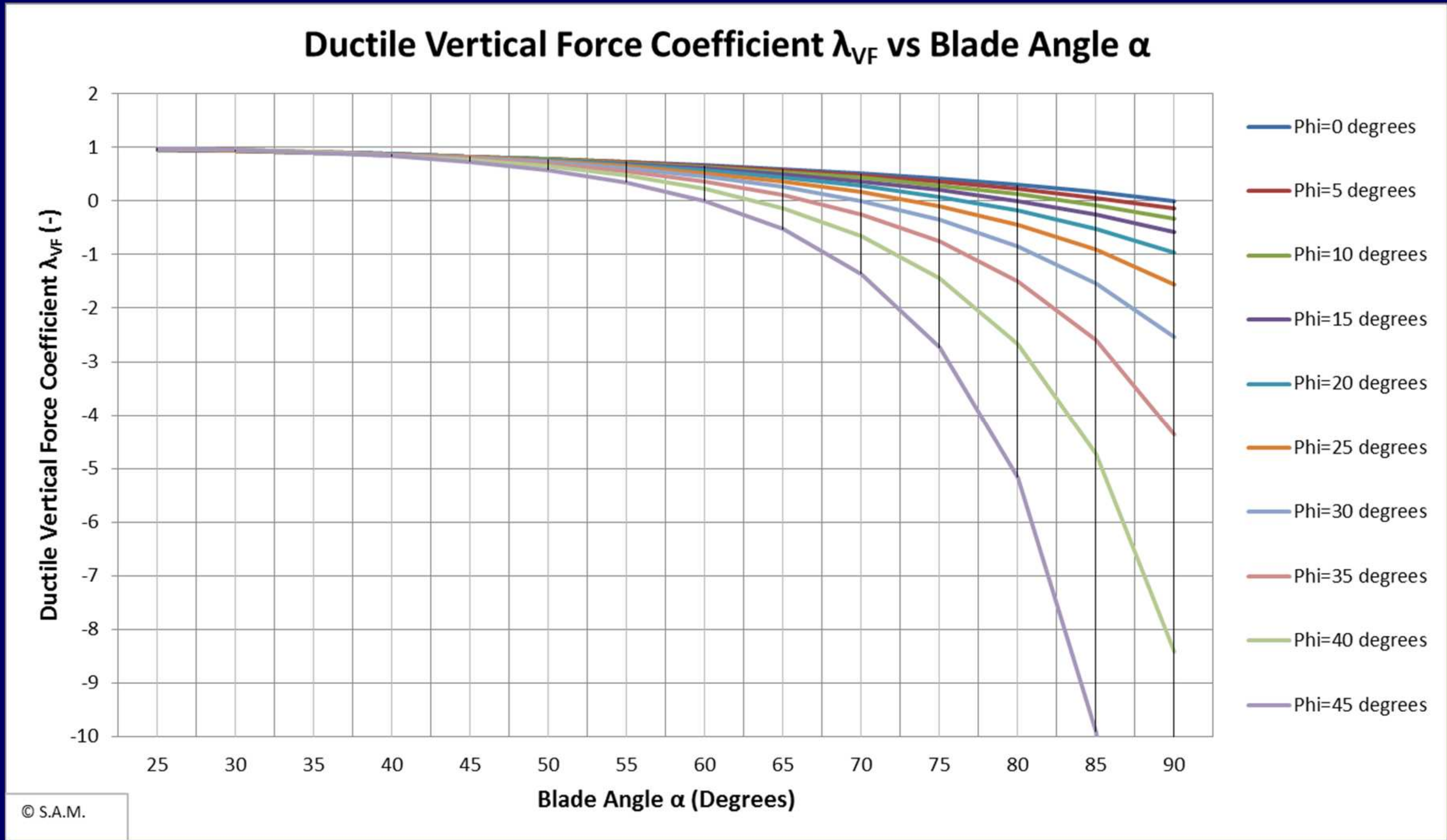
$$F_v = \frac{1}{(n+1)} \cdot \frac{2 \cdot c \cdot h_i \cdot w \cdot \cos(\varphi) \cdot \cos(\alpha+\delta)}{1+\cos(\alpha+\delta+\varphi)} = \frac{1}{(n+1)} \cdot \lambda_{VF} \cdot c \cdot h_i \cdot w$$



The Ductile Horizontal Coefficient



The Ductile Vertical Coefficient



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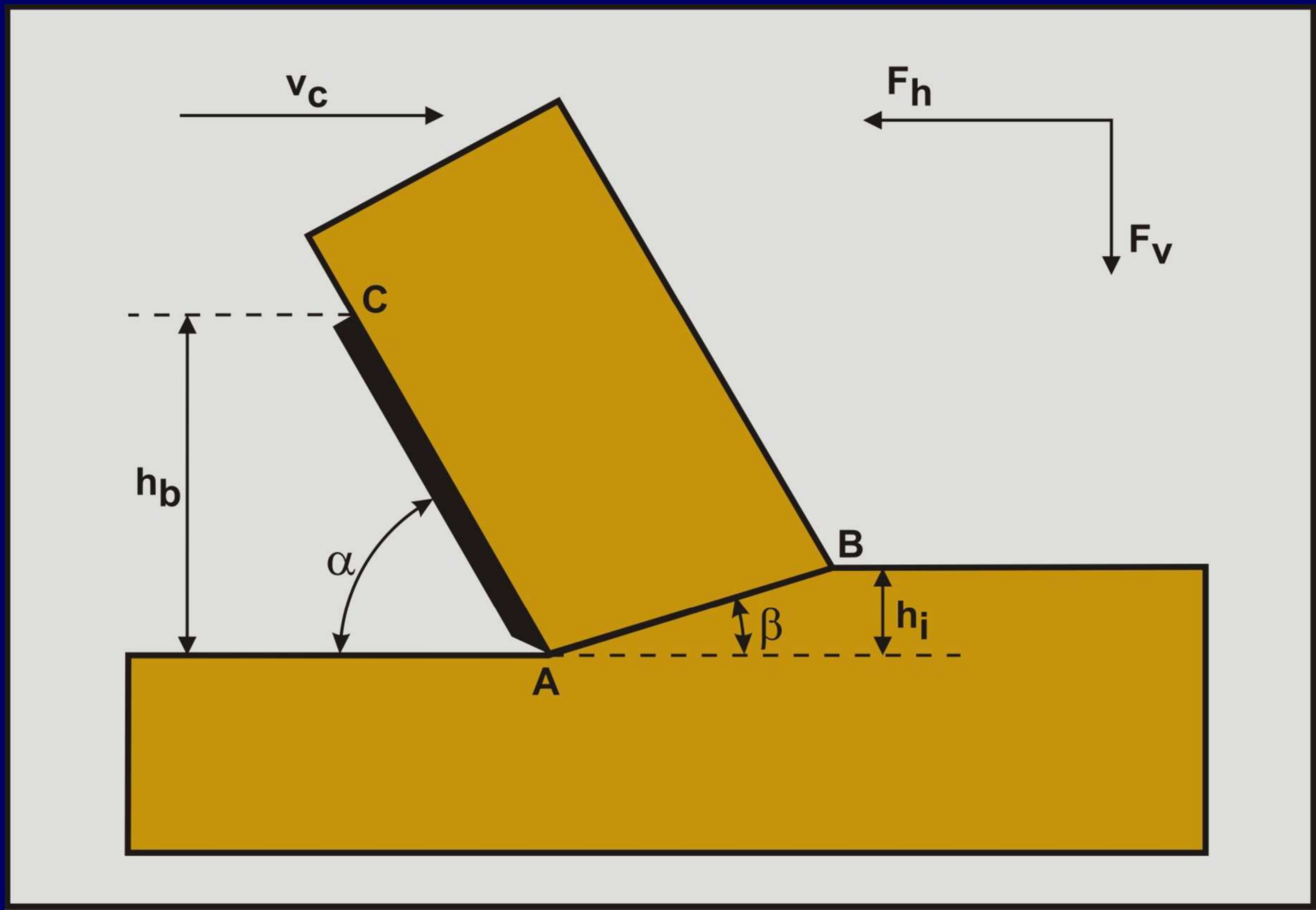
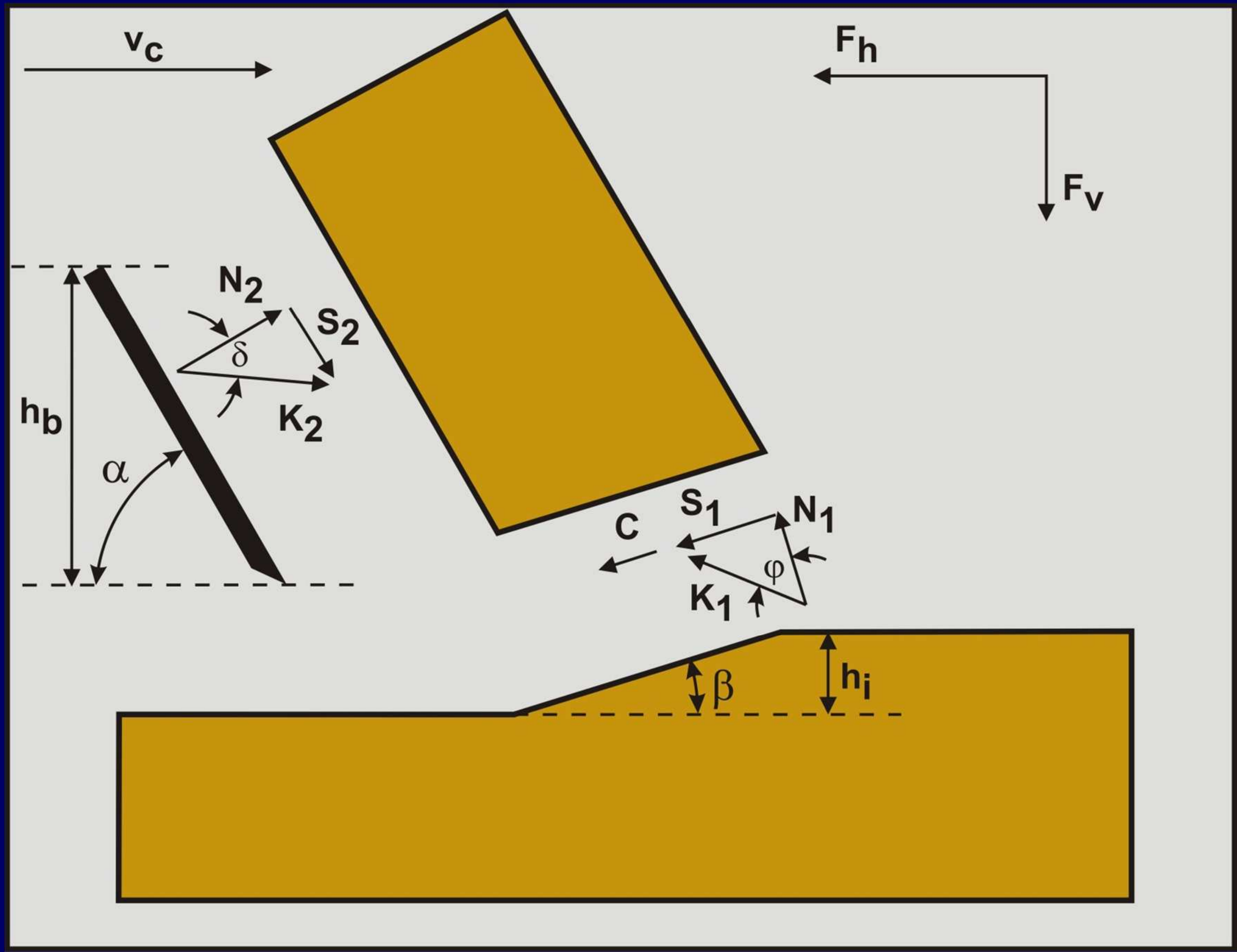
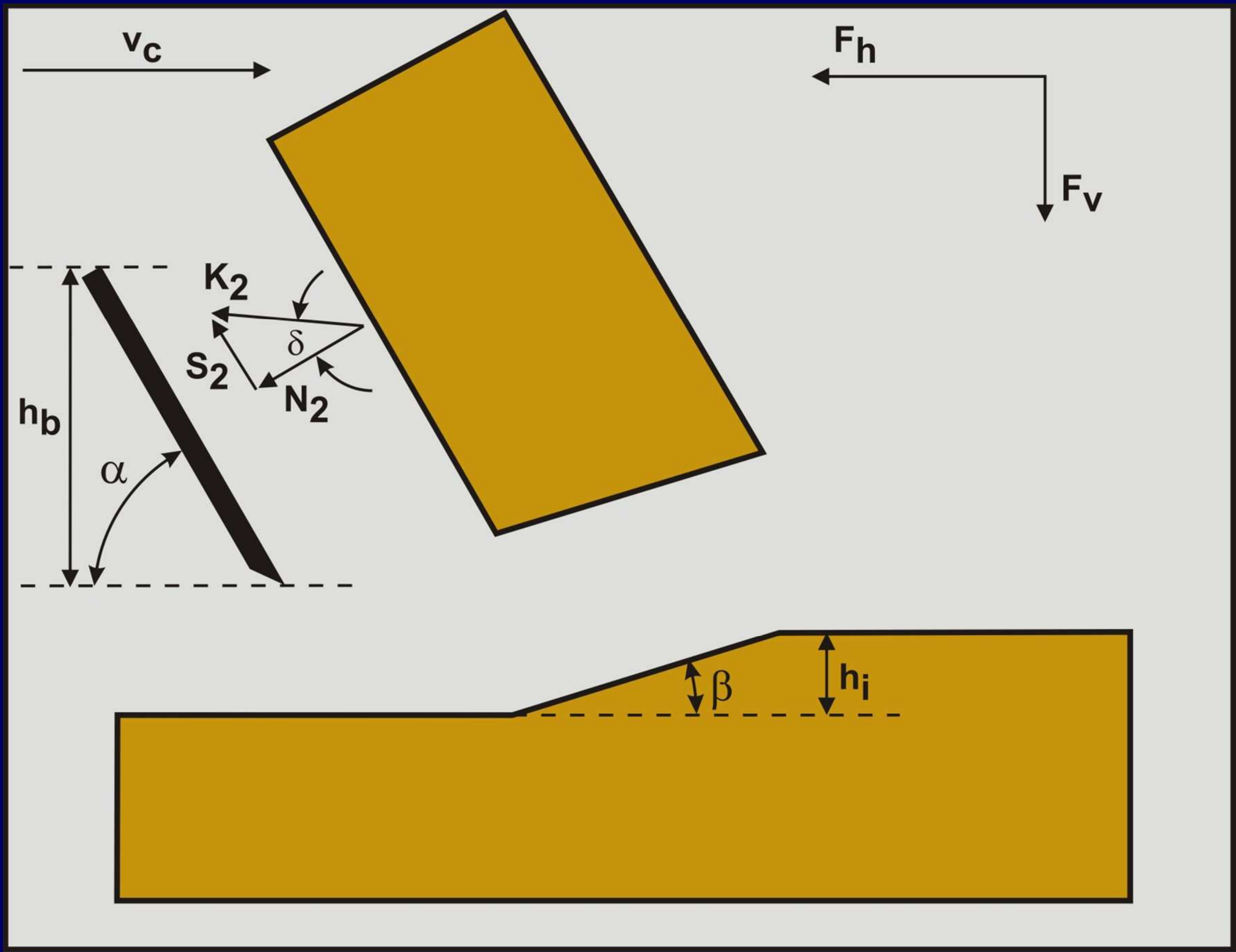
Definitions



Forces on the Layer Cut



Forces on the Blade



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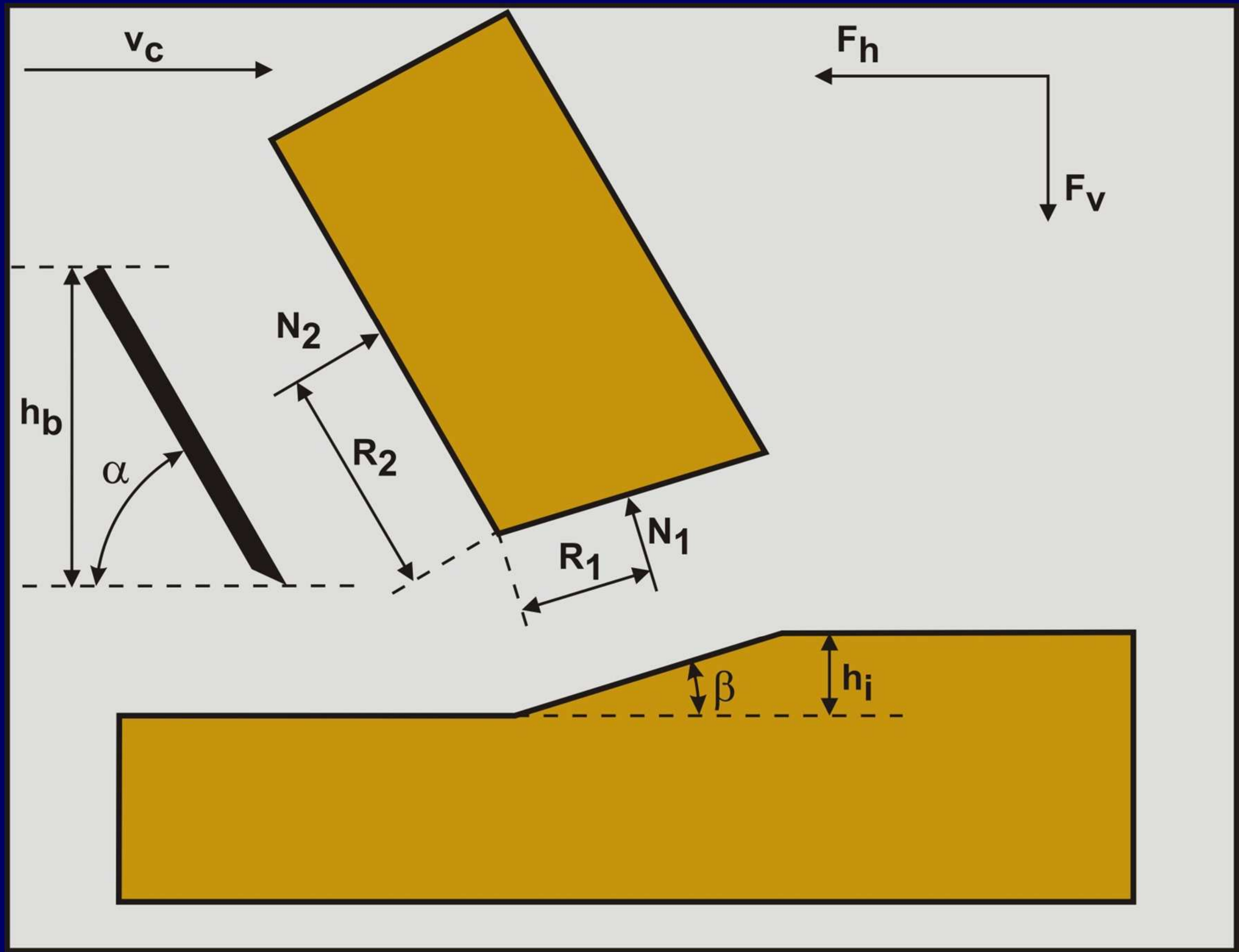
Moments



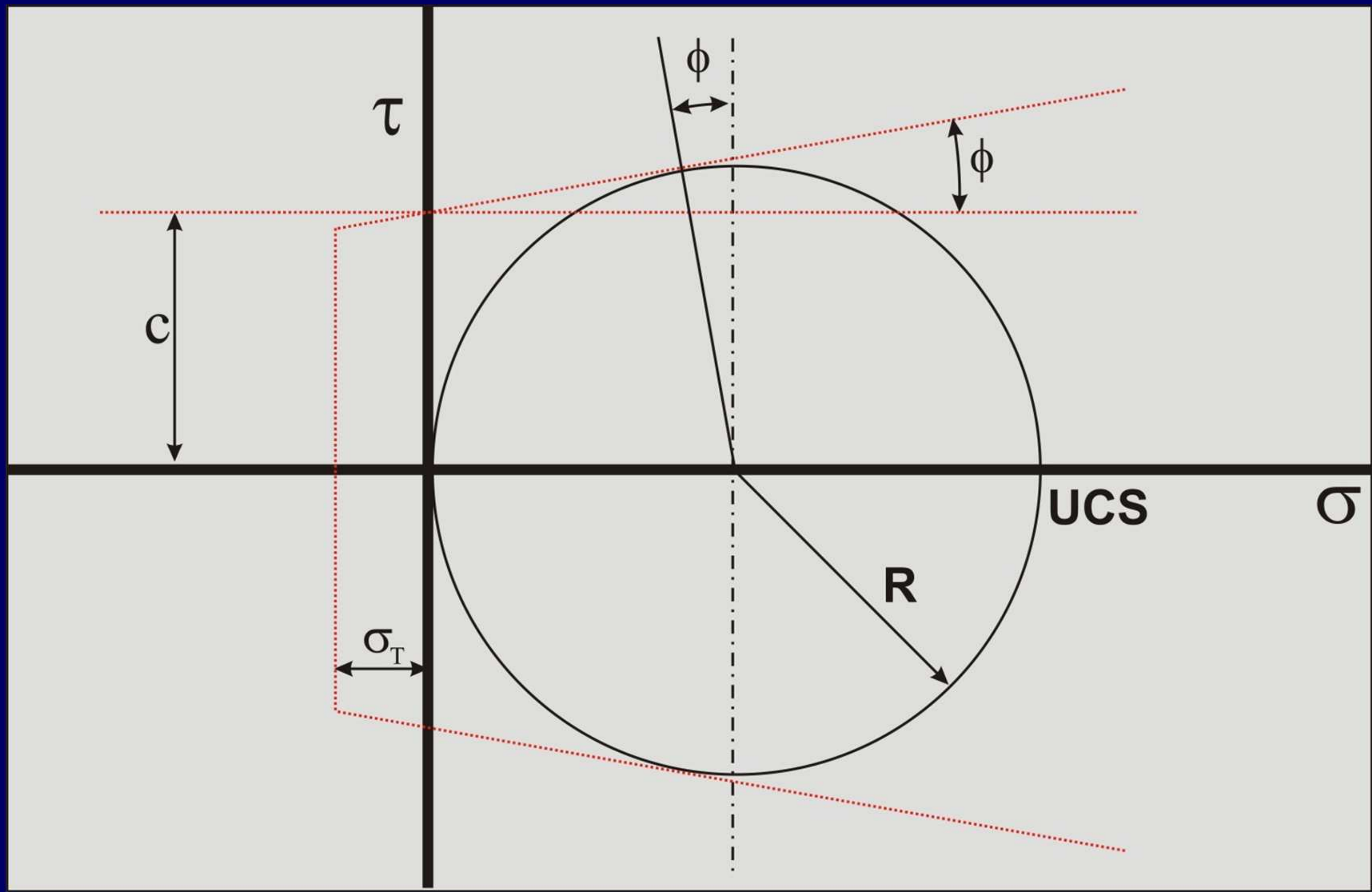
Resulting Equations

$$K_2 = \frac{C \cdot \cos(\varphi)}{\sin(\alpha + \beta + \delta + \varphi)}$$

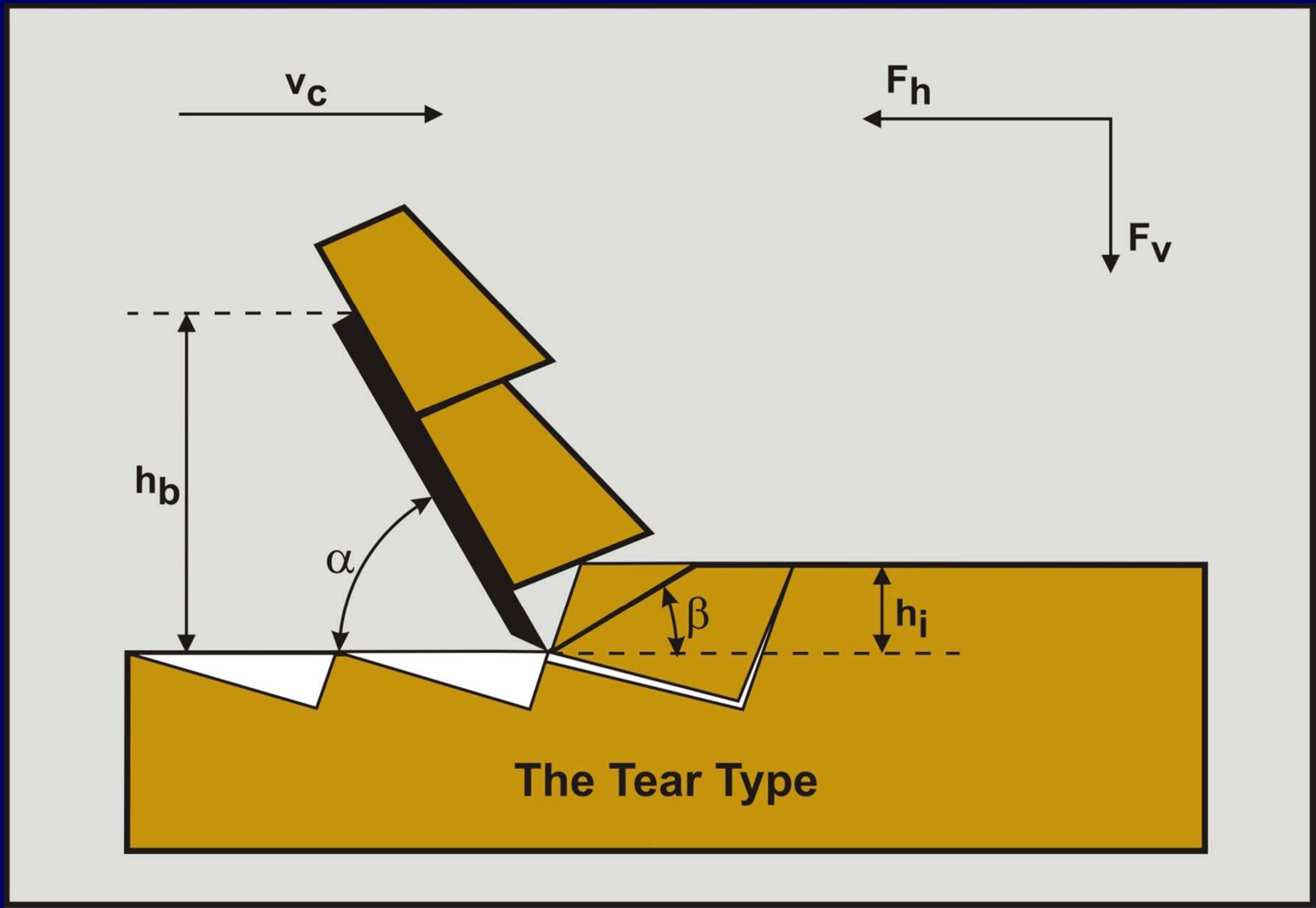
$$F_h = K_2 \cdot \sin(\alpha + \delta)$$

$$F_v = K_2 \cdot \cos(\alpha + \delta)$$

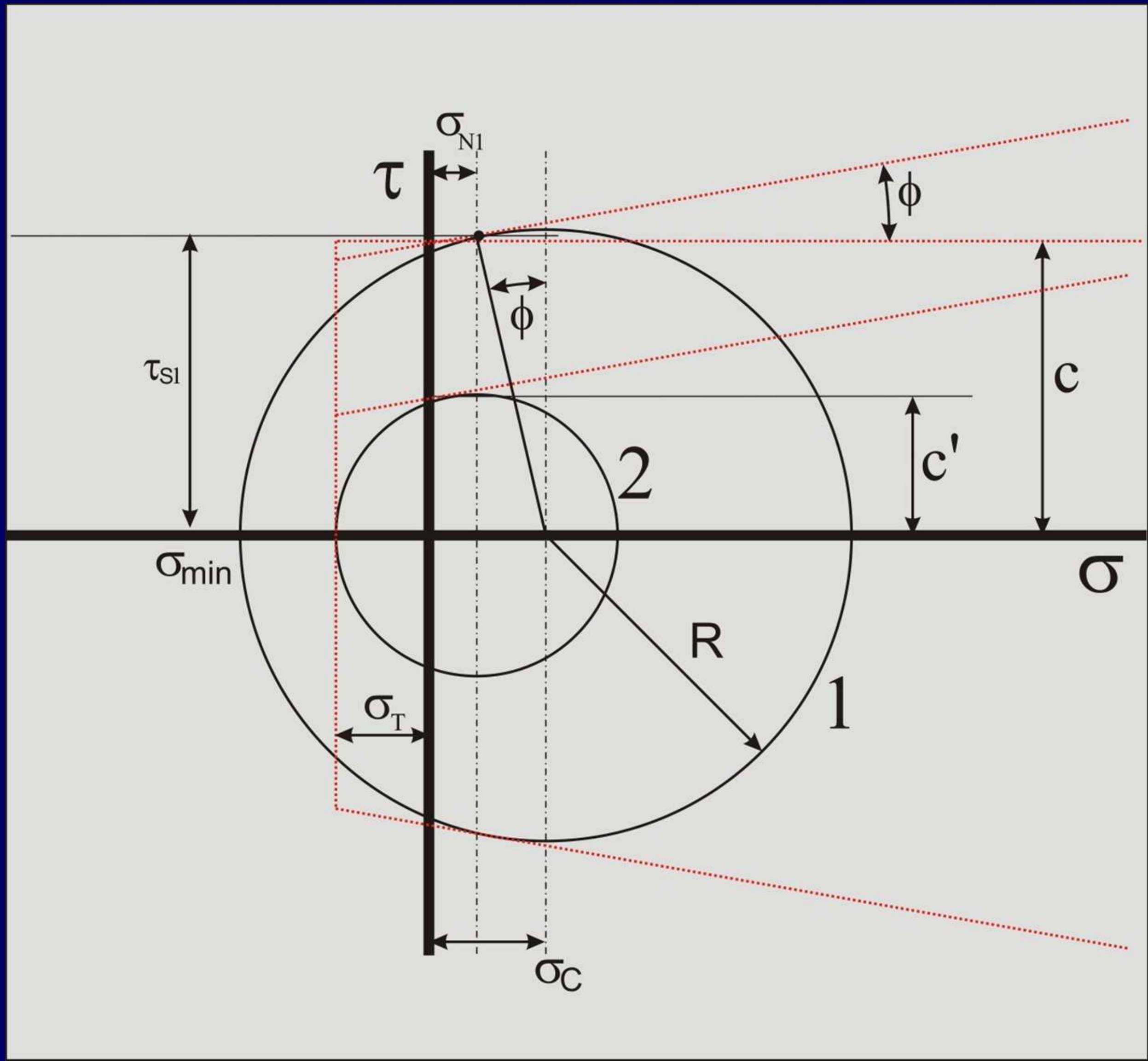
Mohr Circle



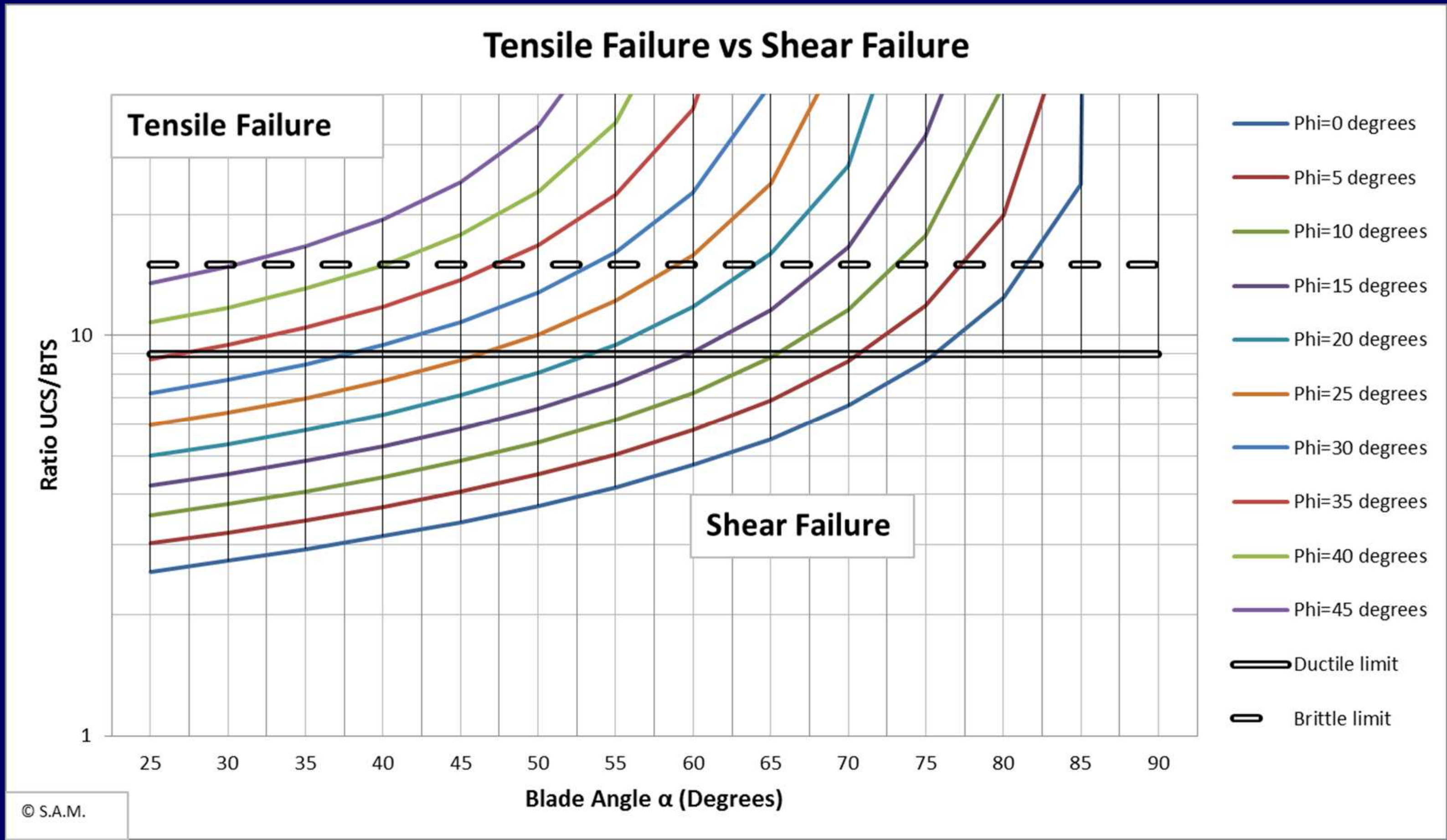
Brittle Cutting



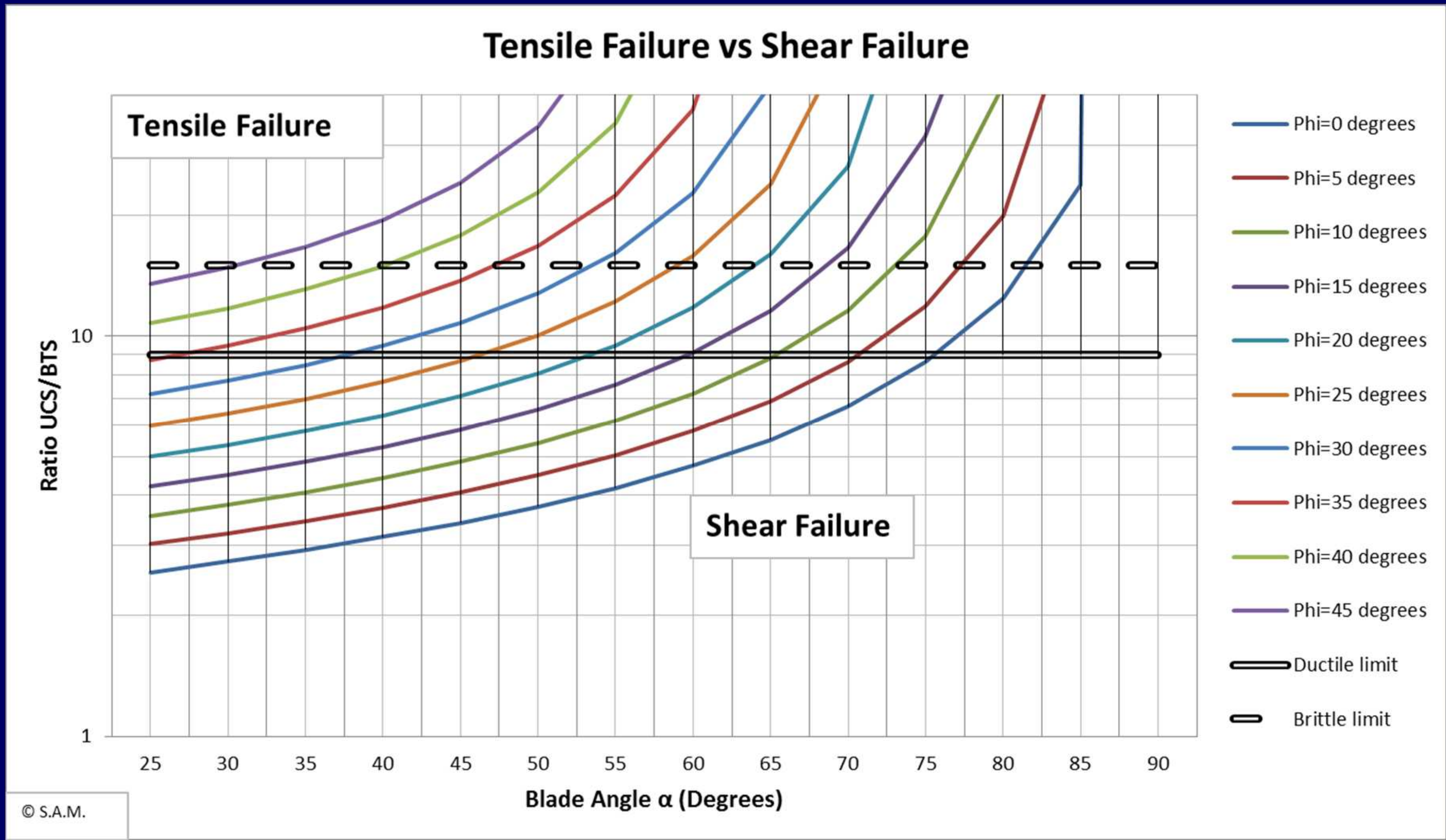
Tensile Failure



Transition Tensile Failure – Shear Failure



Transition Tensile Failure – Shear Failure



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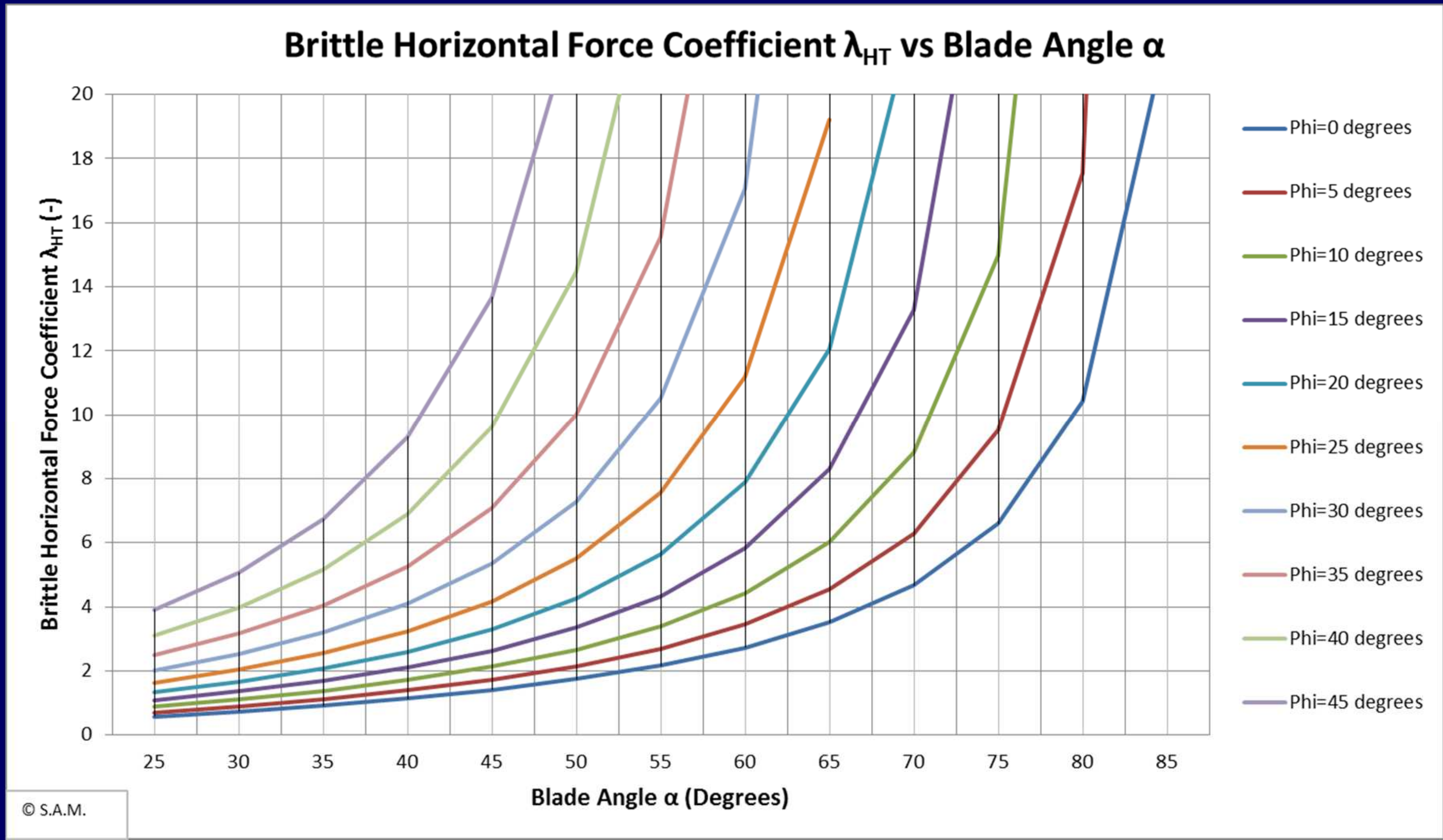
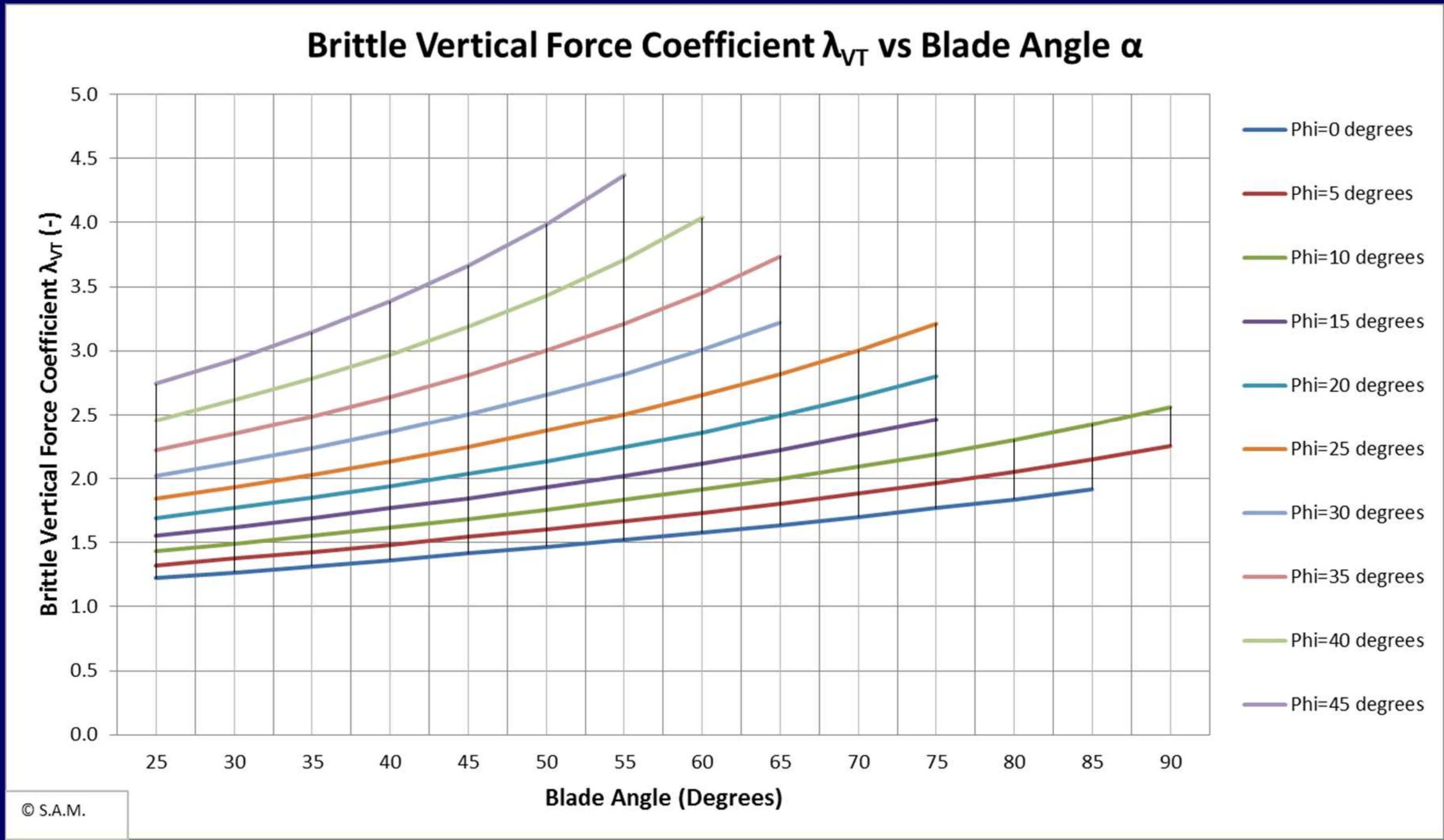
The Brittle Horizontal Coefficients



The Brittle Vertical Coefficients



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Hyperbaric Rock Cutting

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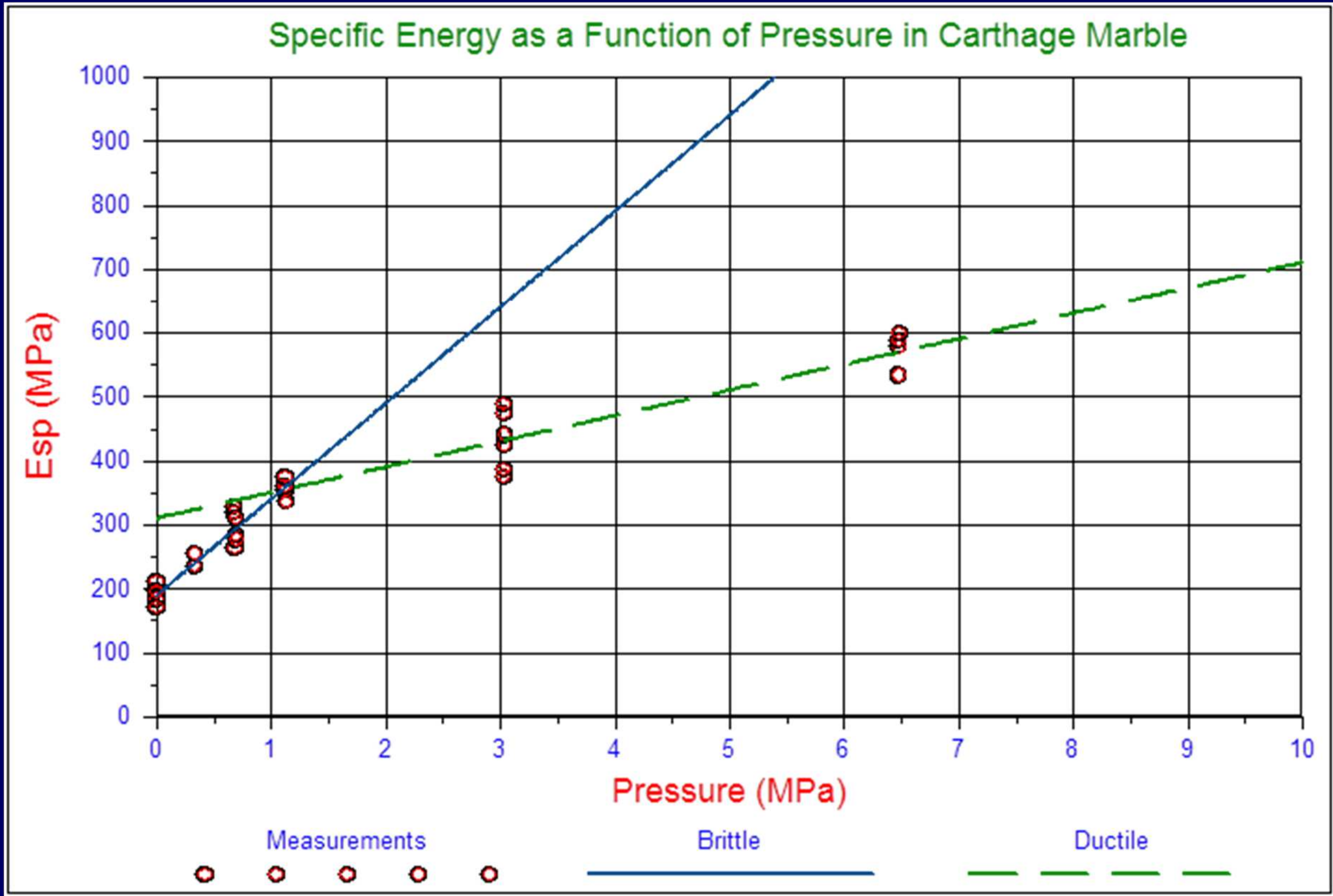
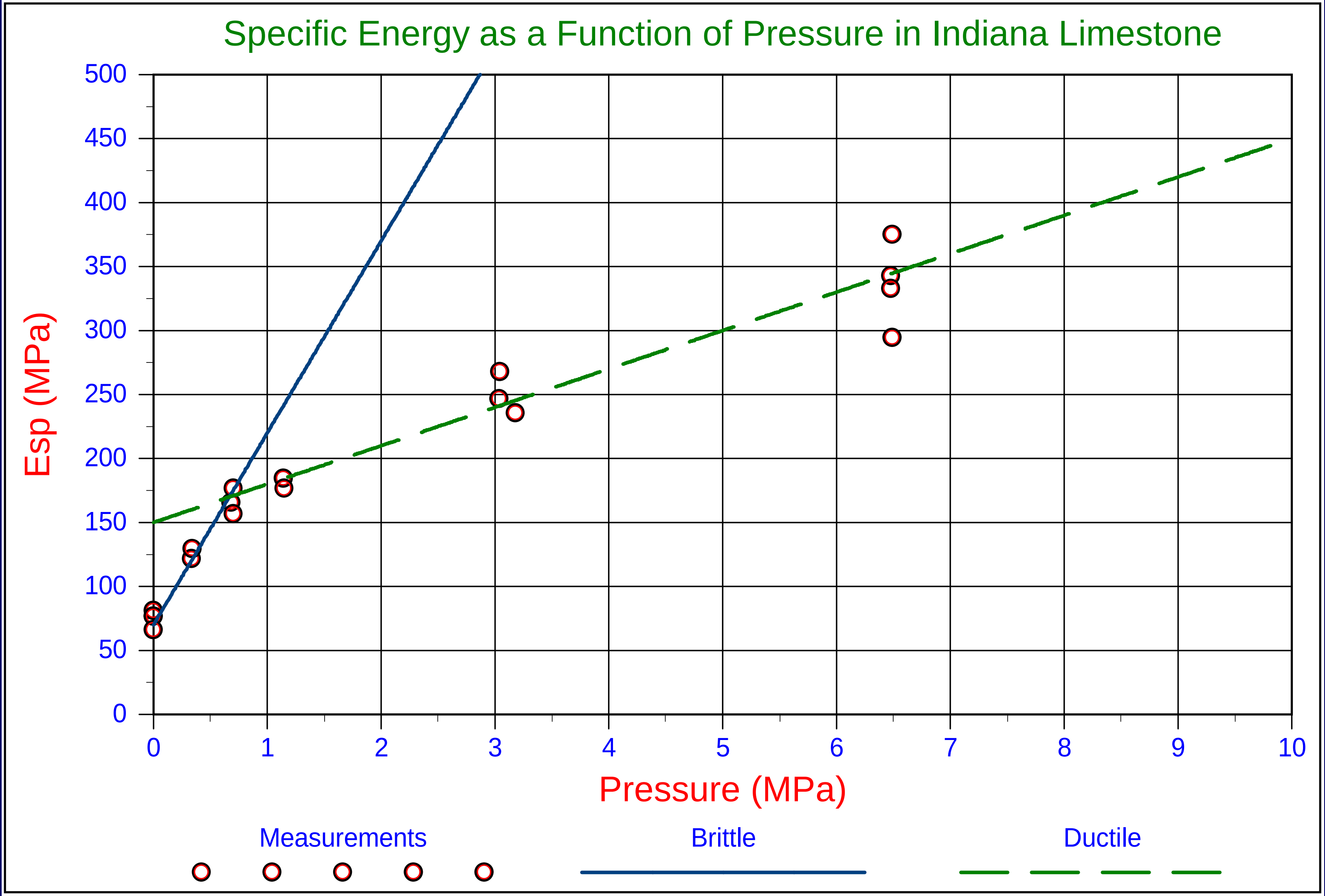
Measurements in Carthage Marble by Rafatian



Measurements in Indiana Limestone by Rafatian



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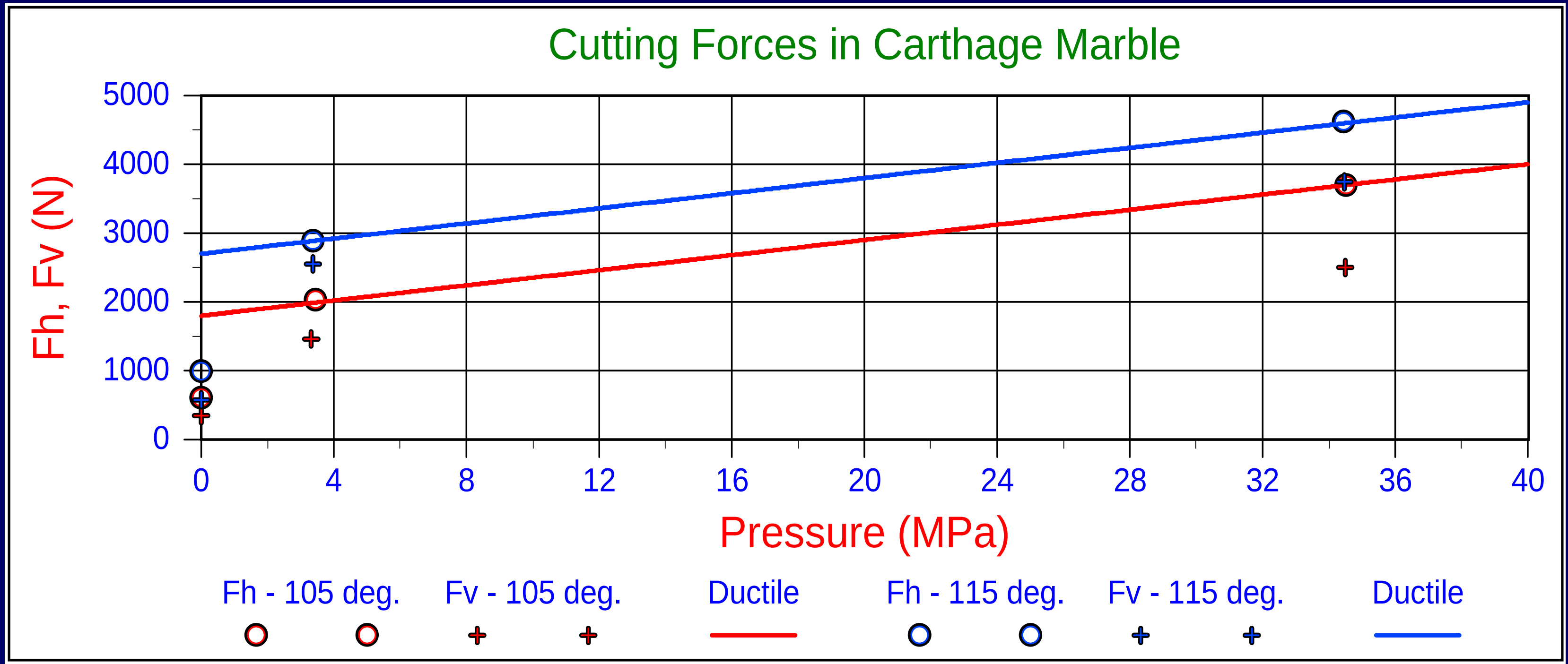
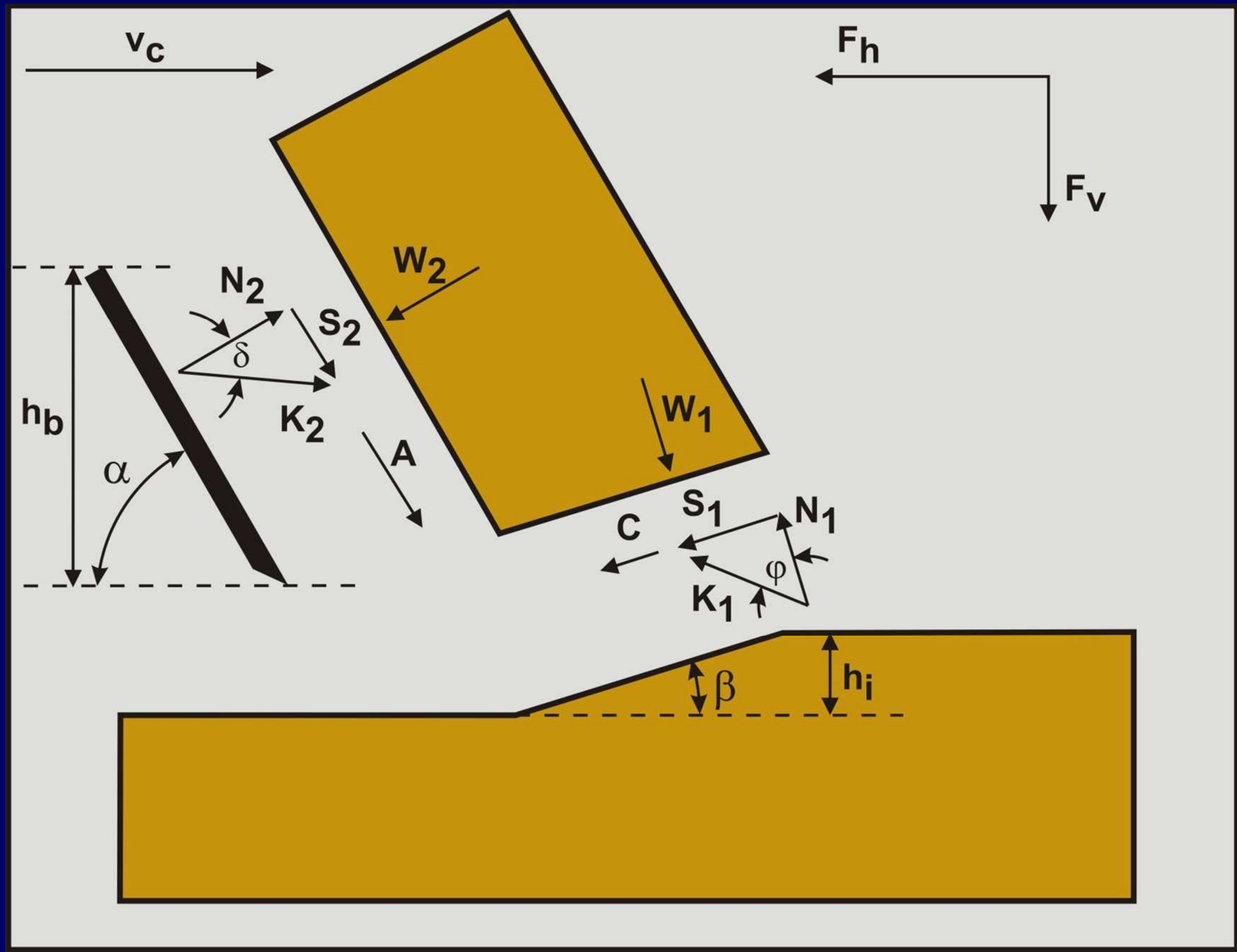
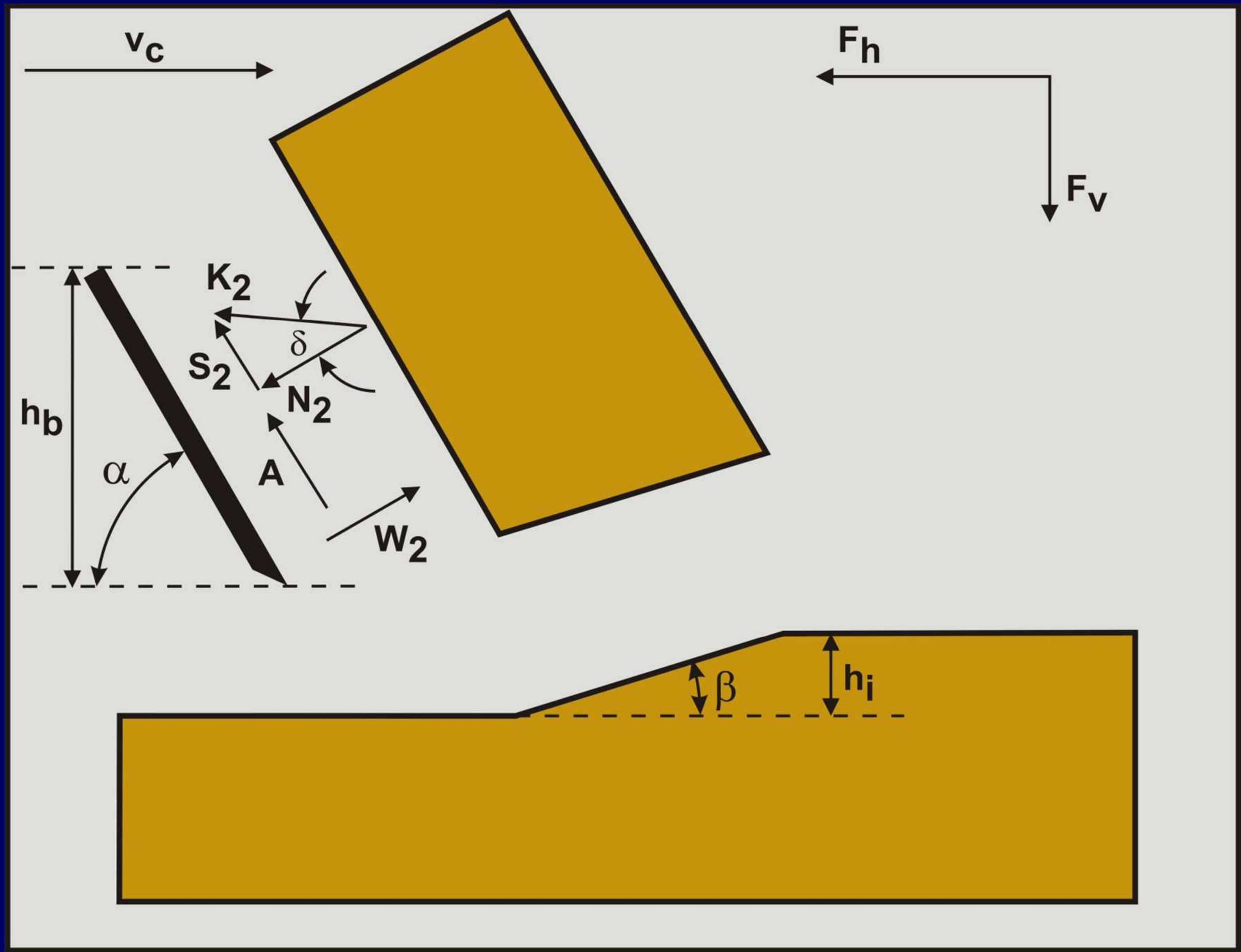
Measurements of Kaitkai & Lei



Forces on the Layer Cut



Forces on the Blade



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Resulting Equations

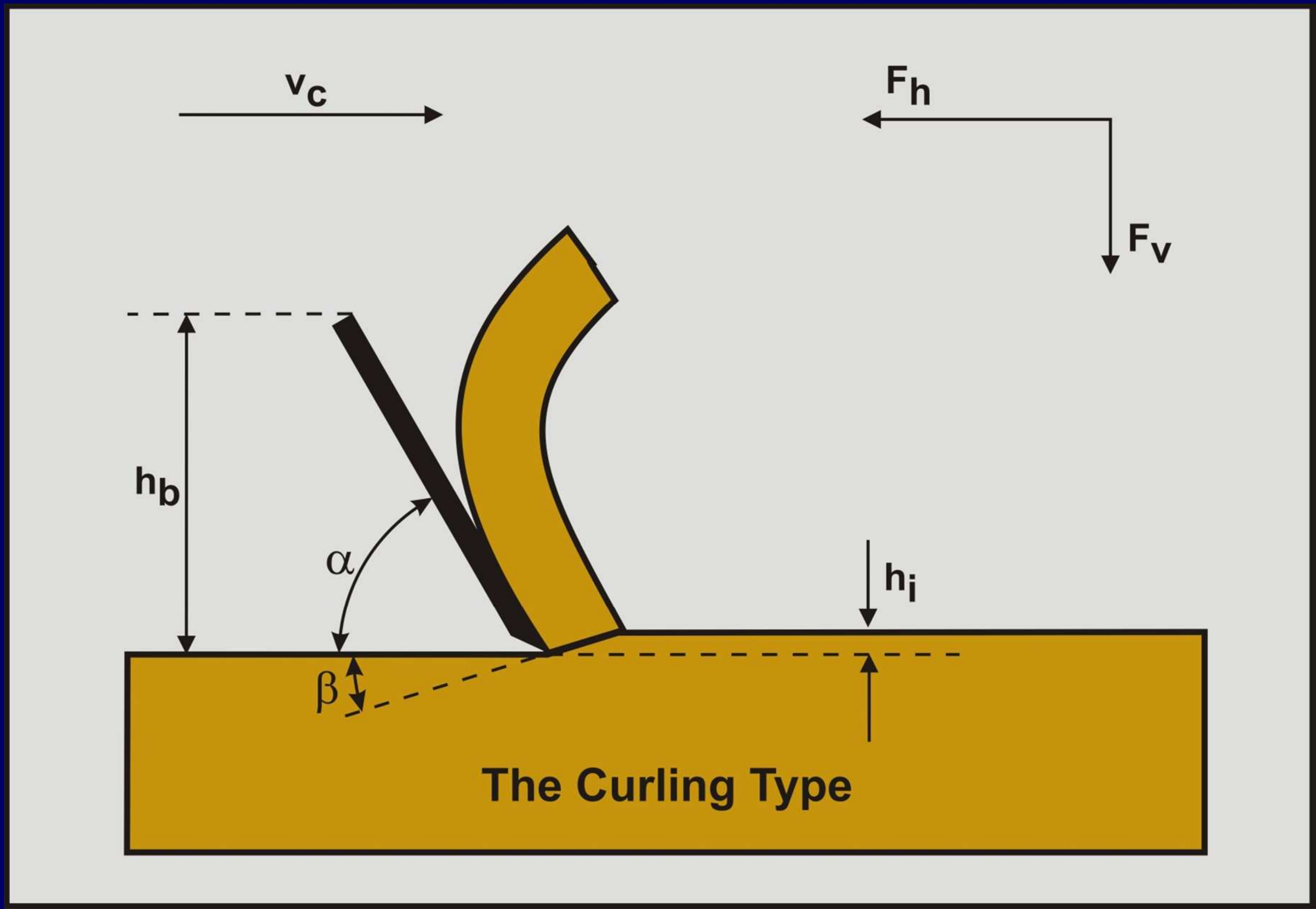
$$K_2 = \frac{W_2 \cdot \sin(\alpha + \beta + \varphi) + W_1 \cdot \sin(\varphi)}{\sin(\alpha + \beta + \delta + \varphi)}$$

$$+ \frac{C \cdot \cos(\varphi)}{\sin(\alpha + \beta + \delta + \varphi)}$$

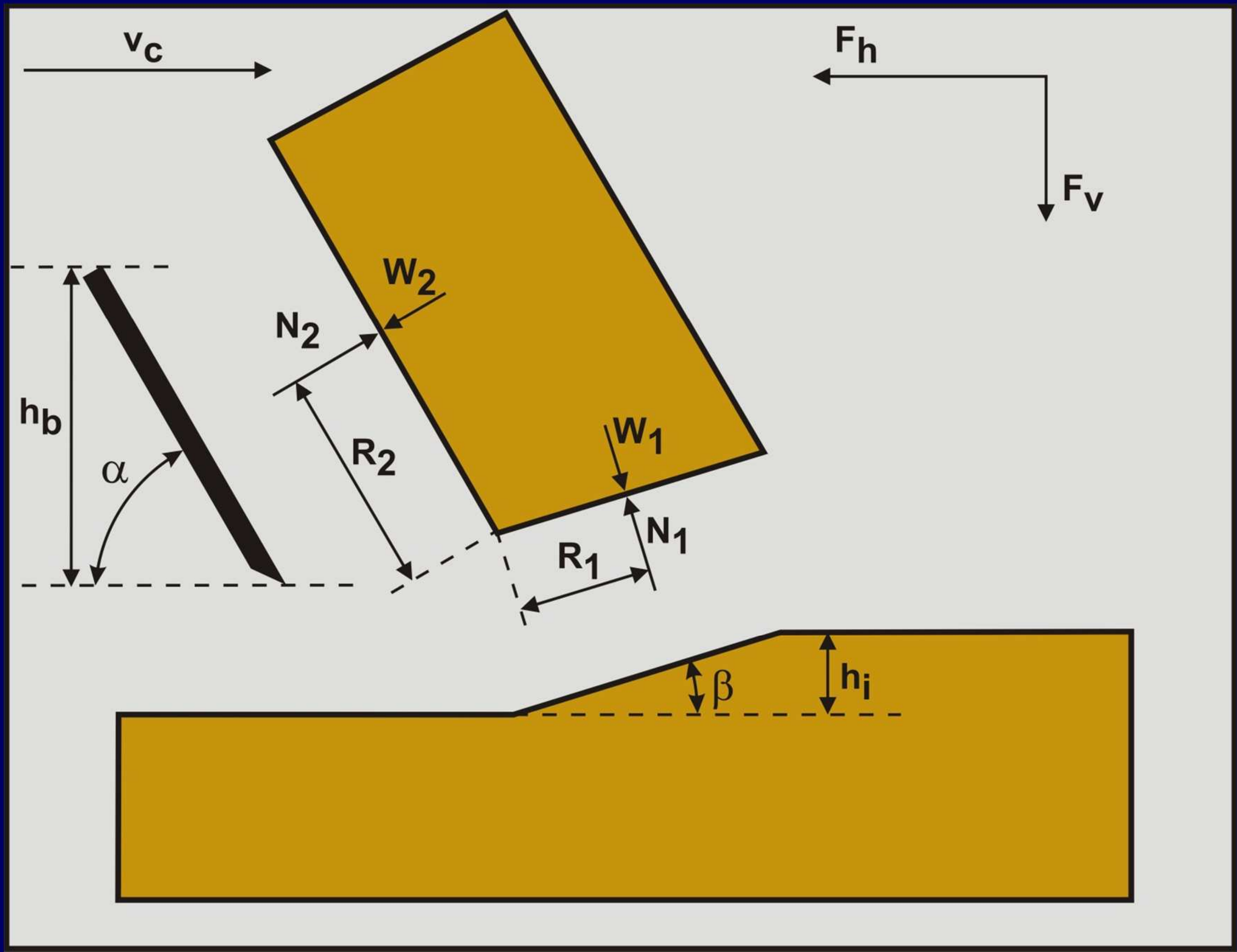
$$F_h = -W_2 \cdot \sin(\alpha) + K_2 \cdot \sin(\alpha + \delta)$$

$$F_v = -W_2 \cdot \cos(\alpha) + K_2 \cdot \cos(\alpha + \delta)$$

Curling/Balling Type



Moments



Equilibrium of Moments

$$\left(\frac{W_2\cdot\sin(\delta)+W_1\cdot\sin(\alpha+\beta+\delta)-C\cdot\cos(\alpha+\beta+\delta)+A\cdot\cos(\delta)}{\sin(\alpha+\beta+\delta+\varphi)}\cdot\cos(\varphi)-W_1\right)\cdot\frac{\lambda_1\cdot h_i}{\sin(\beta)}$$

$$=\left(\frac{W_2\cdot\sin(\alpha+\beta+\varphi)+W_1\cdot\sin(\varphi)+C\cdot\cos(\varphi)-A\cdot\cos(\alpha+\beta+\varphi)}{\sin(\alpha+\beta+\delta+\varphi)}\cdot\cos(\delta)-W_2\right)\cdot\frac{\lambda_2\cdot h_b'}{\sin(\alpha)}$$

$$A\cdot x^2+B\cdot x+C=0$$

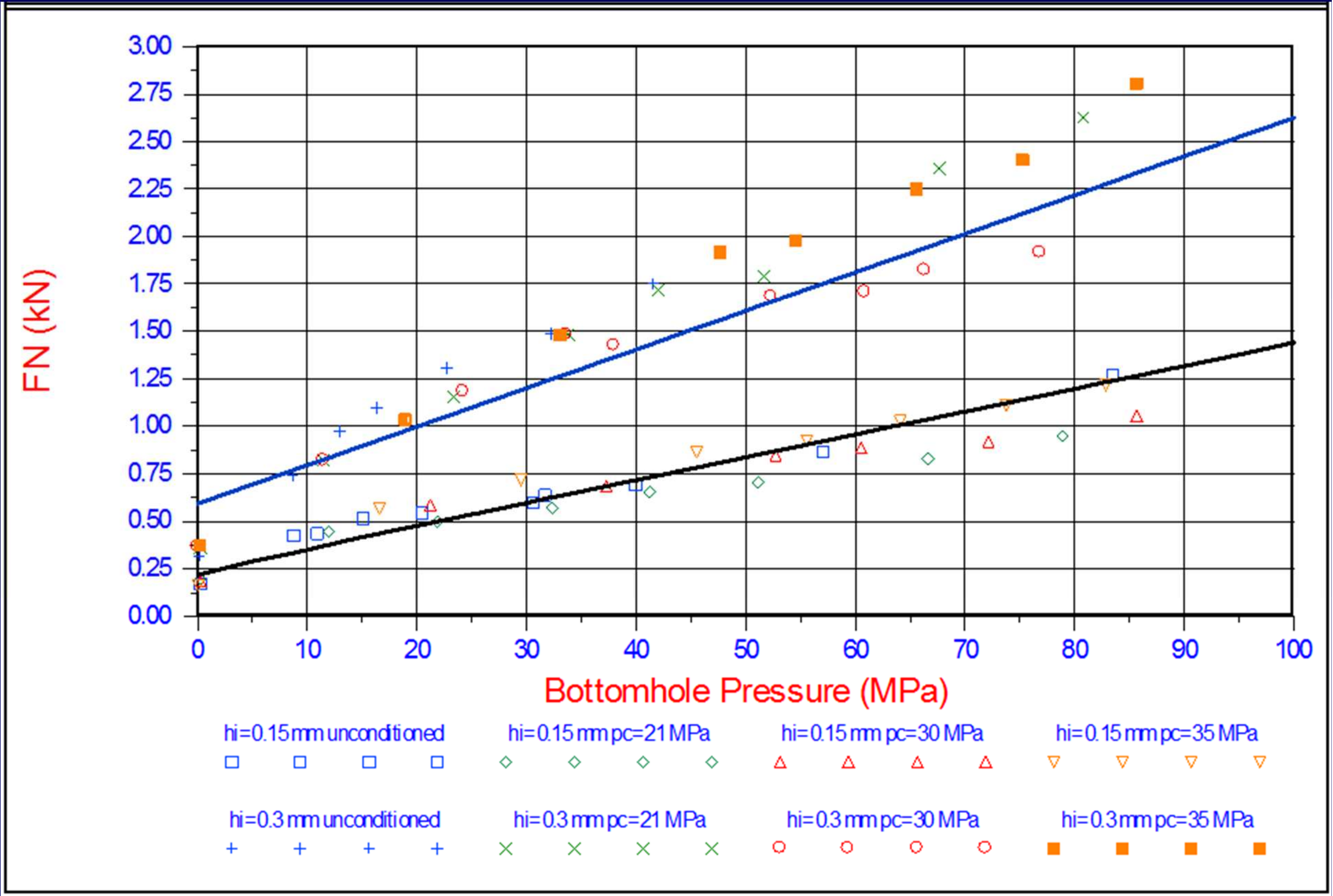
$$h_b'=x=\frac{-B-\sqrt{B^2-4\cdot A\cdot C}}{2\cdot A}$$

$$A=\frac{\lambda_2\cdot p_{2m}\cdot\sin(\alpha+\beta+\delta+\varphi)-\lambda_2\cdot p_{2m}\cdot\sin(\alpha+\beta+\varphi)\cdot\cos(\delta)+a\cdot\lambda_2\cdot\cos(\alpha+\beta+\varphi)\cdot\cos(\delta)}{\sin(\alpha)\cdot\sin(\alpha)}$$

$$B=\frac{\lambda_1\cdot p_{2m}\cdot\sin(\delta)\cdot\cos(\varphi)-\lambda_2\cdot p_{1m}\cdot\cos(\delta)\cdot\sin(\varphi)-c\cdot\lambda_2\cdot\cos(\delta)\cdot\cos(\varphi)+a\cdot\lambda_1\cdot\cos(\varphi)\cdot\cos(\delta)}{\sin(\alpha)\cdot\sin(\beta)}\cdot h_i$$

$$C=\frac{\lambda_1\cdot p_{1m}\cdot\sin(\alpha+\beta+\delta)\cdot\cos(\varphi)-\lambda_1\cdot p_{1m}\cdot\sin(\alpha+\beta+\delta+\varphi)-c\cdot\lambda_1\cdot\cos(\alpha+\beta+\delta)\cdot\cos(\varphi)}{\sin(\beta)\cdot\sin(\beta)}\cdot h_i\cdot h_i$$

Forces measured by Zijsling



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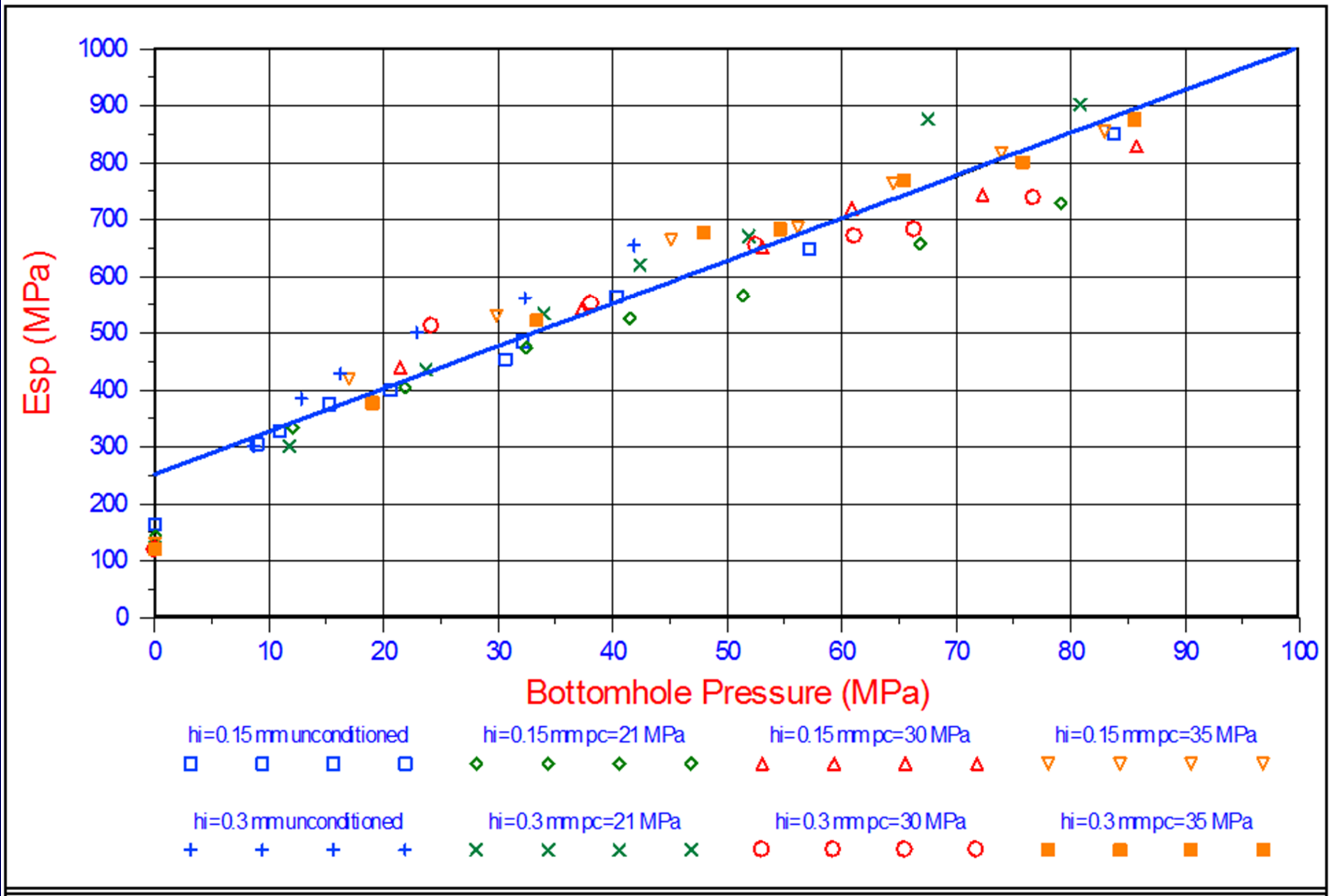
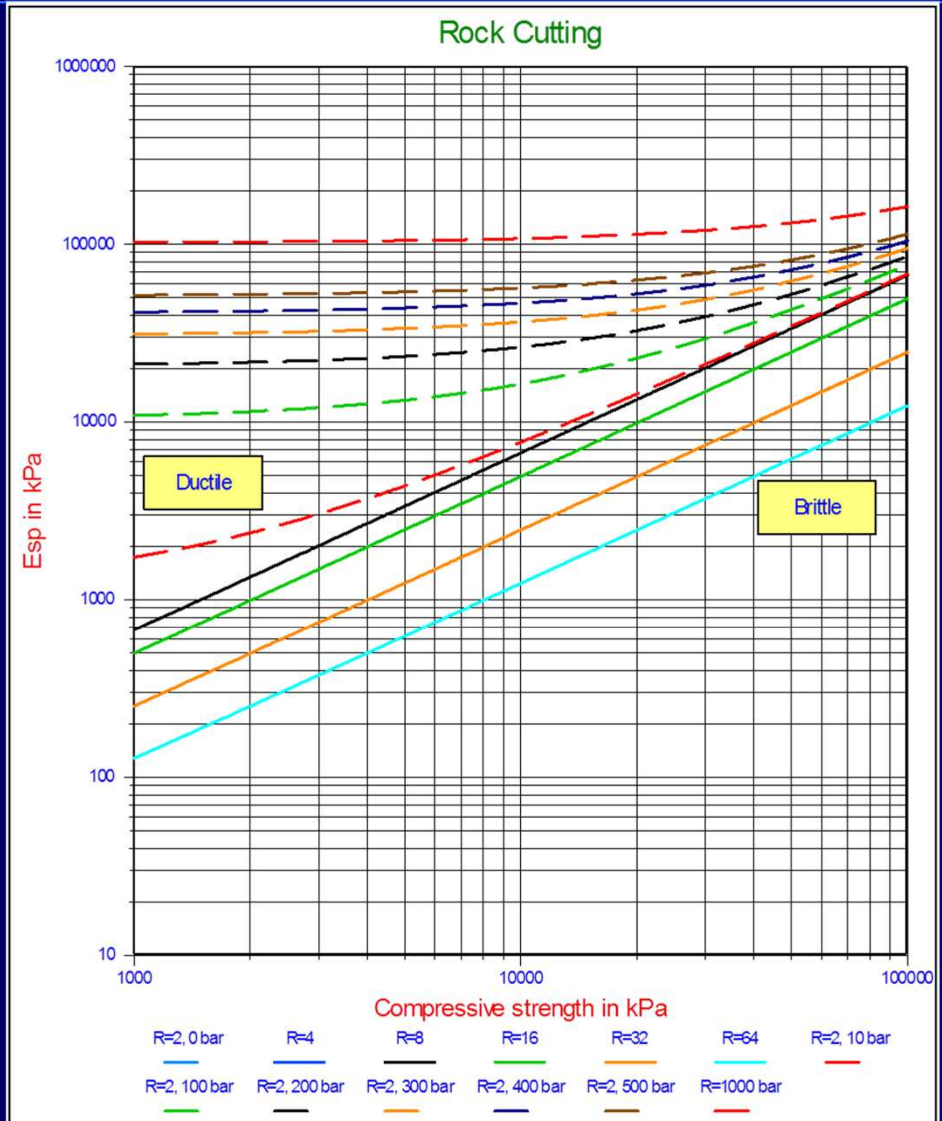
Specific Energy measured by Zijsling

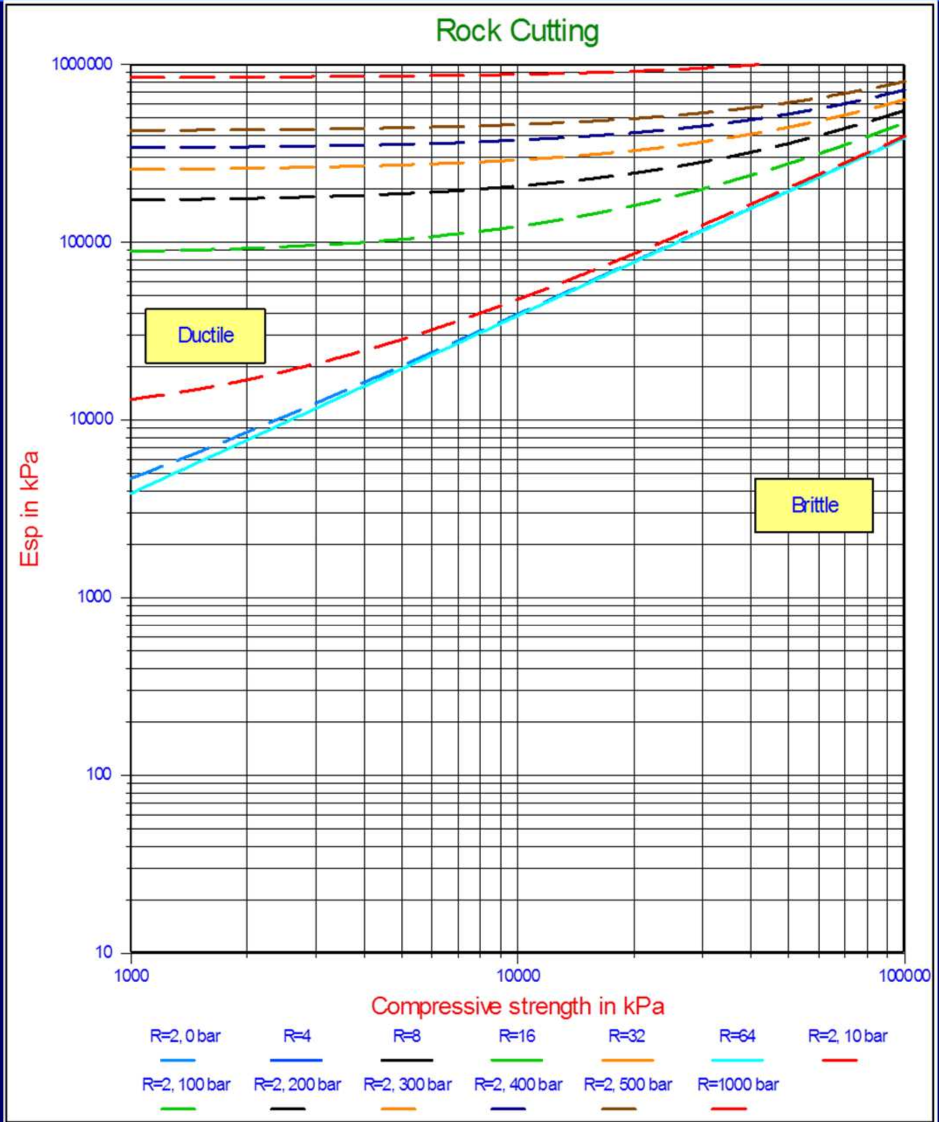


Specific Energy 60 Degrees



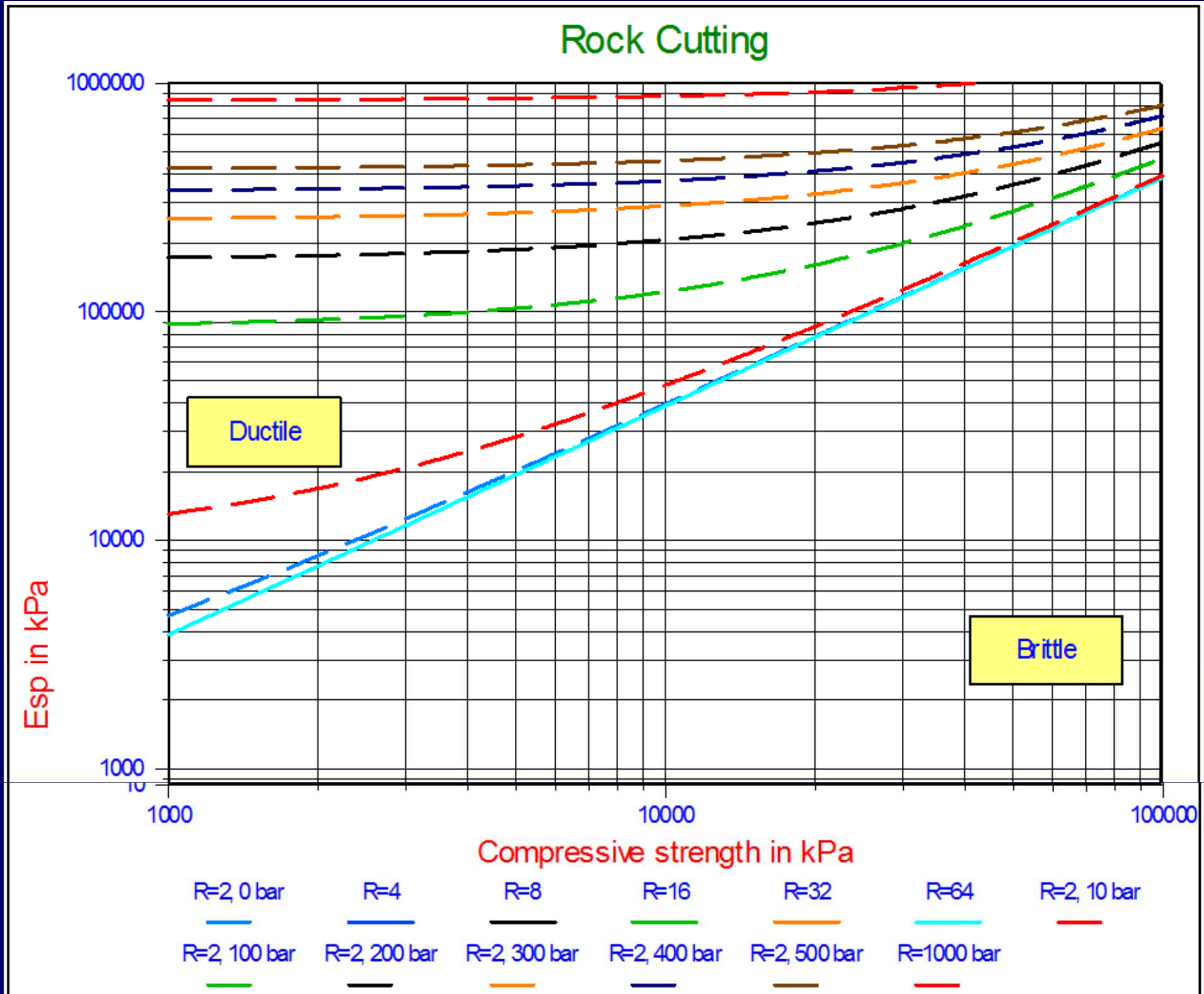
The specific energy Esp as a function of the compressive strength of rock,
for different ratio's between the compressive strength and the tensile strength.
For a 60 degree blade.

Specific Energy 110 Degrees



The specific energy Esp as a function of the compressive strength of rock, for different ratio's between the compressive strength and the tensile strength. For a 110 degree blade.

Specific Energy



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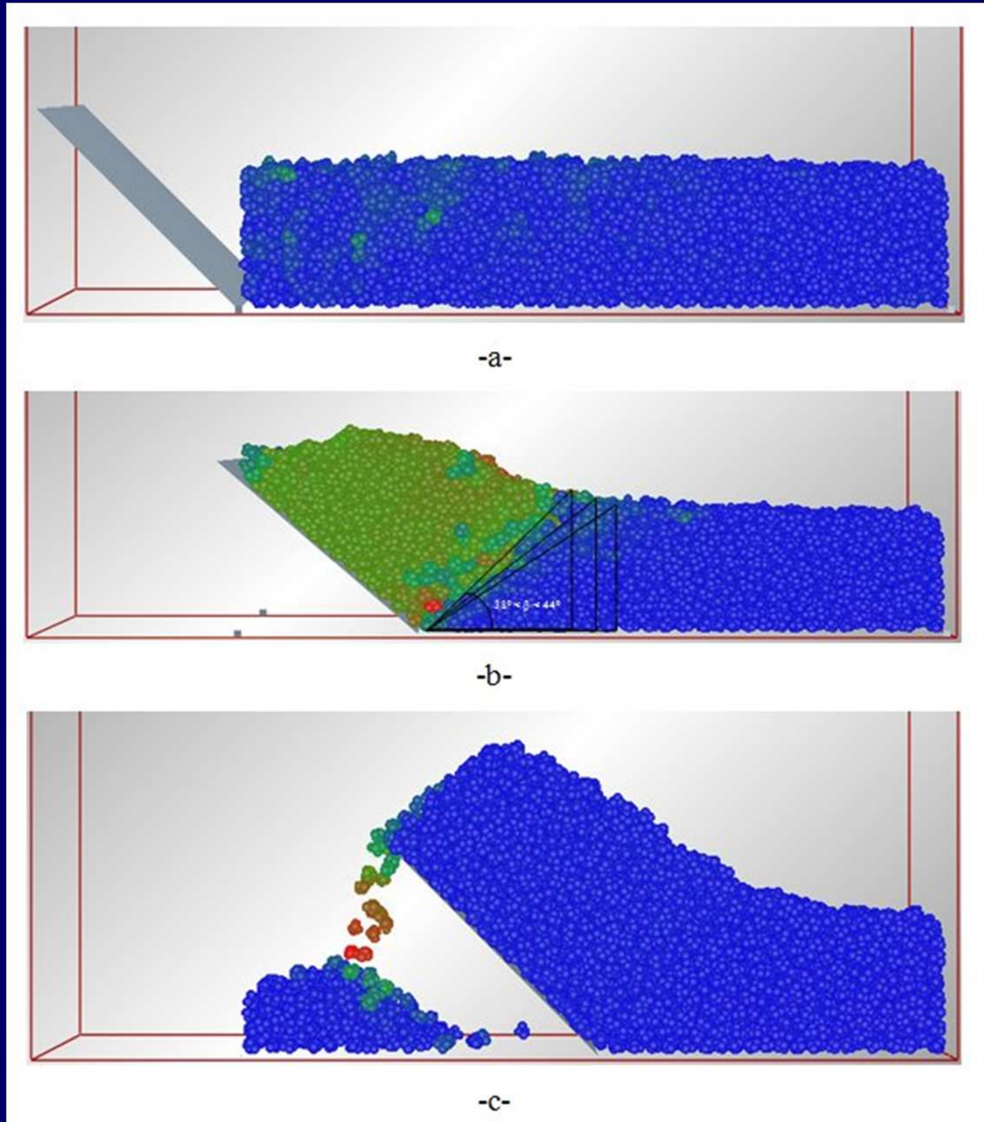
Deep Sea Mining



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Questions?

Sources images

1. A model cutter head, source: Delft University of Technology.
2. Off shore platform, source: Castrol (Switzerland) AG
3. Off shore platform, source: http://www.wireropetraining.com
4. Different rock cutterheads, source: unknown.
5. Brittle and ductile rock cutting, source: unknown.