Dredging Processes

Dr.ir. Sape A. Miedema

4. Sand Cutting

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Dredging A Way Of Life

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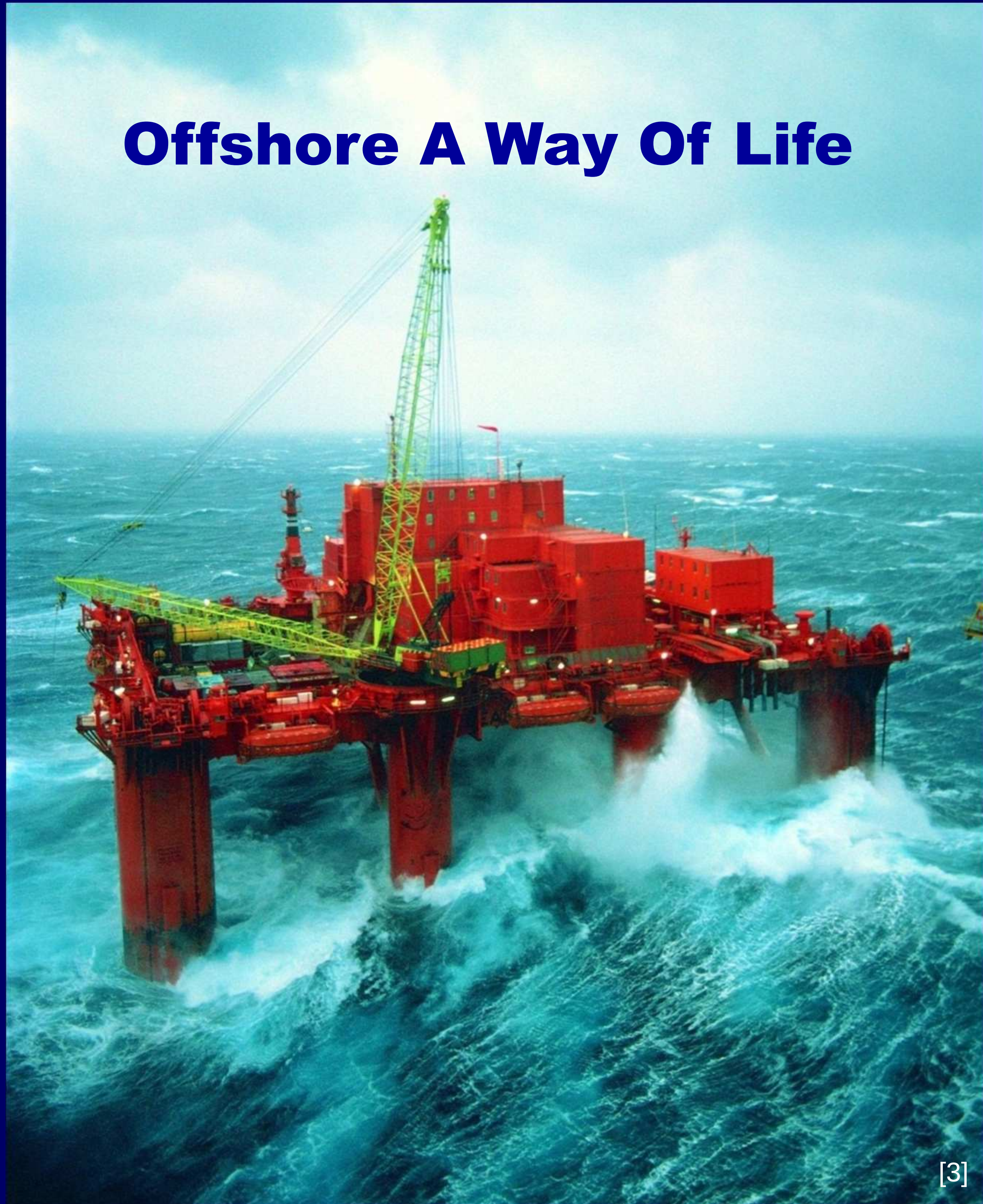
Offshore A Way Of Life



[3]

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Offshore & Dredging Engineering

Dr.ir. Sape A. Miedema
Educational Director

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Dry Sand

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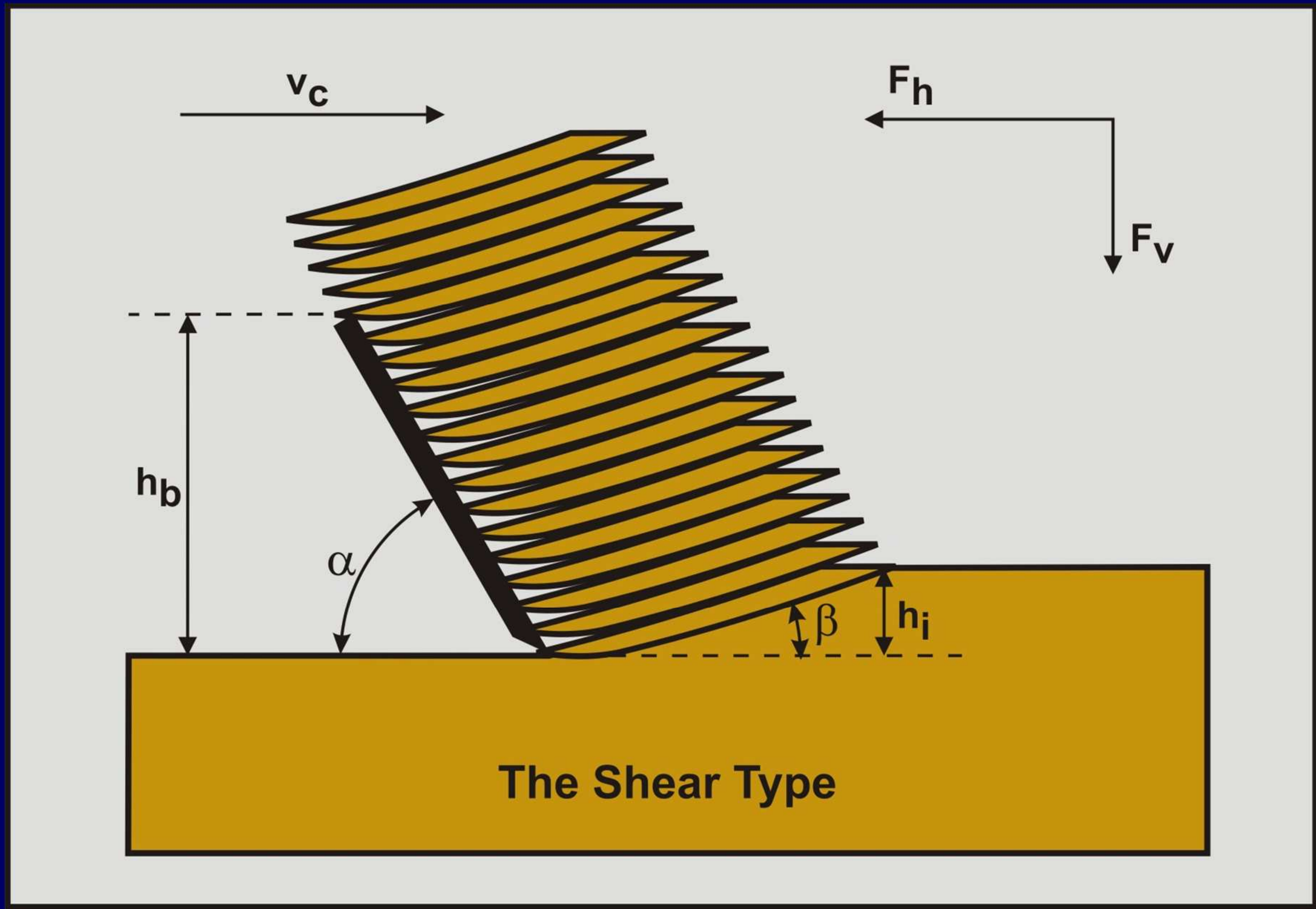
Dry Sand Mechanism



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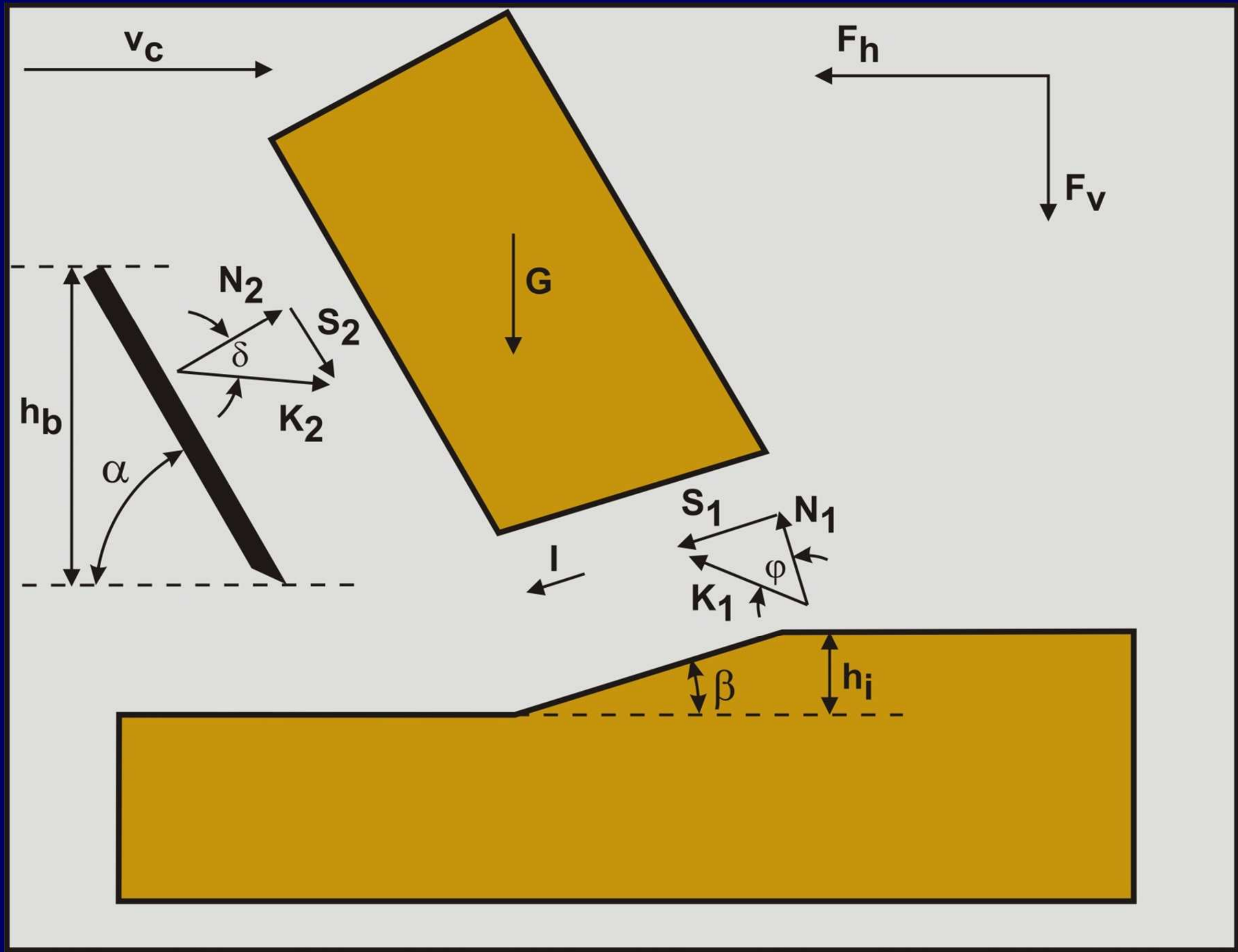
Dry Sand Forces on the Layer Cut



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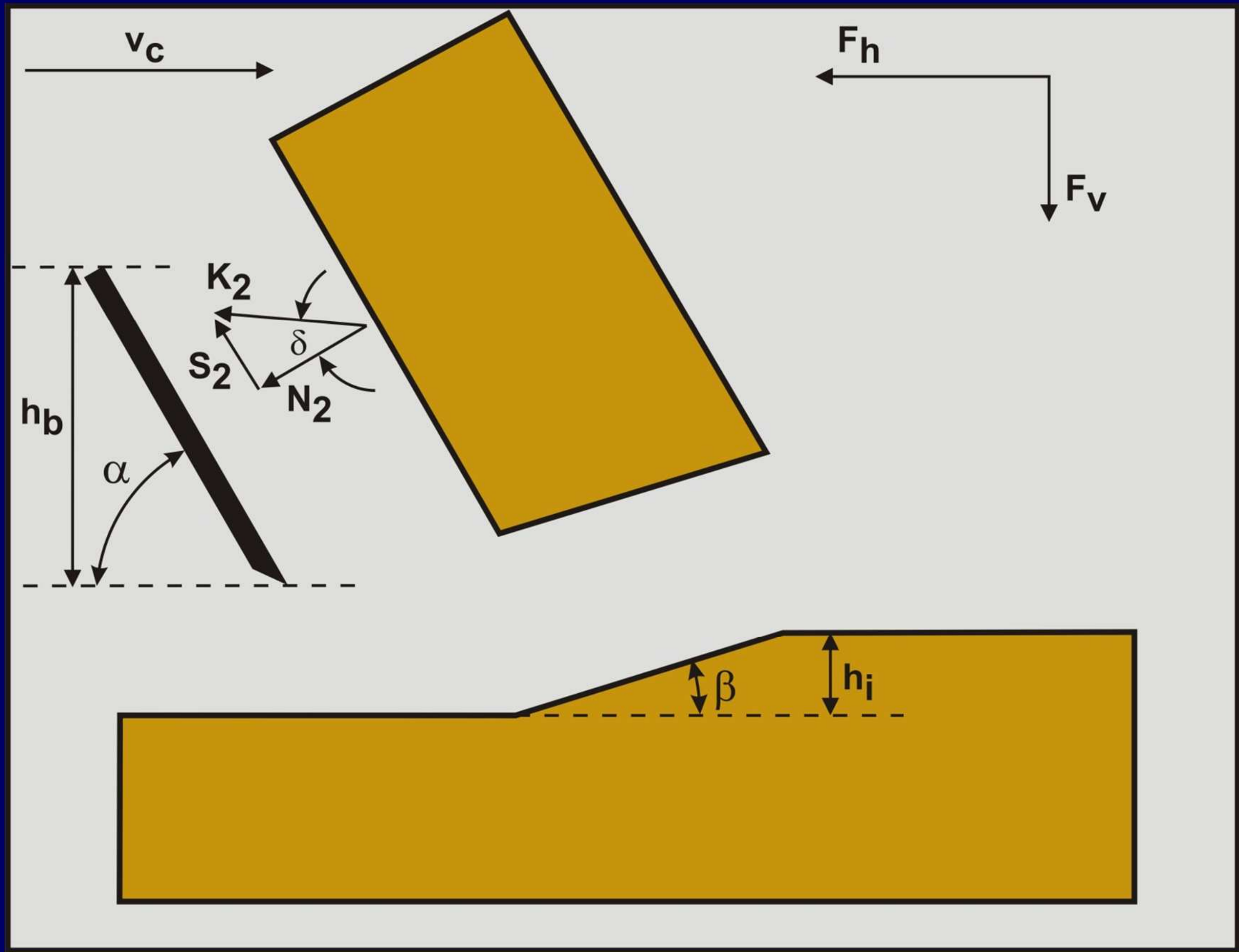
Dry Sand Forces on the Blade



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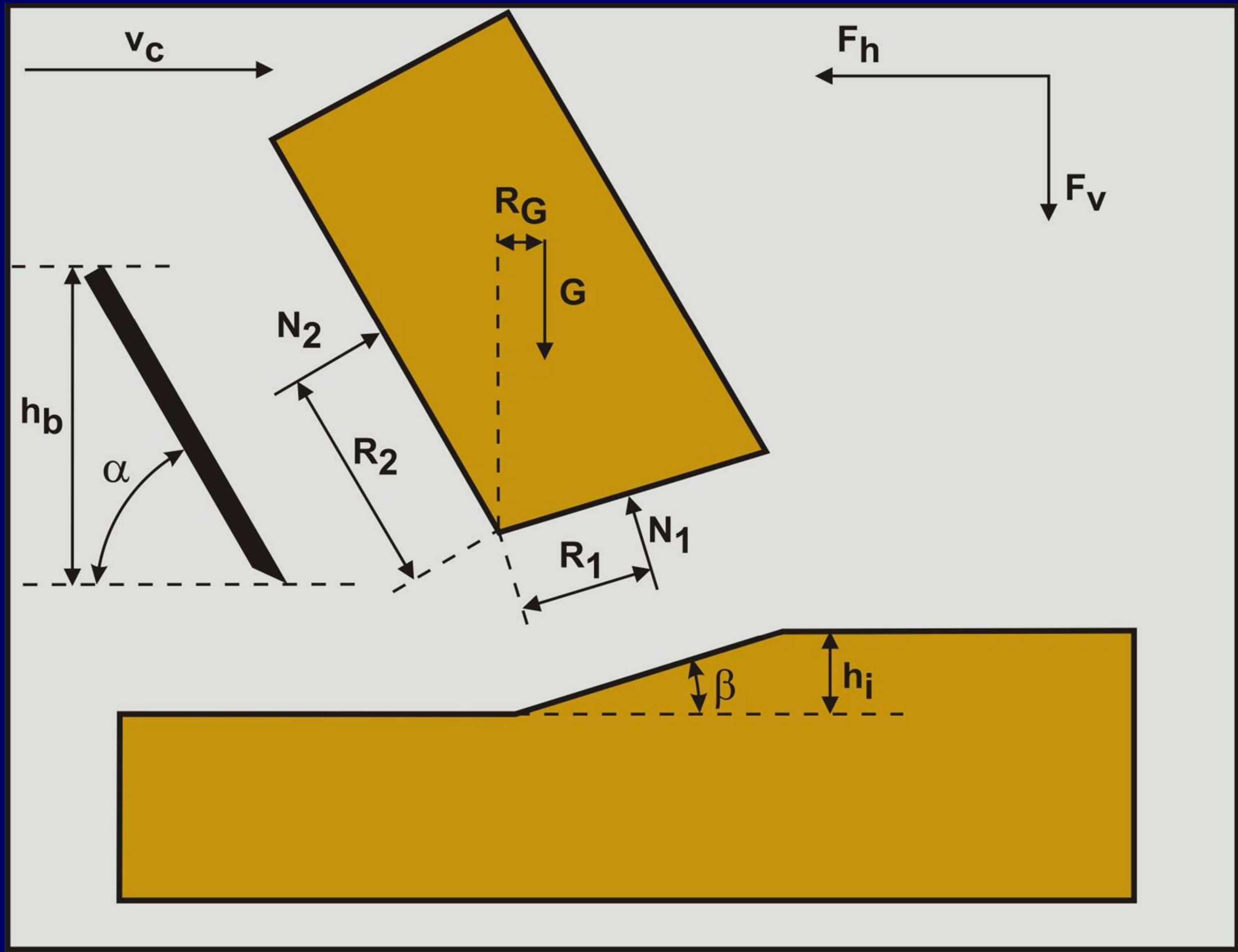
Dry Sand Moments



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Dry Sand Resulting Equations

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

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

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

Saturated Sand

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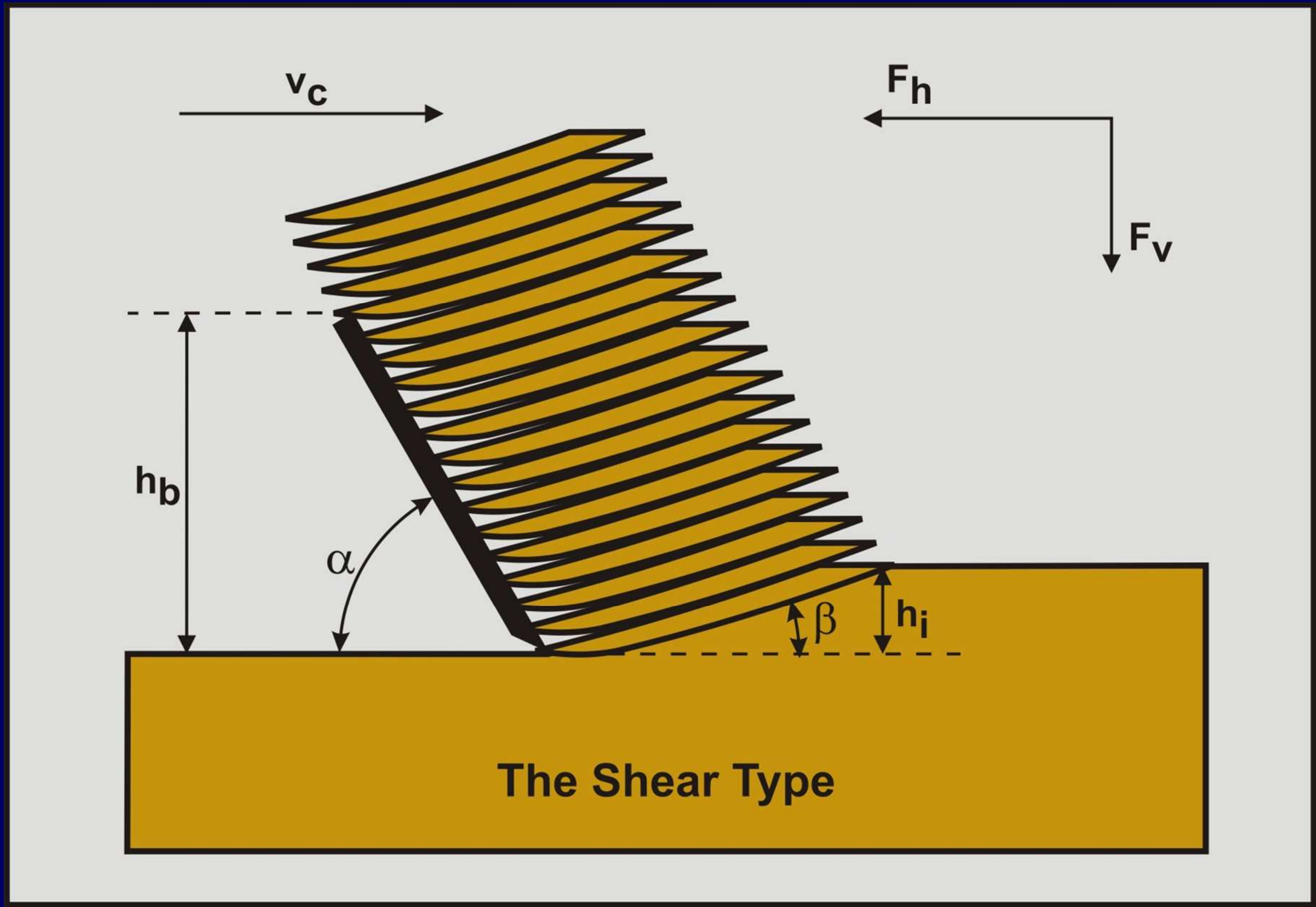
Saturated Sand Mechanism



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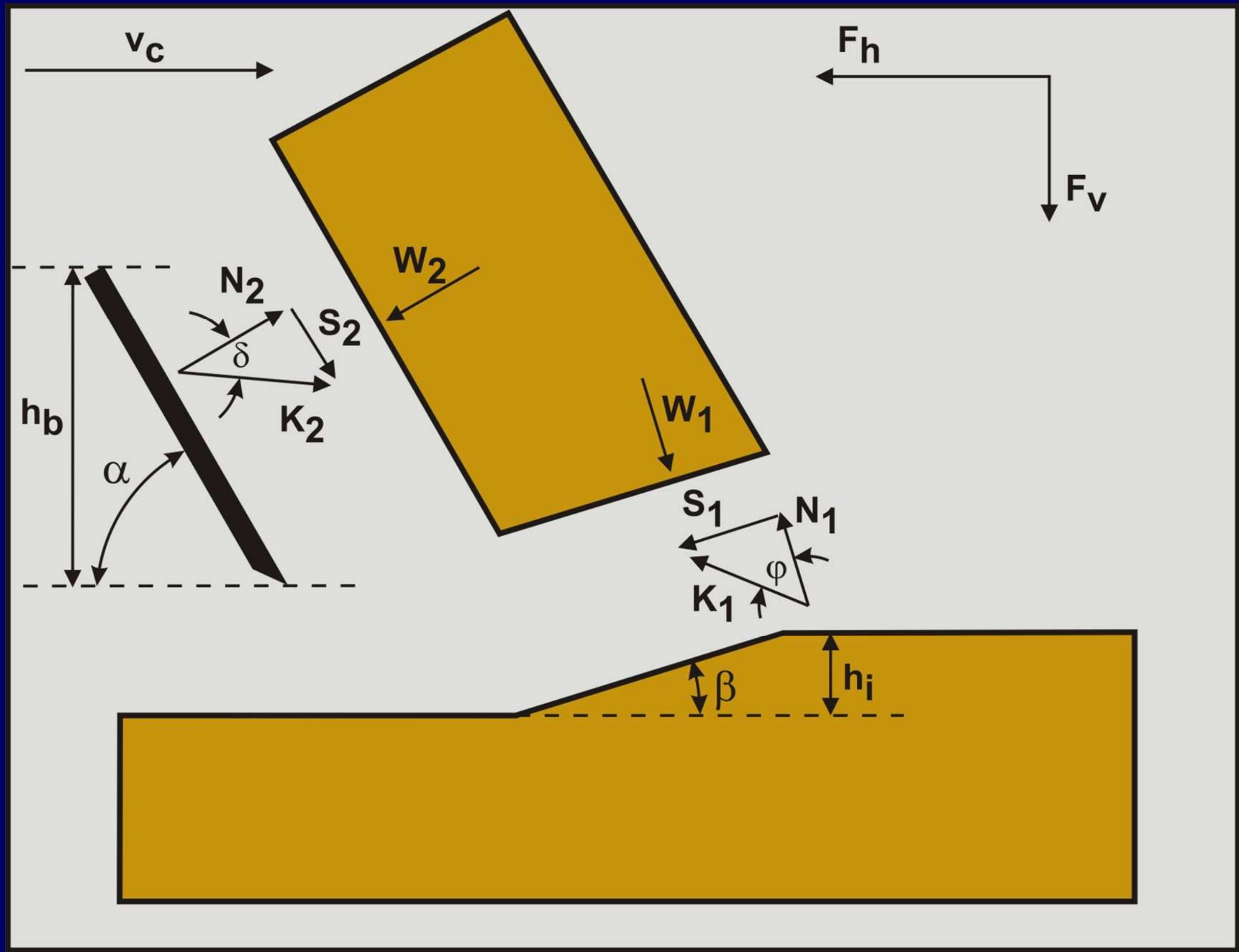
Saturated Sand Forces on the Layer Cut



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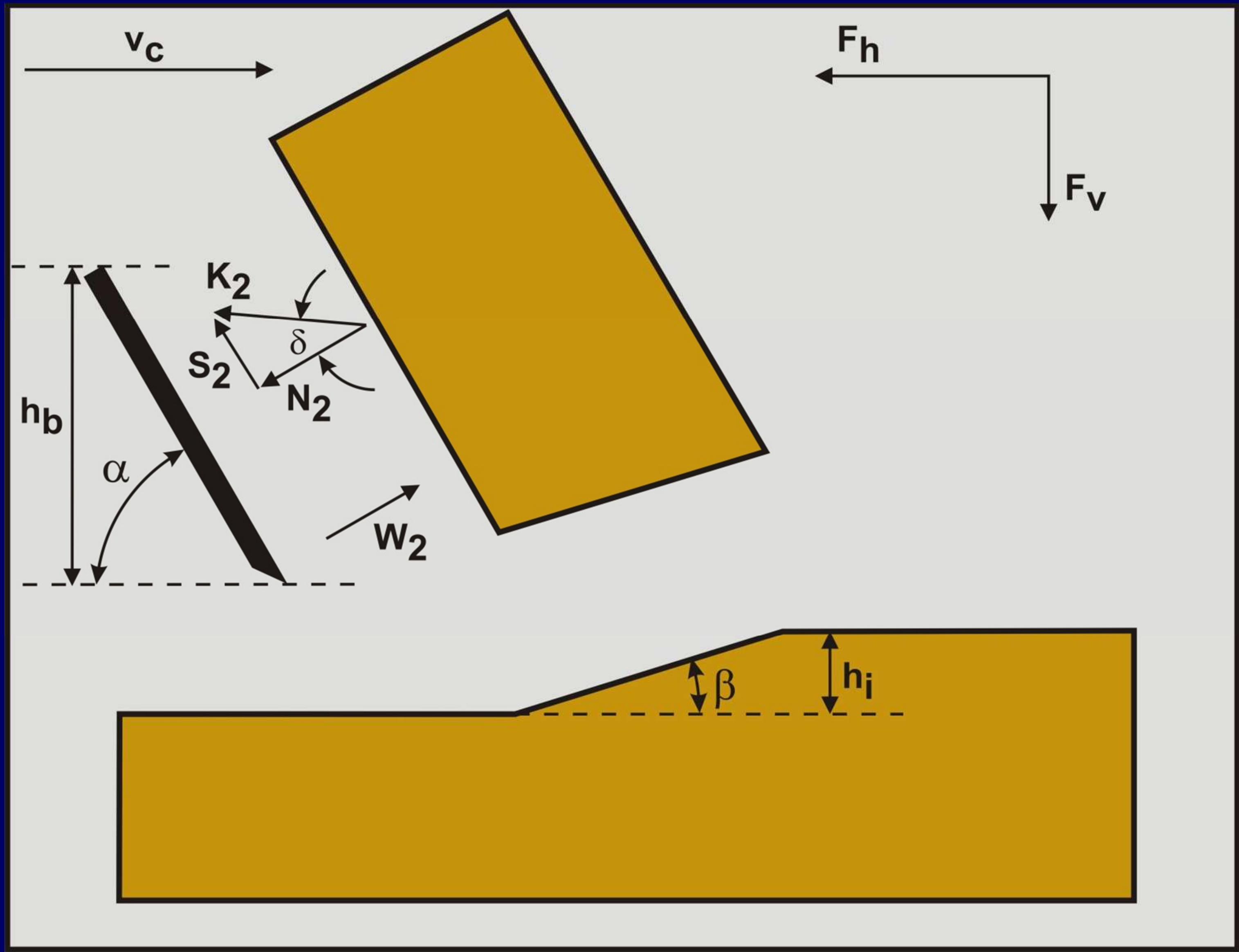
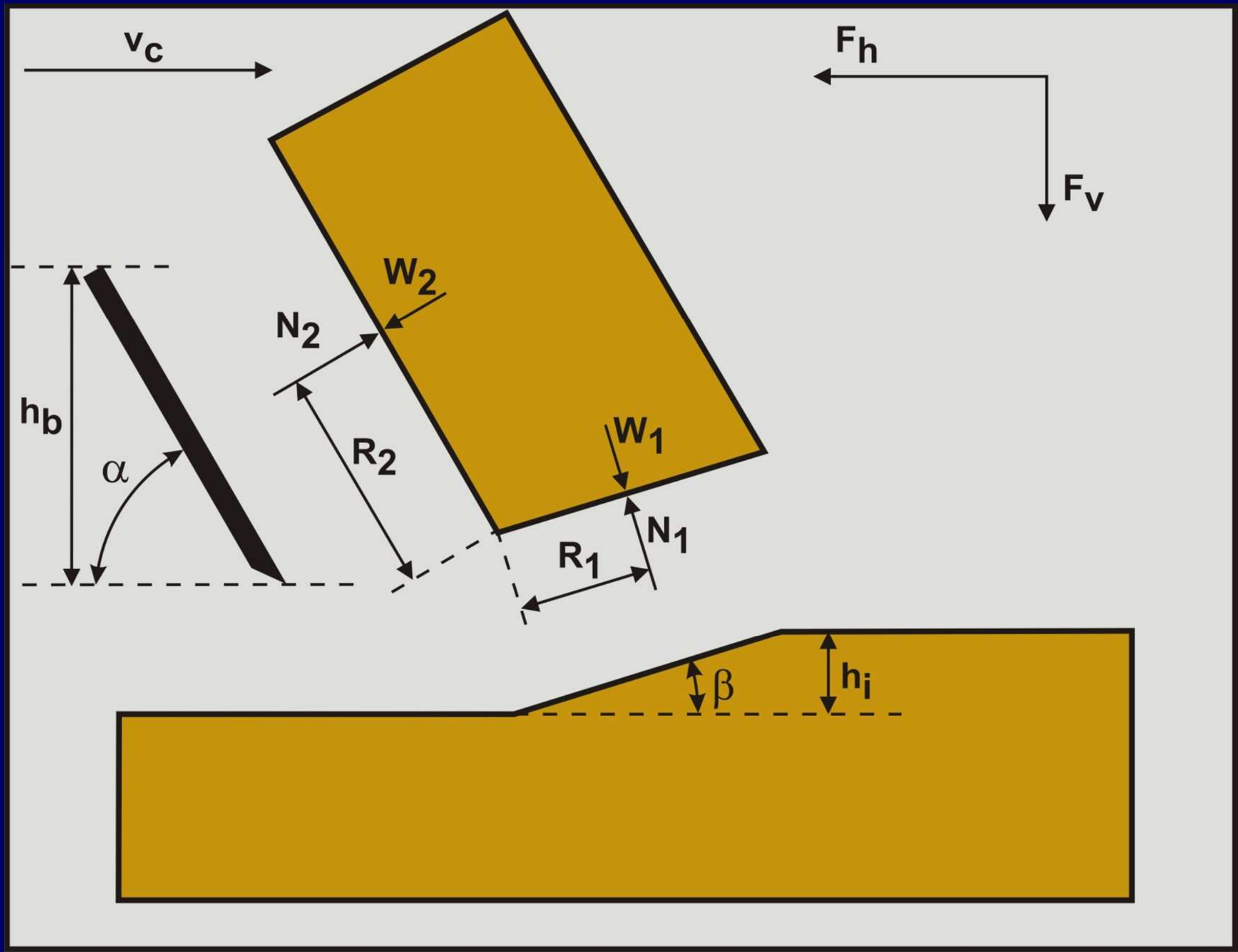
Saturated Sand Forces on the Blade



Saturated Sand Moments



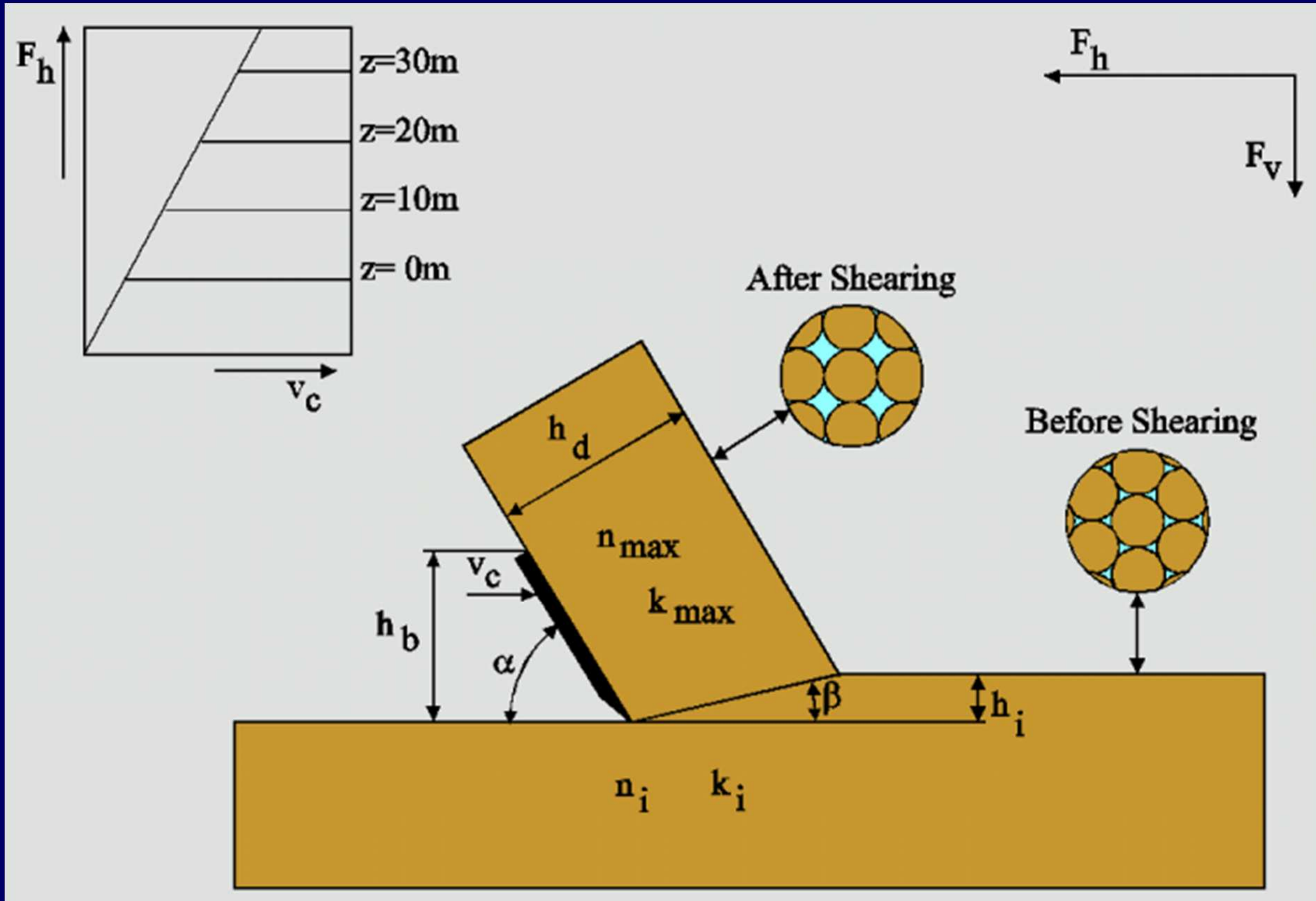
Saturated Sand Resulting Equations

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

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

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

Saturated Sand Dilatation



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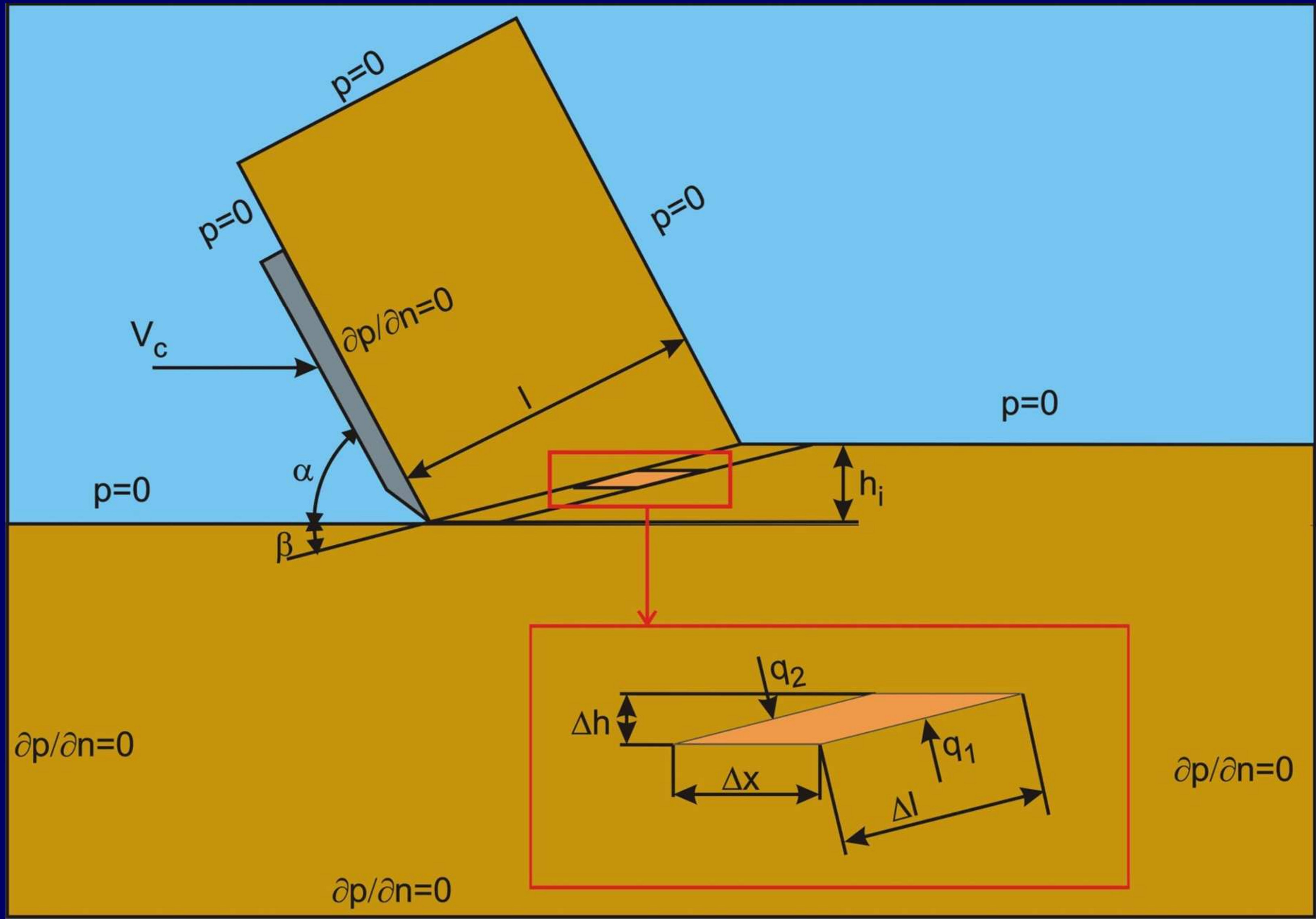
Saturated Sand Specific Flow



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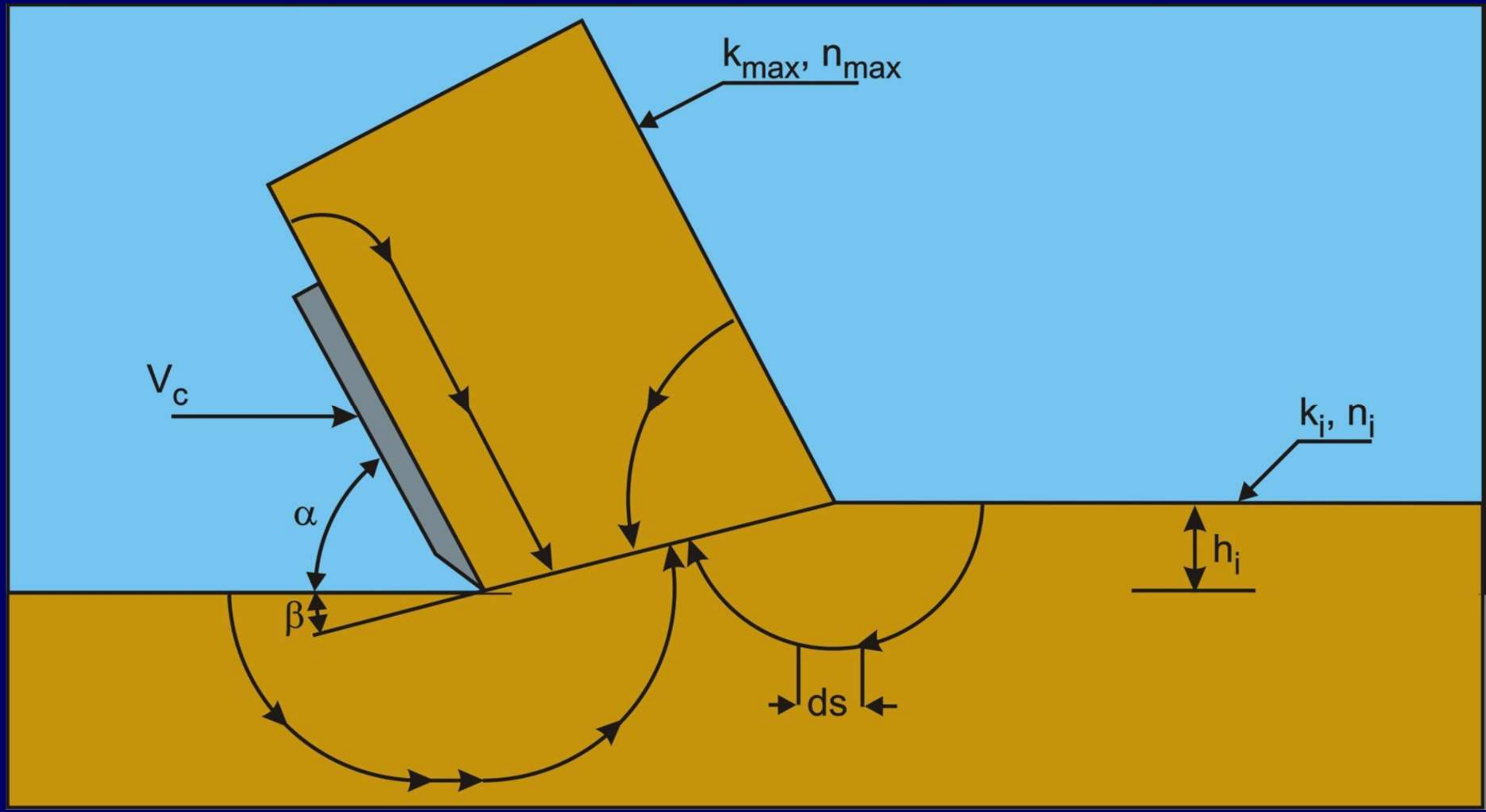
Saturated Sand Flow Lines



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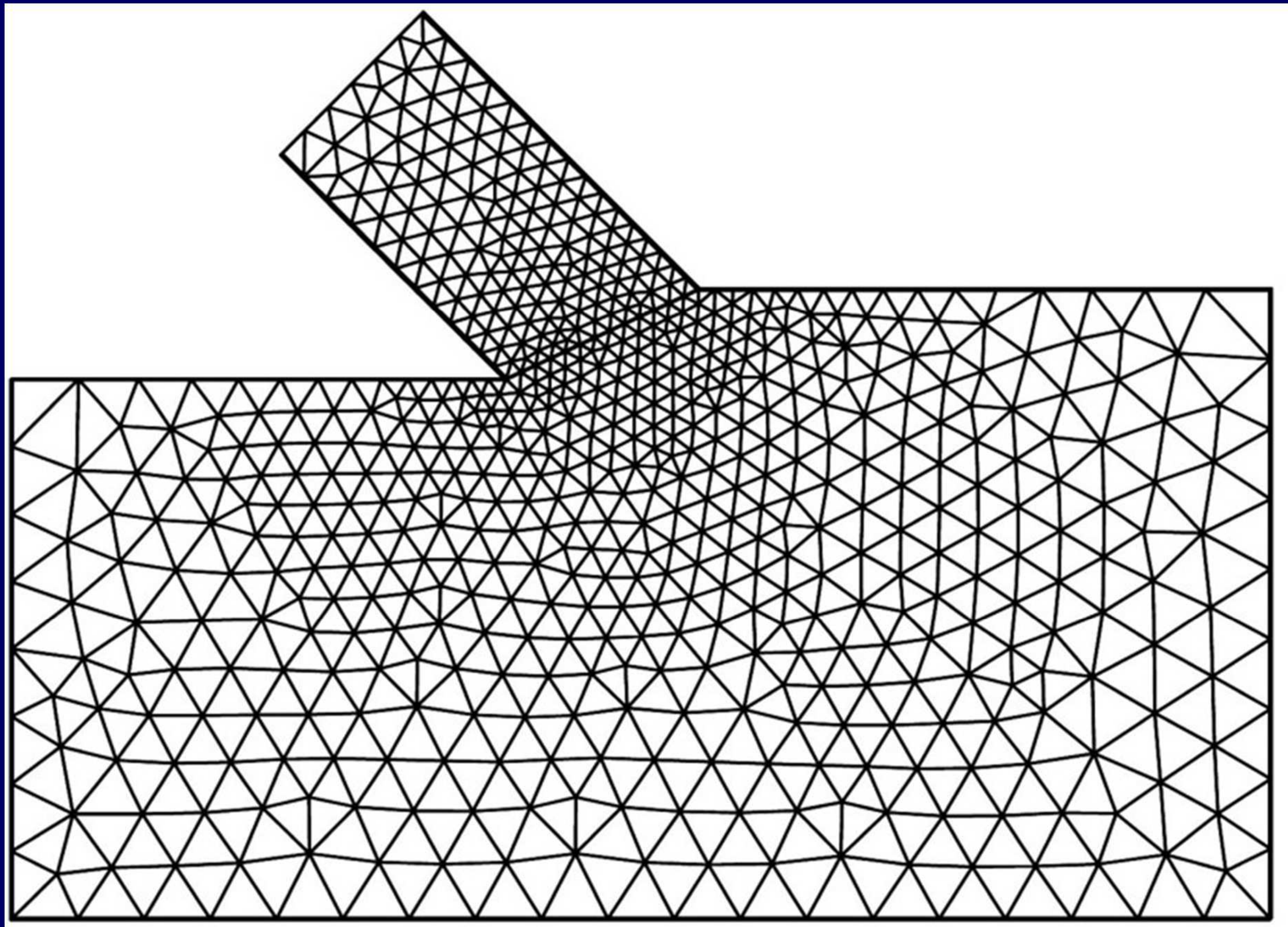
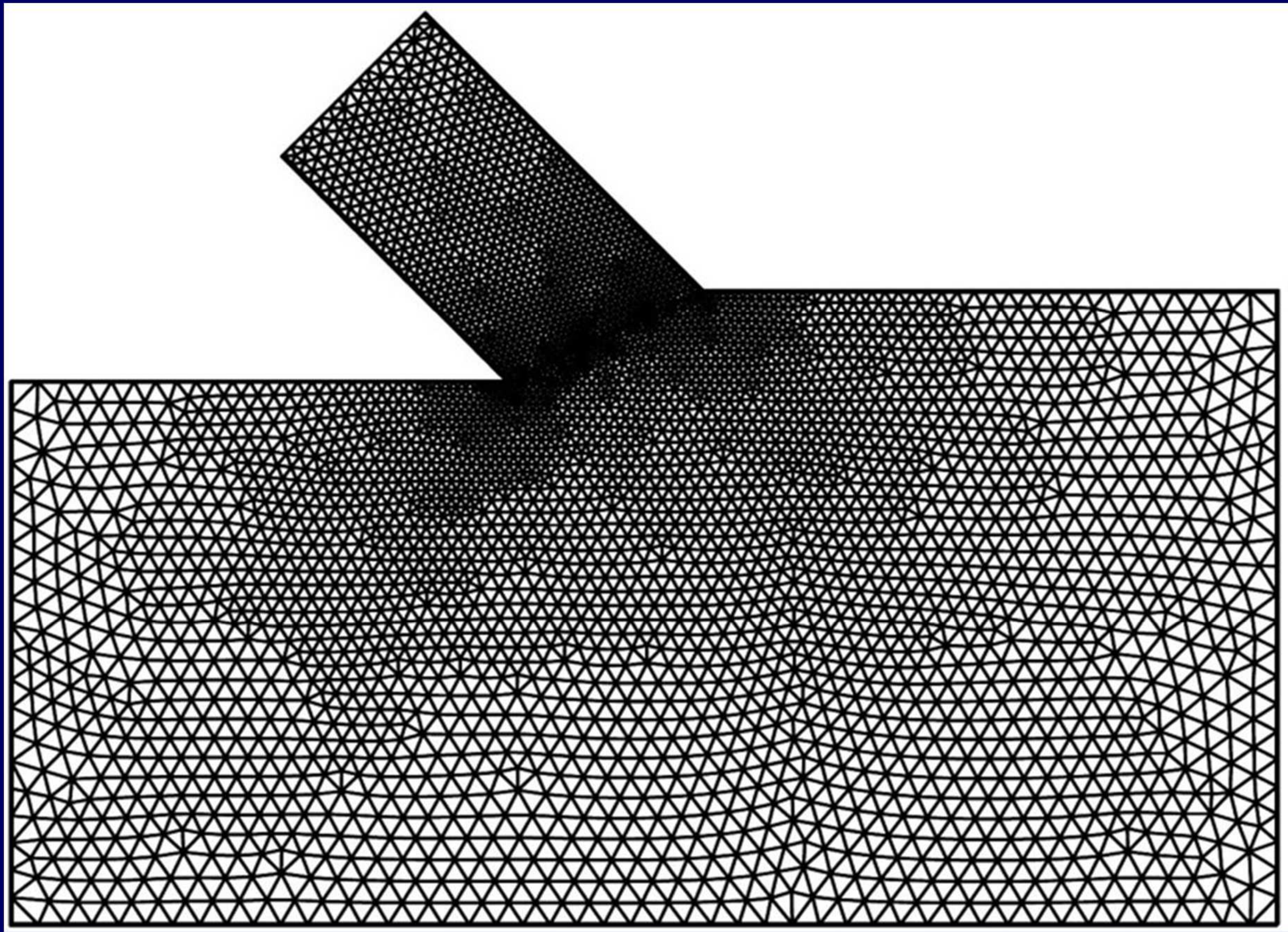
Saturated Sand Mesh Coarse



Saturated Sand Mesh Fine



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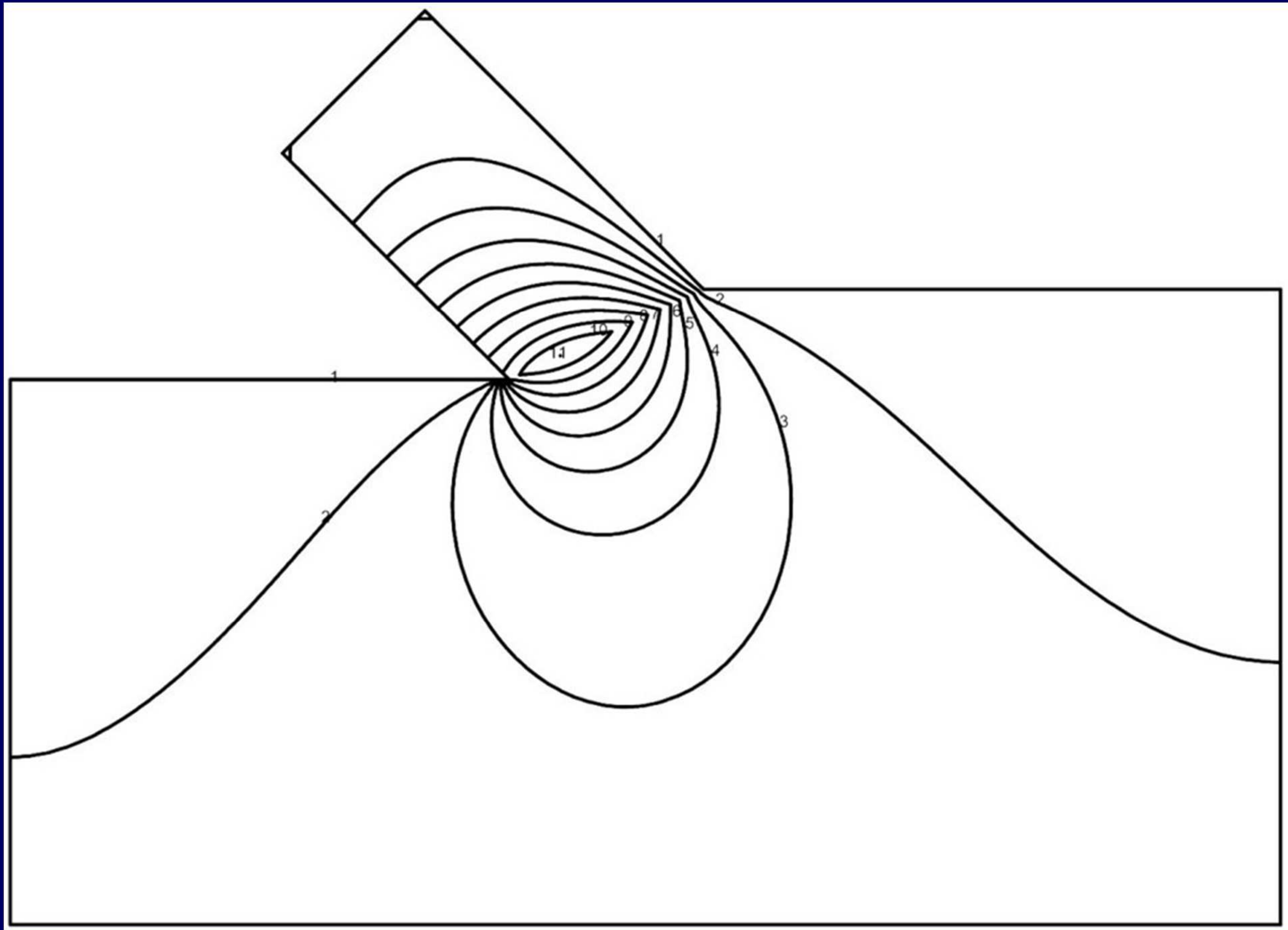
Saturated Sand Equipotential Lines



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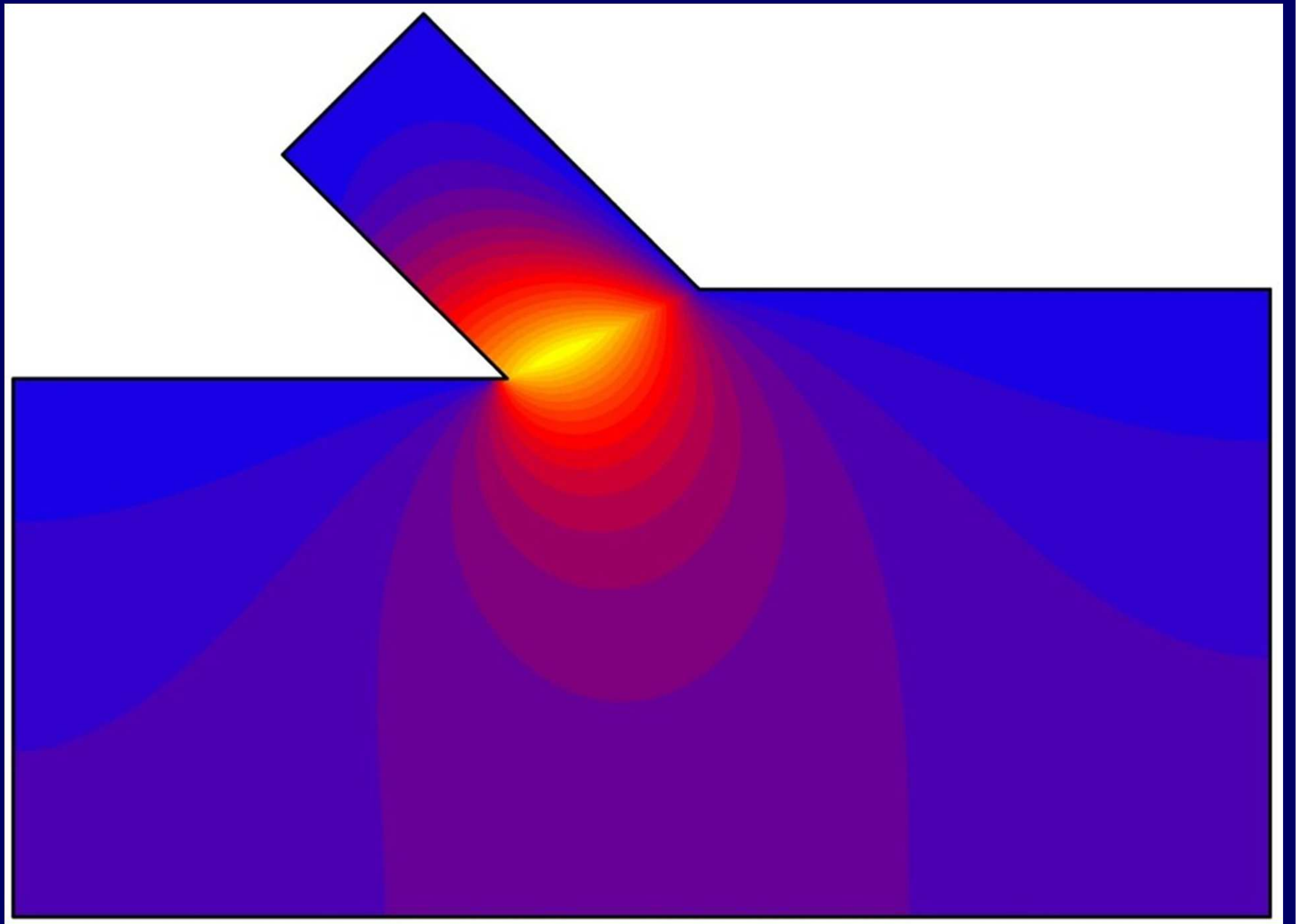
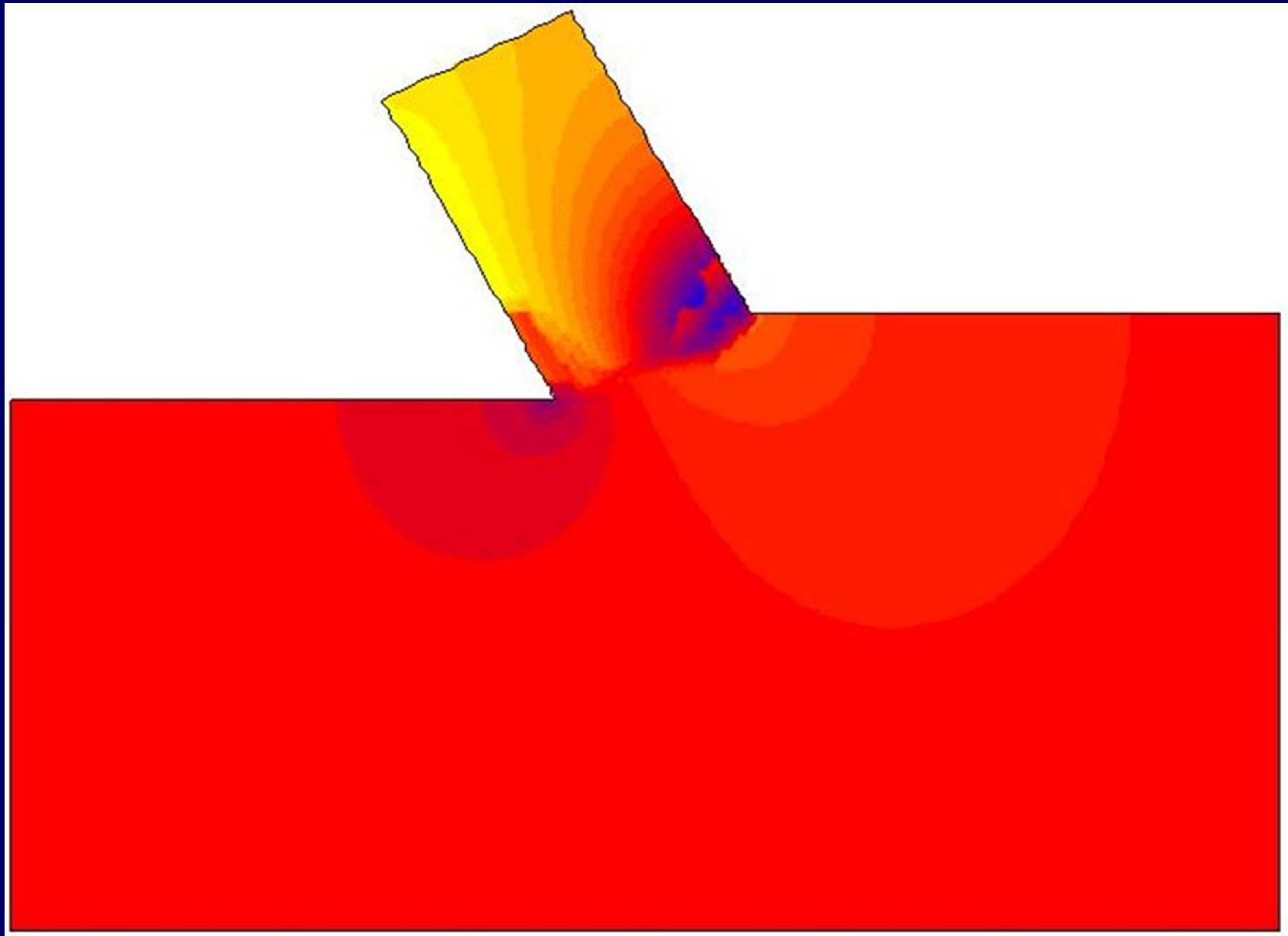
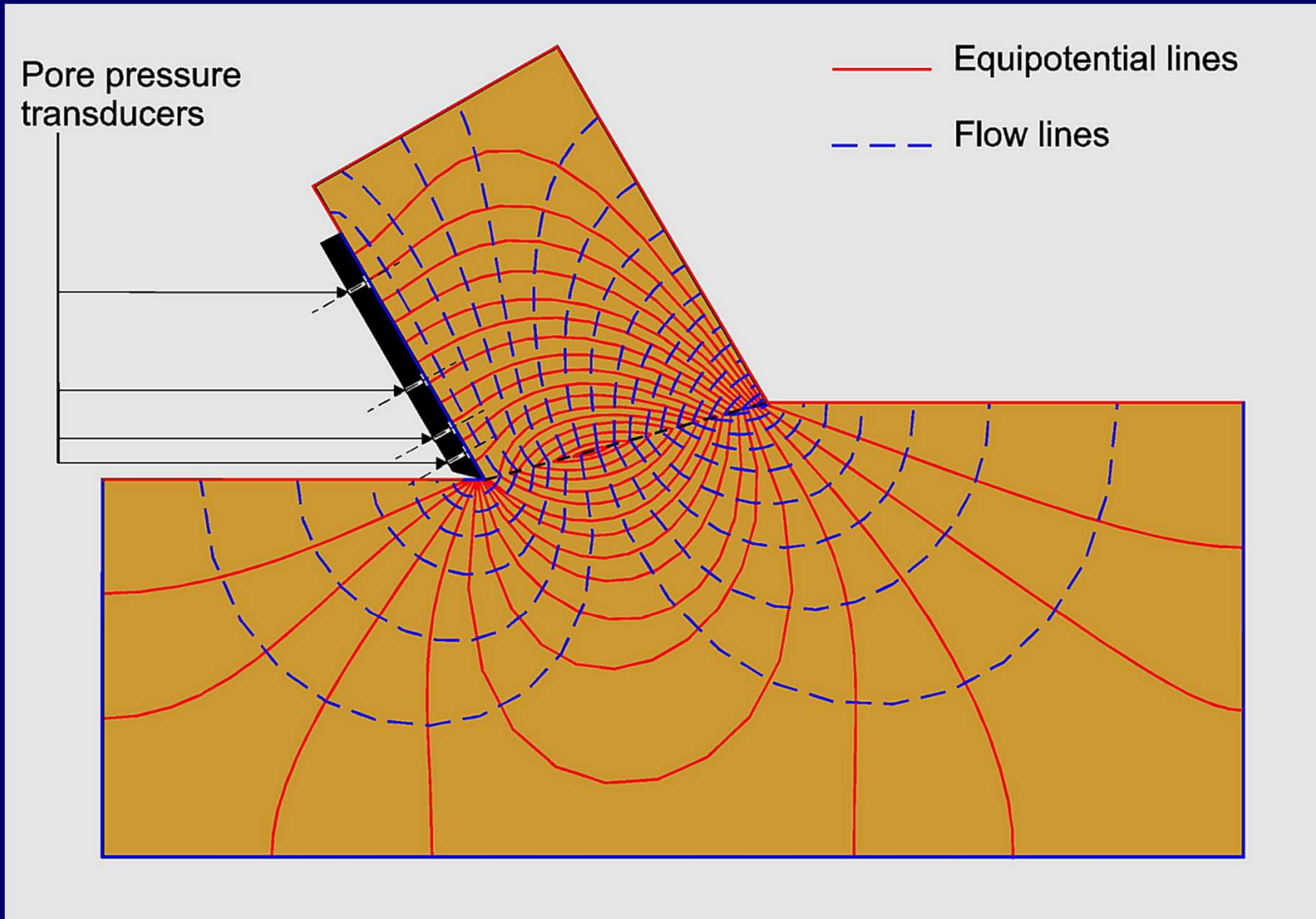
Saturated Sand Equipotential Lines



Flow Lines



Saturated Sand



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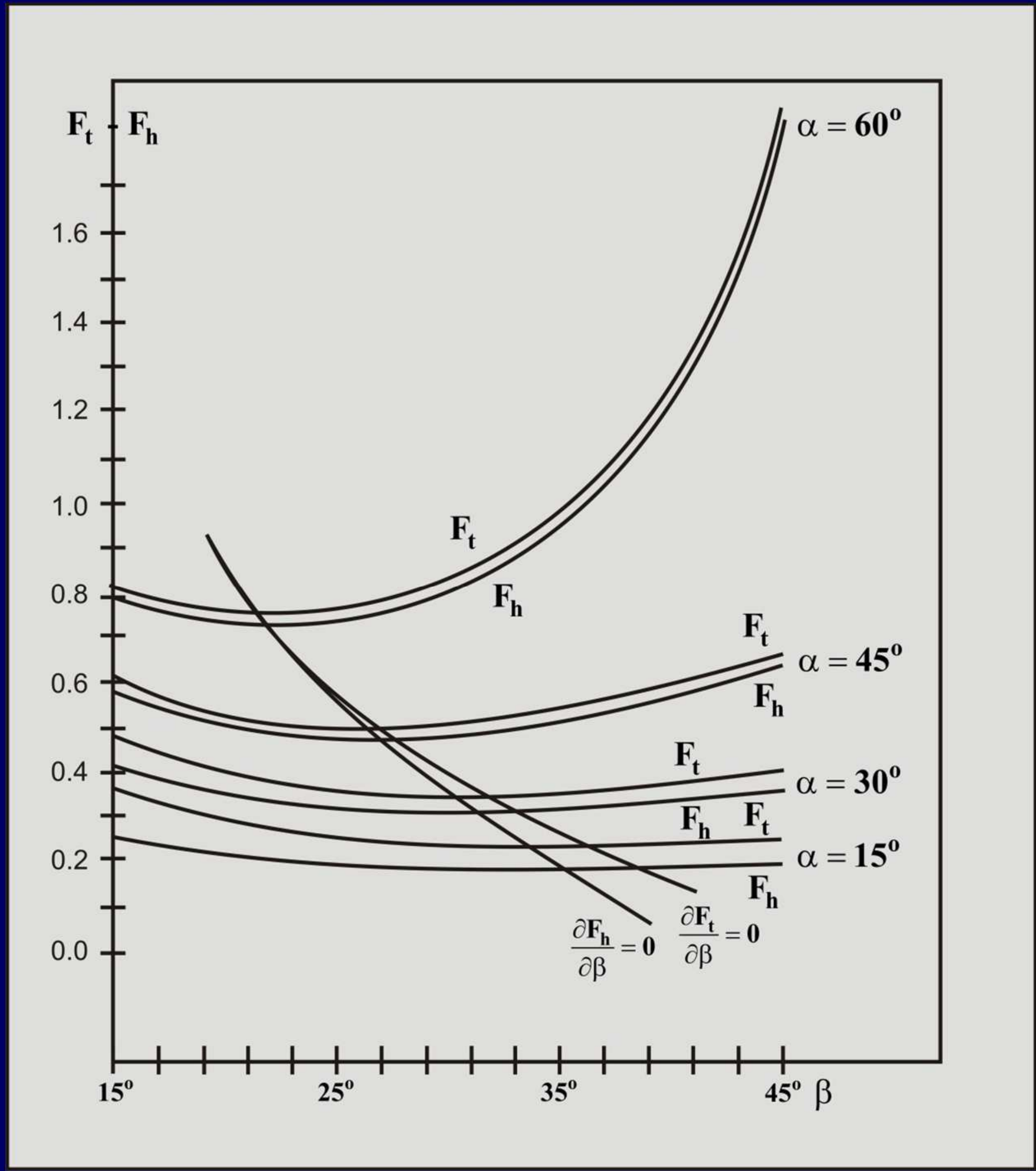
Determining the Shear Angle



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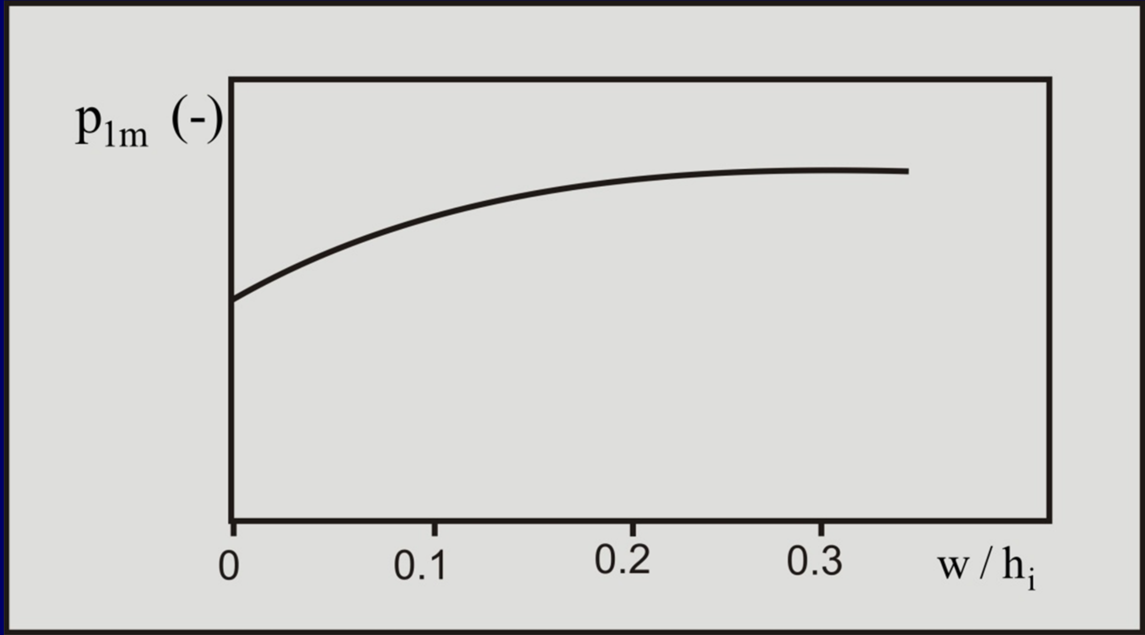
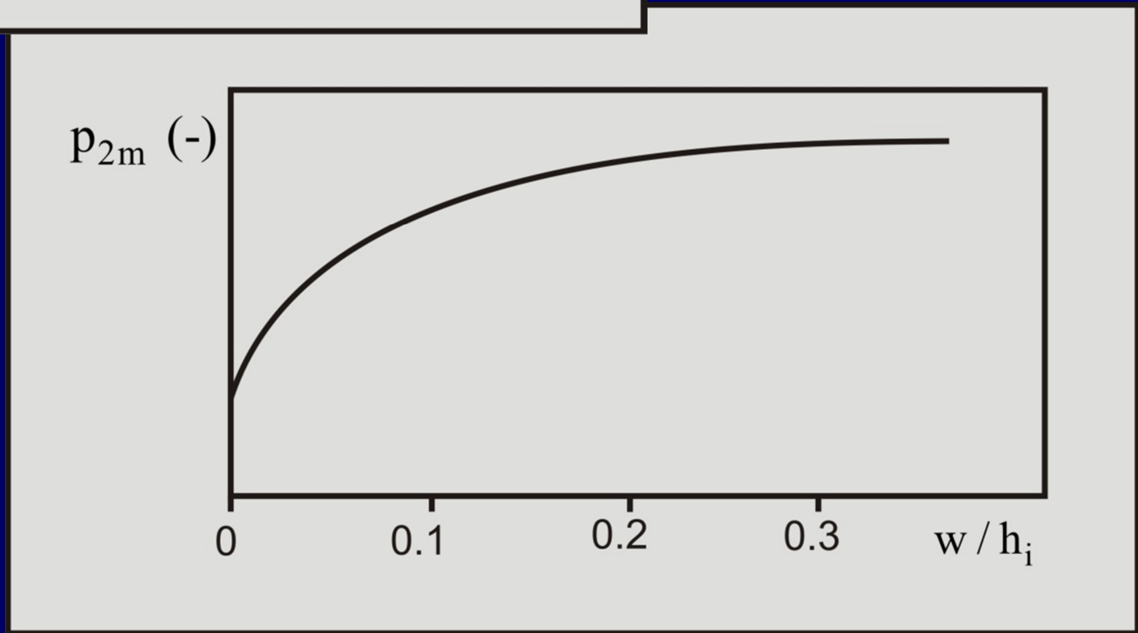
The Influence of Wear





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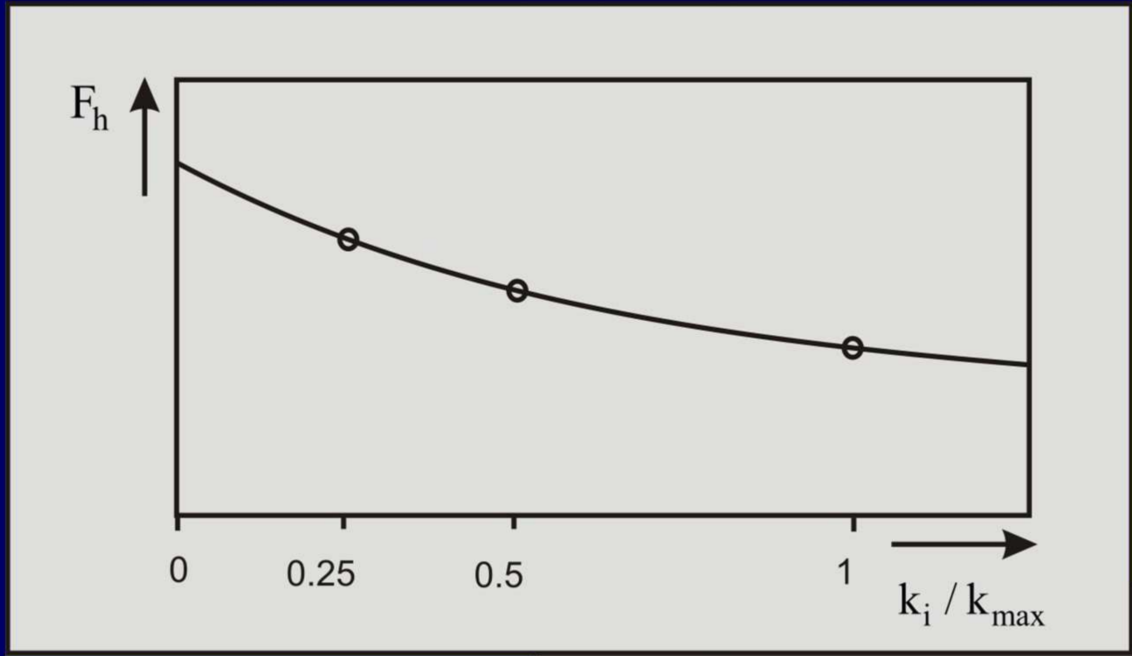
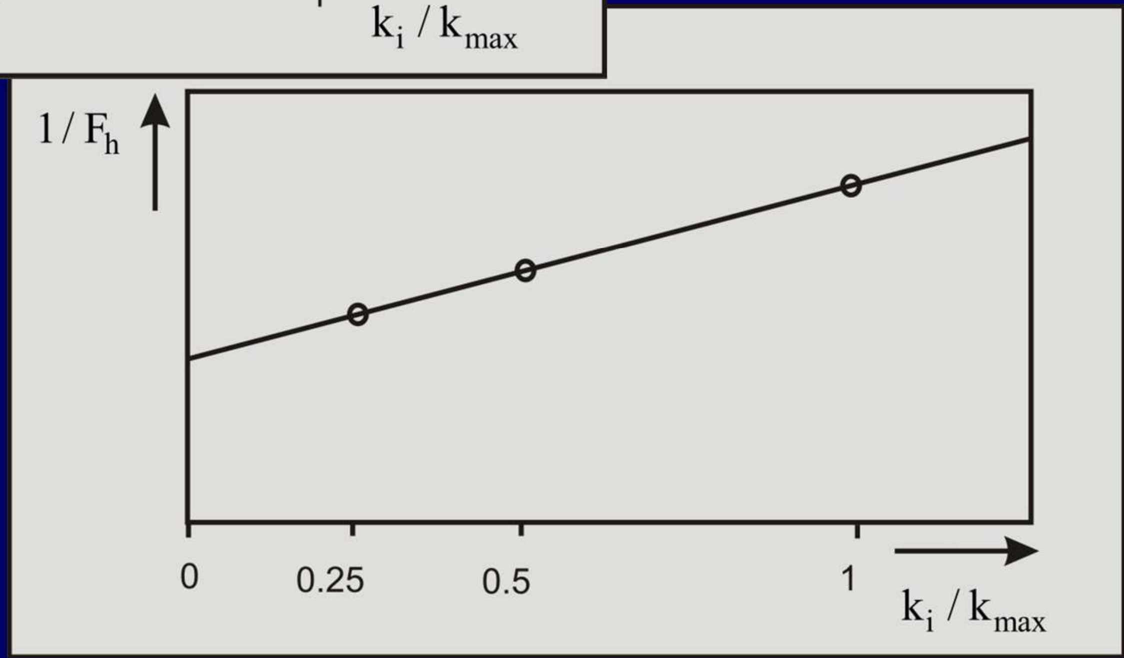
The Permeability Ratio





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Saturated Sand Cutting Equations

Non-Cavitating Equations

$$F_h = \frac{c_1 \cdot \rho_w \cdot g \cdot v_c \cdot h_i^2 \cdot b \cdot e}{k_m}$$

$$F_v = \frac{c_2 \cdot \rho_w \cdot g \cdot v_c \cdot h_i^2 \cdot b \cdot e}{k_m}$$

Cavitating Equations

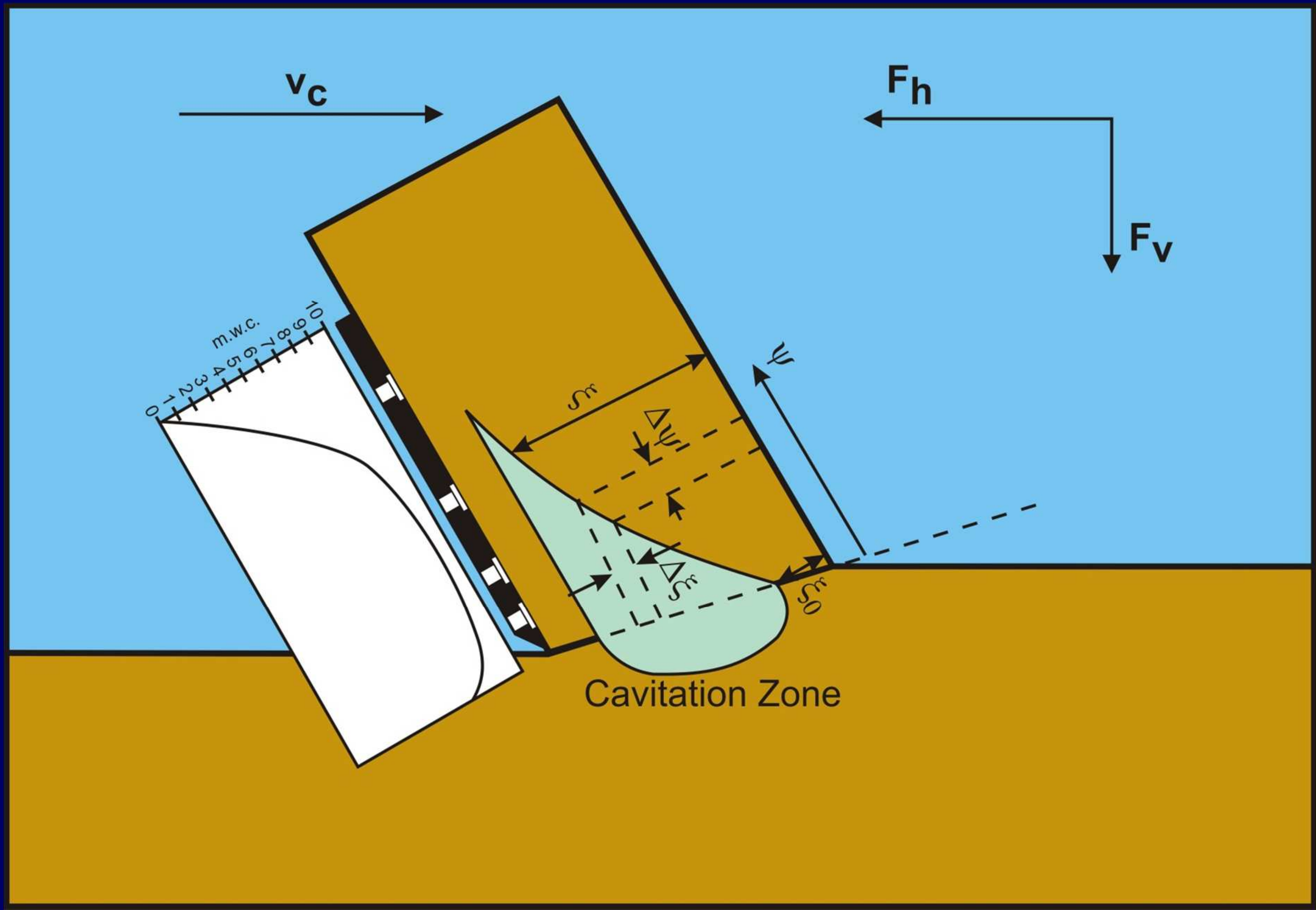
$$F_h = d_1 \cdot \rho_w \cdot g \cdot (z+10) \cdot h_i \cdot b$$

$$F_v = d_2 \cdot \rho_w \cdot g \cdot (z+10) \cdot h_i \cdot b$$

Cavitation Transition

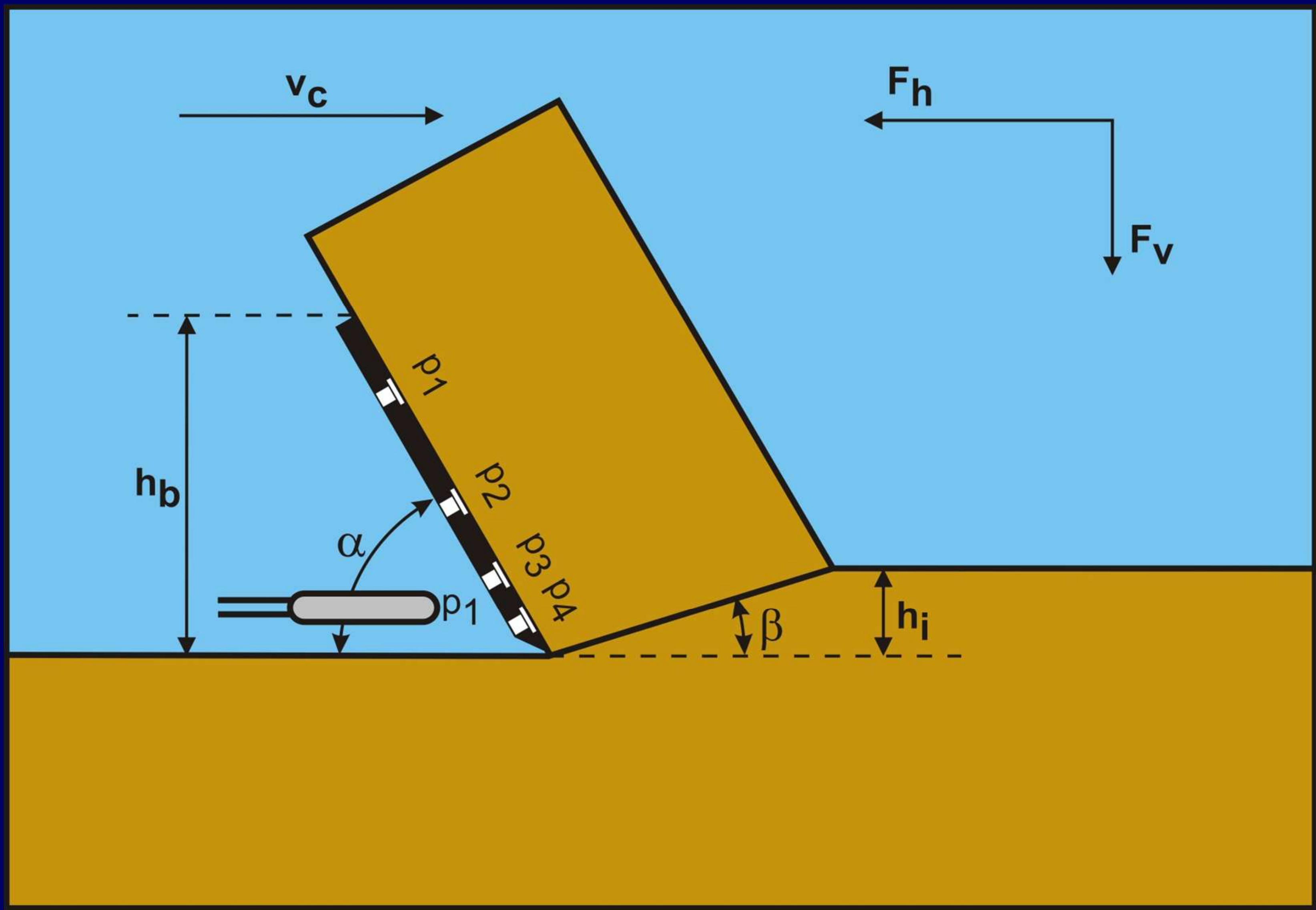
$$\frac{\mathbf{d_1 \cdot (z+10)}}{\mathbf{c_1 \cdot v_c \cdot h_i \cdot e / k_m}} < \mathbf{1}$$

Cavitation

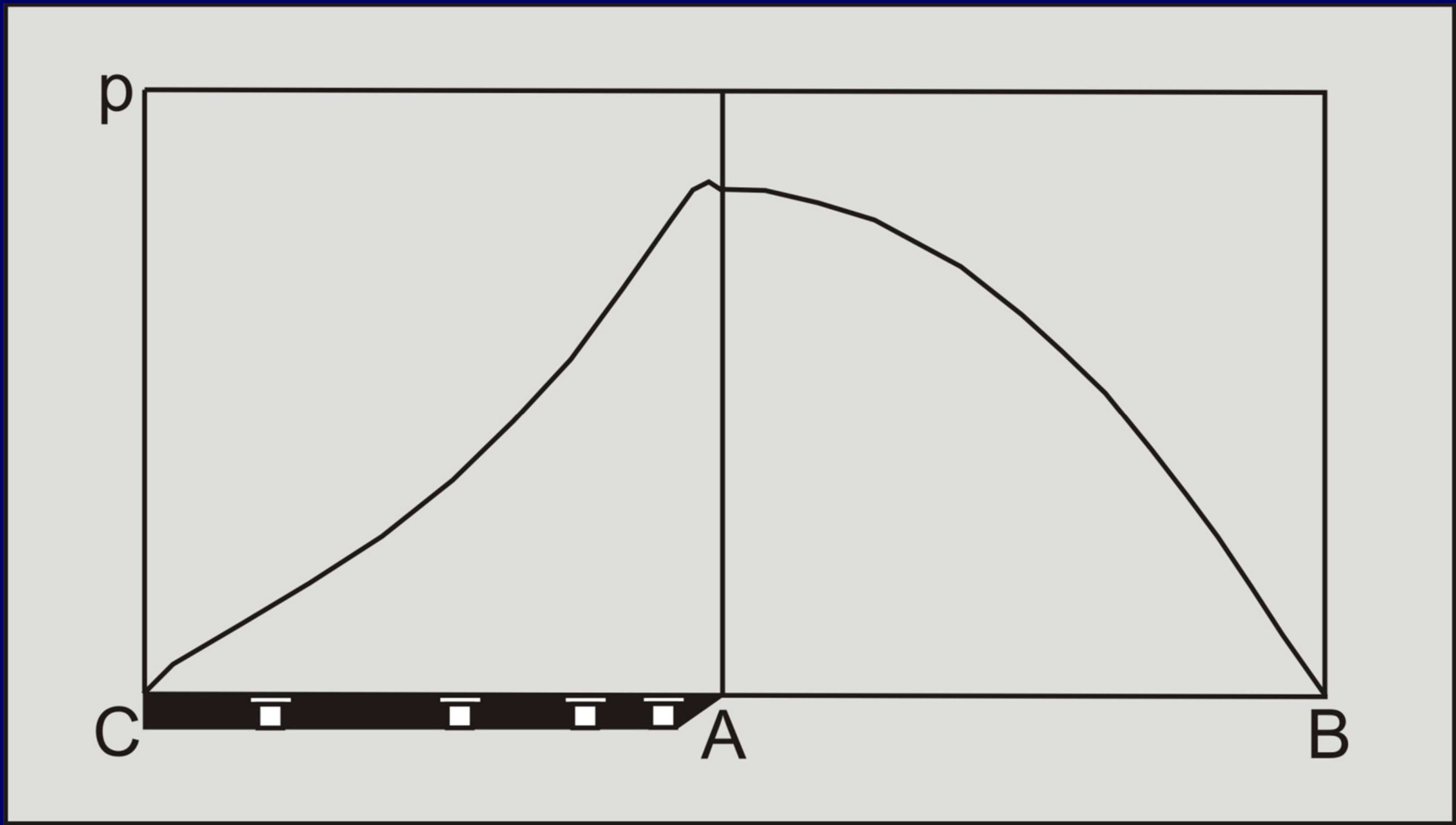


v_c
F_h
F_v
m.w.c.
0 1 2 3 4 5 6 7 8 9 10
ξ
$\Delta\psi$
ψ
$\Delta\xi$
ξ_0
Cavitation Zone

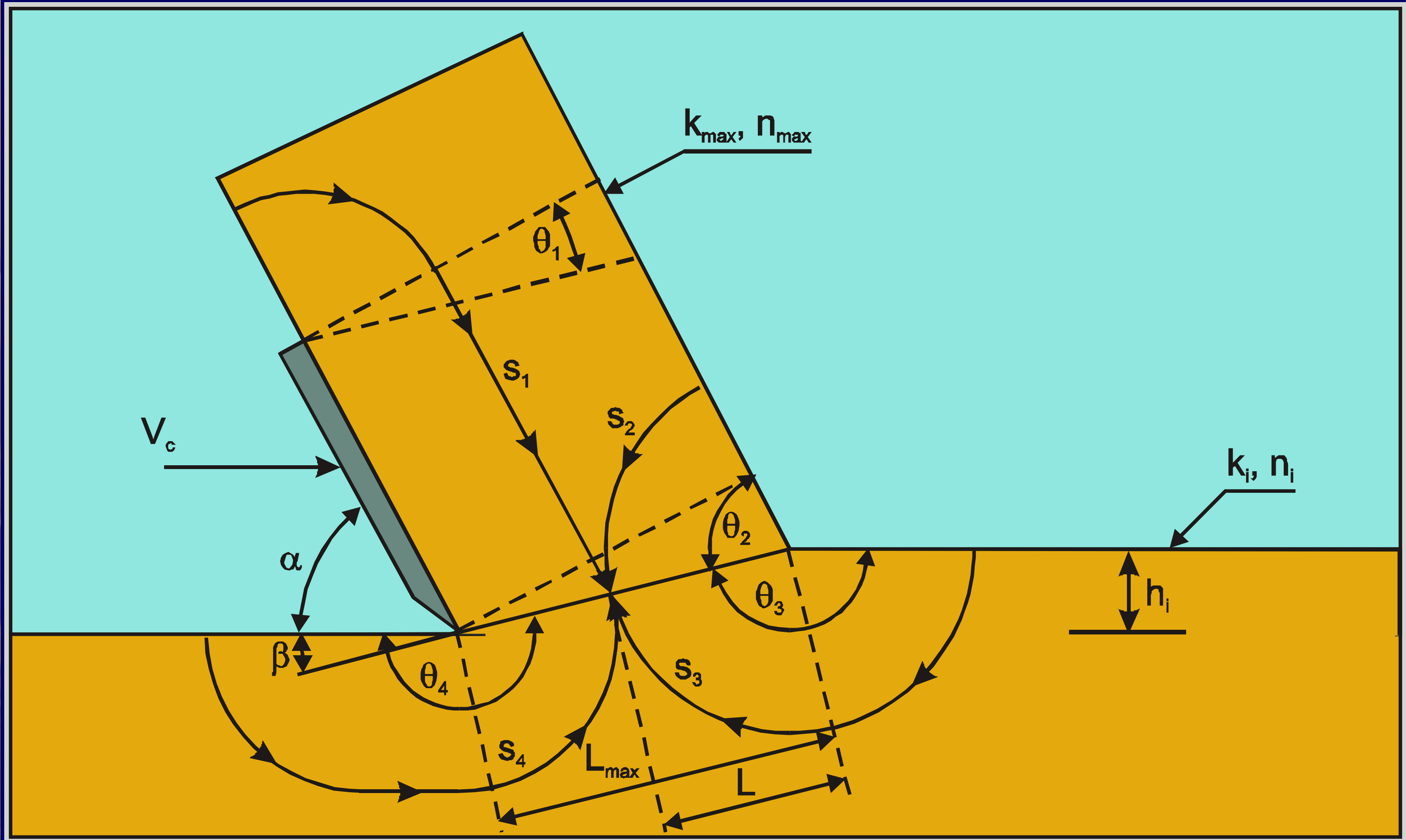
Pressure Transducers



Pore Pressures



Analytical method (parallel resistors)



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Resistors

$$R = \frac{s}{k}$$

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$\Delta p = \rho_w \cdot g \cdot v_c \cdot e \cdot \sin(\beta) \cdot R_t$$

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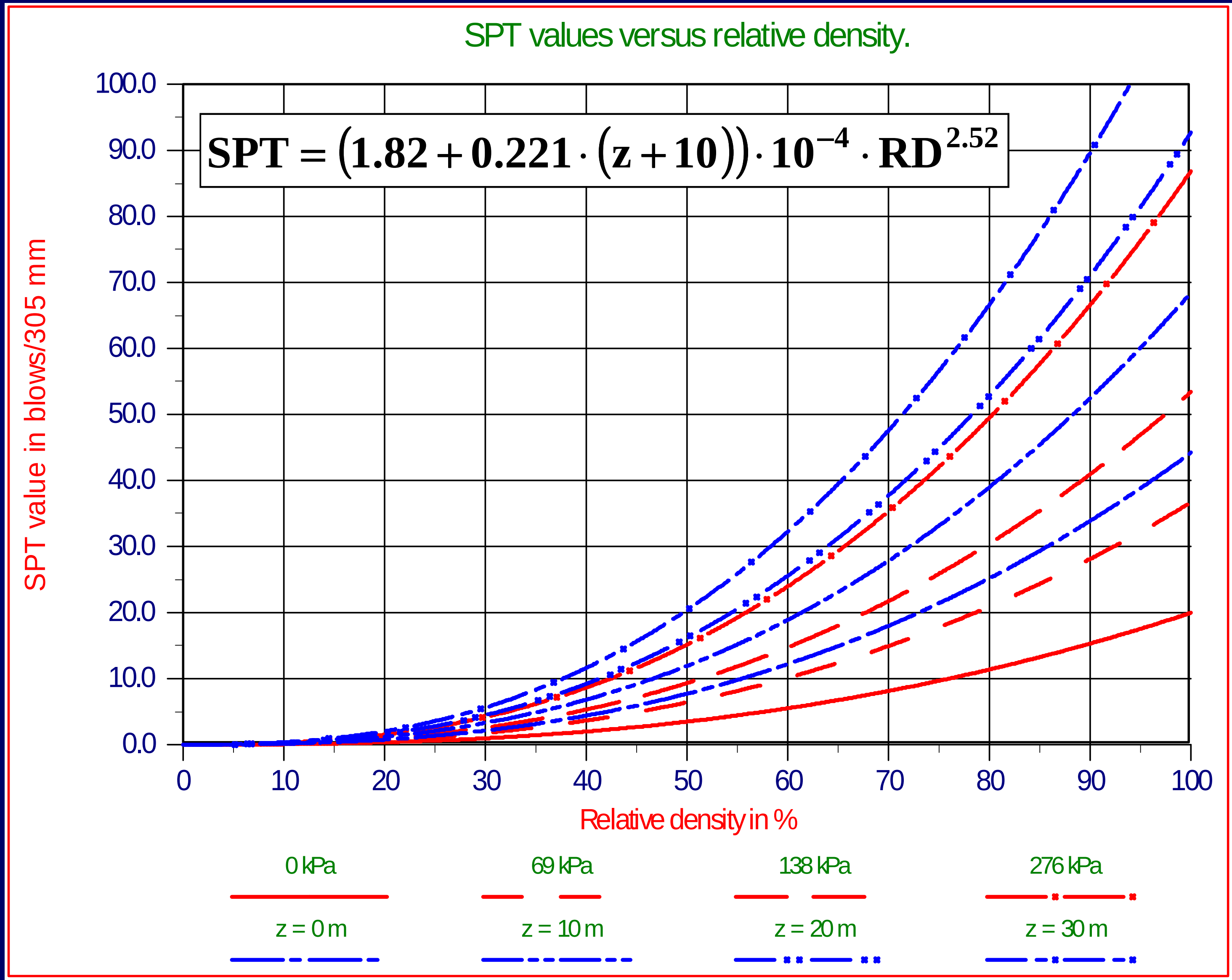
SPT value versus relative density

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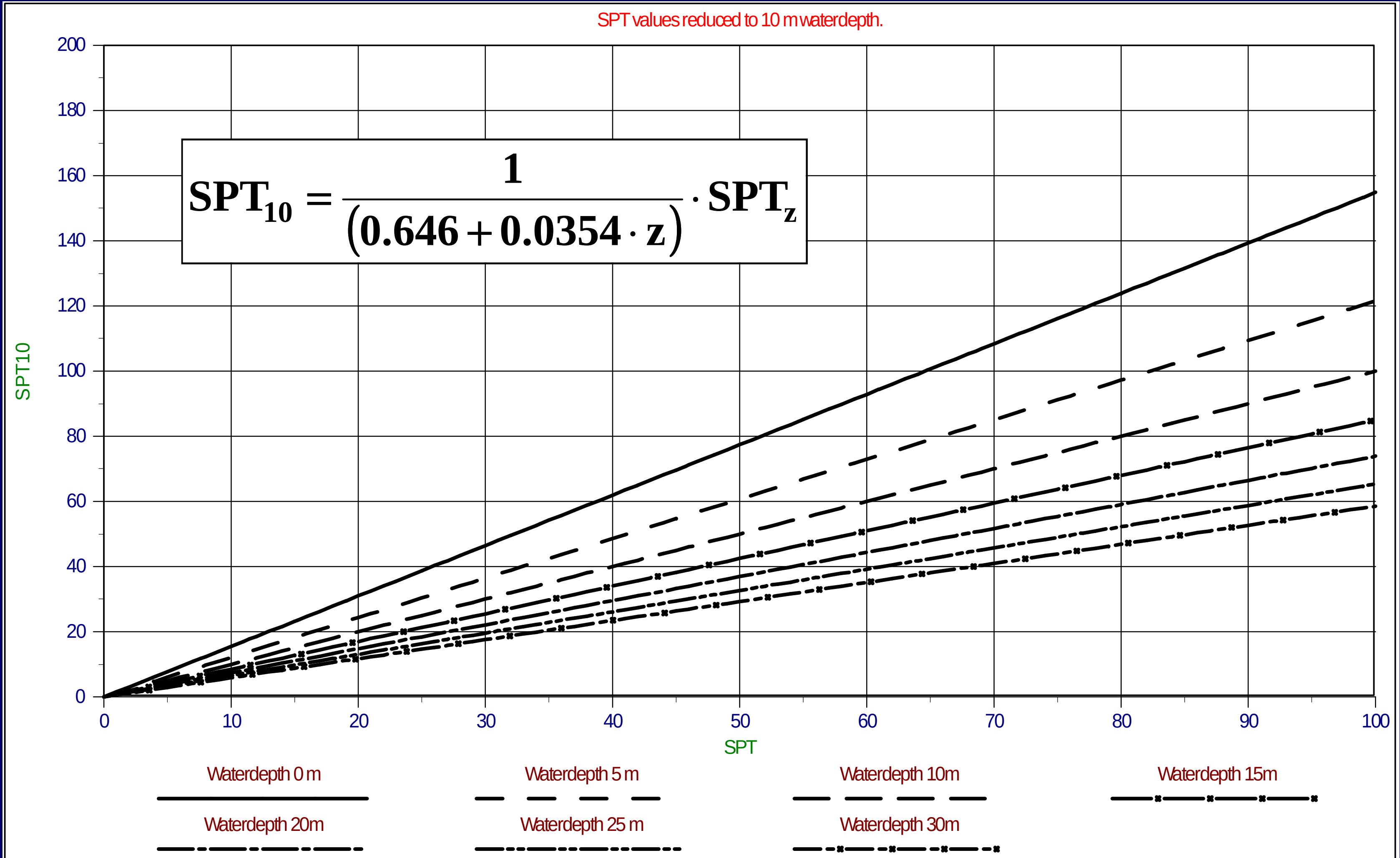
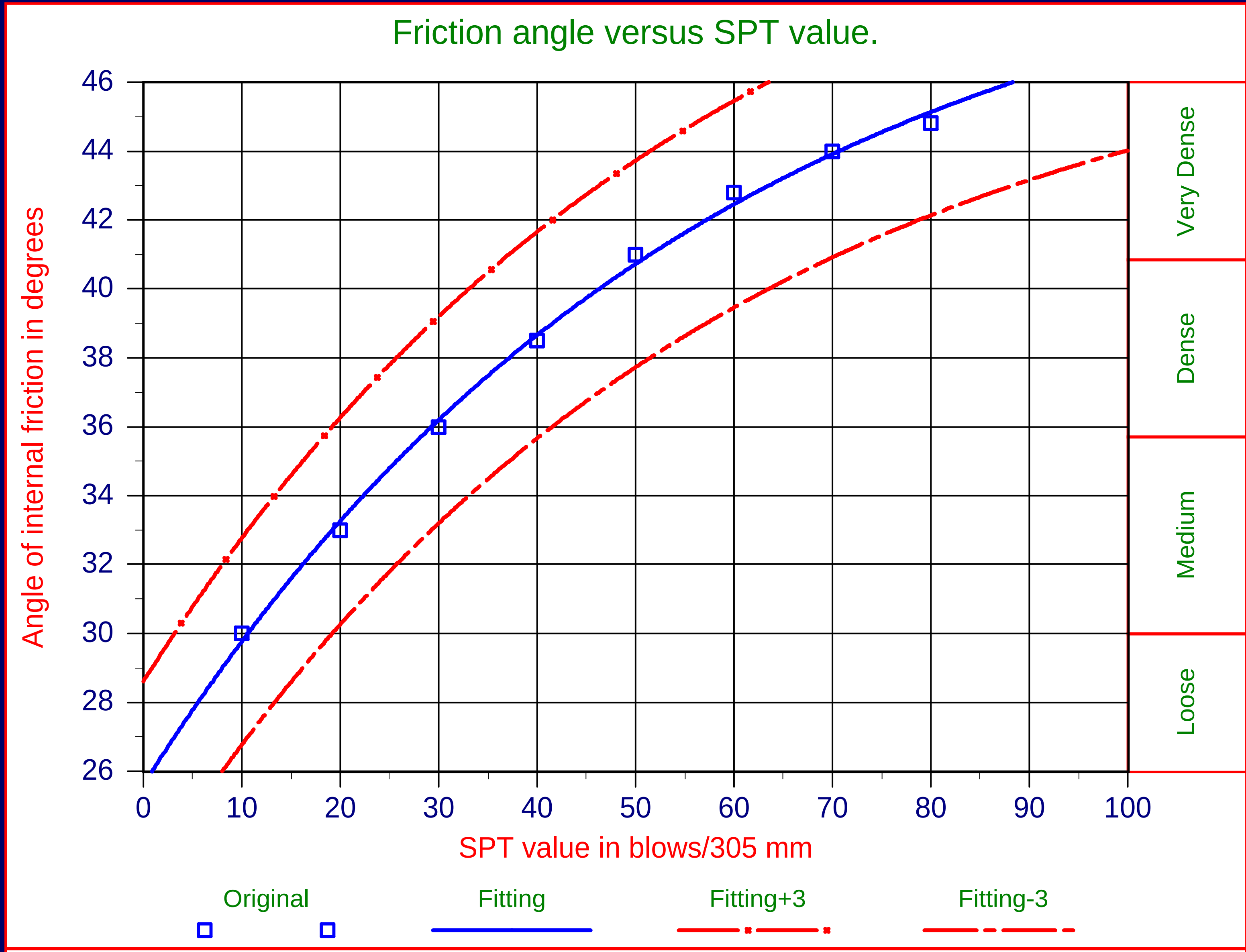
Normalised SPT values



$$SPT_{10} = \frac{1}{(0.646 + 0.0354 \cdot z)} \cdot SPT_z$$

The measured SPT value reduced to the SPT value at 10 m waterdepth for water saturated sand.

Internal Friction Angle vs SPT Value



Saturated Sand Specific Energy

$$E_s = \frac{P_c}{Q_c} = \frac{F_h \cdot v_c}{h_i \cdot b \cdot v_c} = d_1 \cdot \rho_w \cdot g \cdot (z + 10)$$

$$\mathbf{E_s = \rho_w \cdot g \cdot (z + 10) \cdot d_1}$$

$$\mathbf{Q = \frac{P_a}{E_s} = \frac{P_a}{\rho_w \cdot g \cdot (z + 10) \cdot d_1}}$$

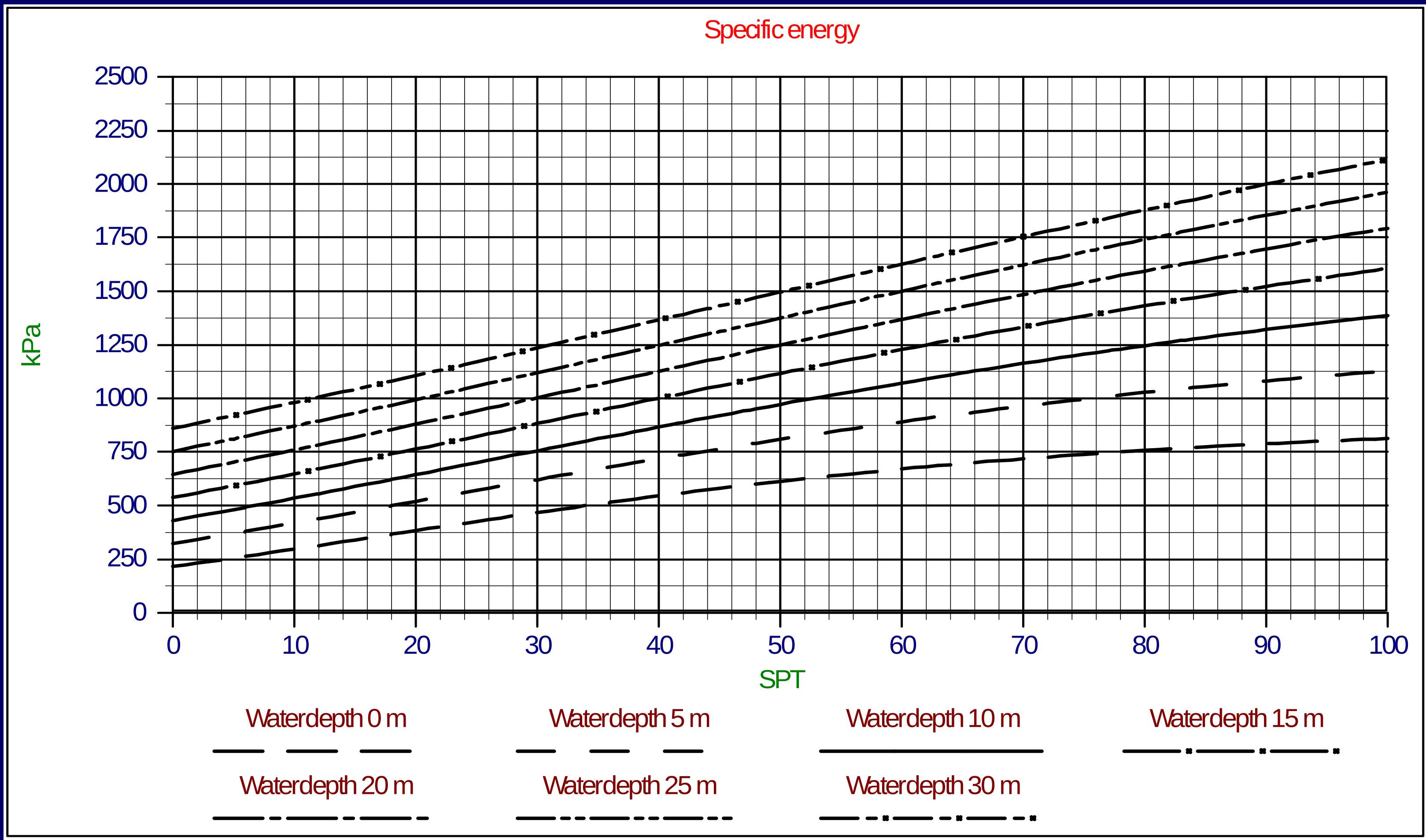
$$\mathbf{d_1 = -0.185 + 0.666 \cdot e^{0.0444 \cdot \varphi}}$$ **30 degree blade angle**

$$\mathbf{d_1 = +0.304 + 0.333 \cdot e^{0.0597 \cdot \varphi}}$$ **45 degree blade angle**

$$\mathbf{d_1 = +0.894 + 0.154 \cdot e^{0.0818 \cdot \varphi}}$$ **60 degree blade angle**

Specific Energy in Sand, 45 Degree Blade

$$E_s = \frac{P_c}{Q_c} = \frac{F_h \cdot v_c}{h_i \cdot b \cdot v_c} = d_1 \cdot \rho_w \cdot g \cdot (z + 10)$$



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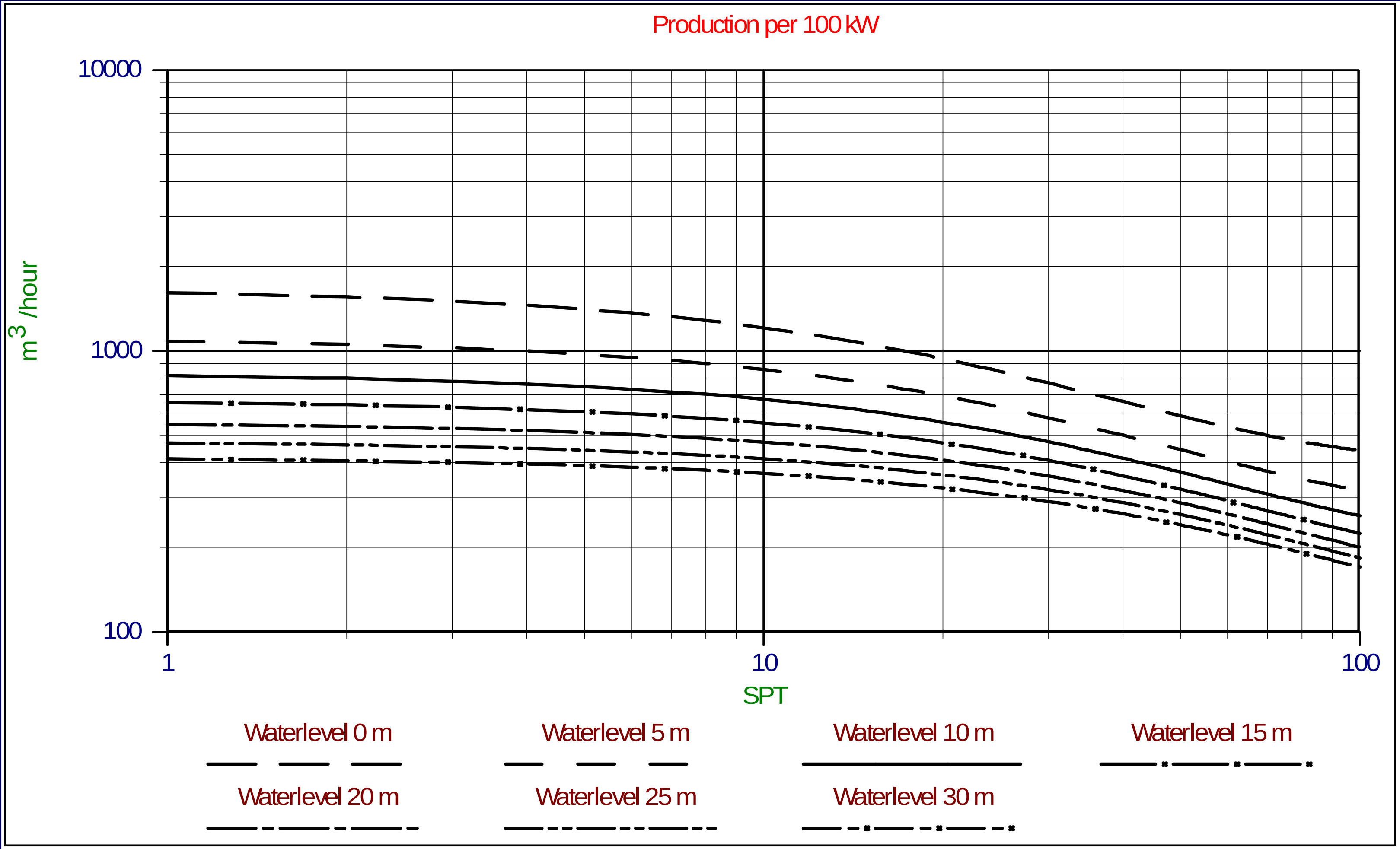
Production in Sand, 45 Degree Blade

$$Q_c = {P_c}/{E_s}$$



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Experiments

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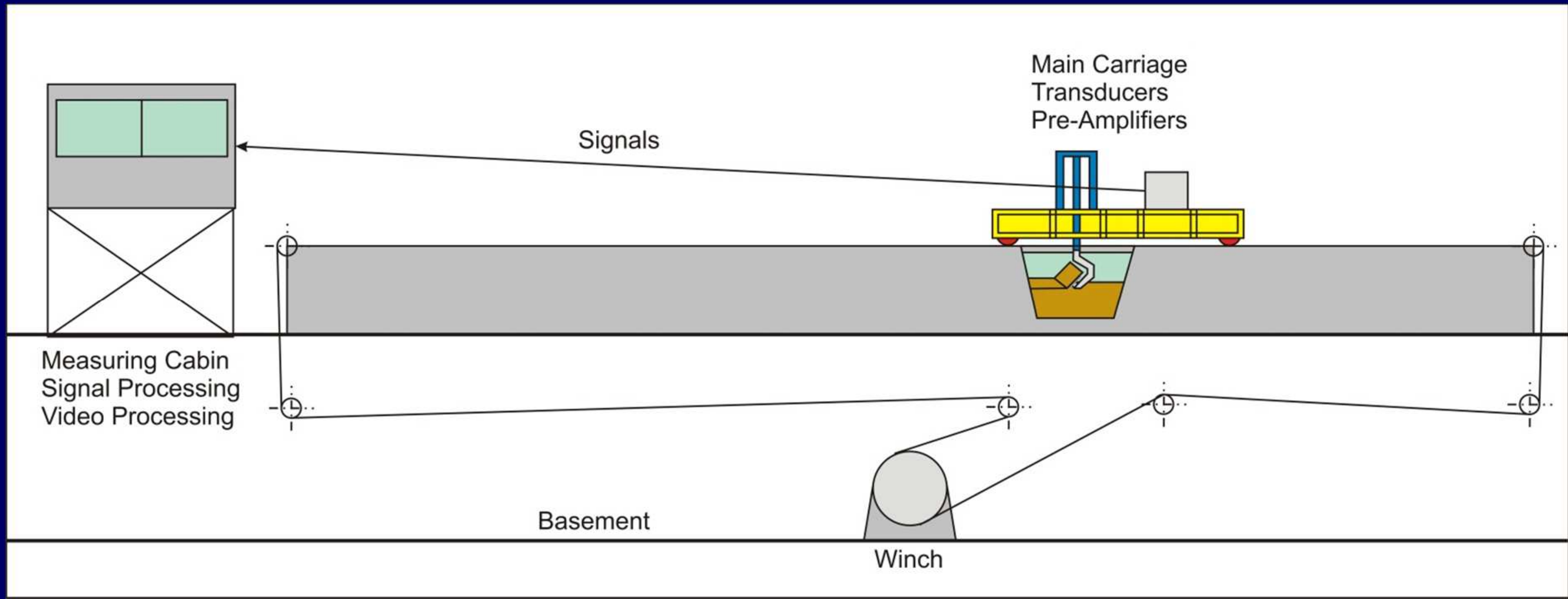
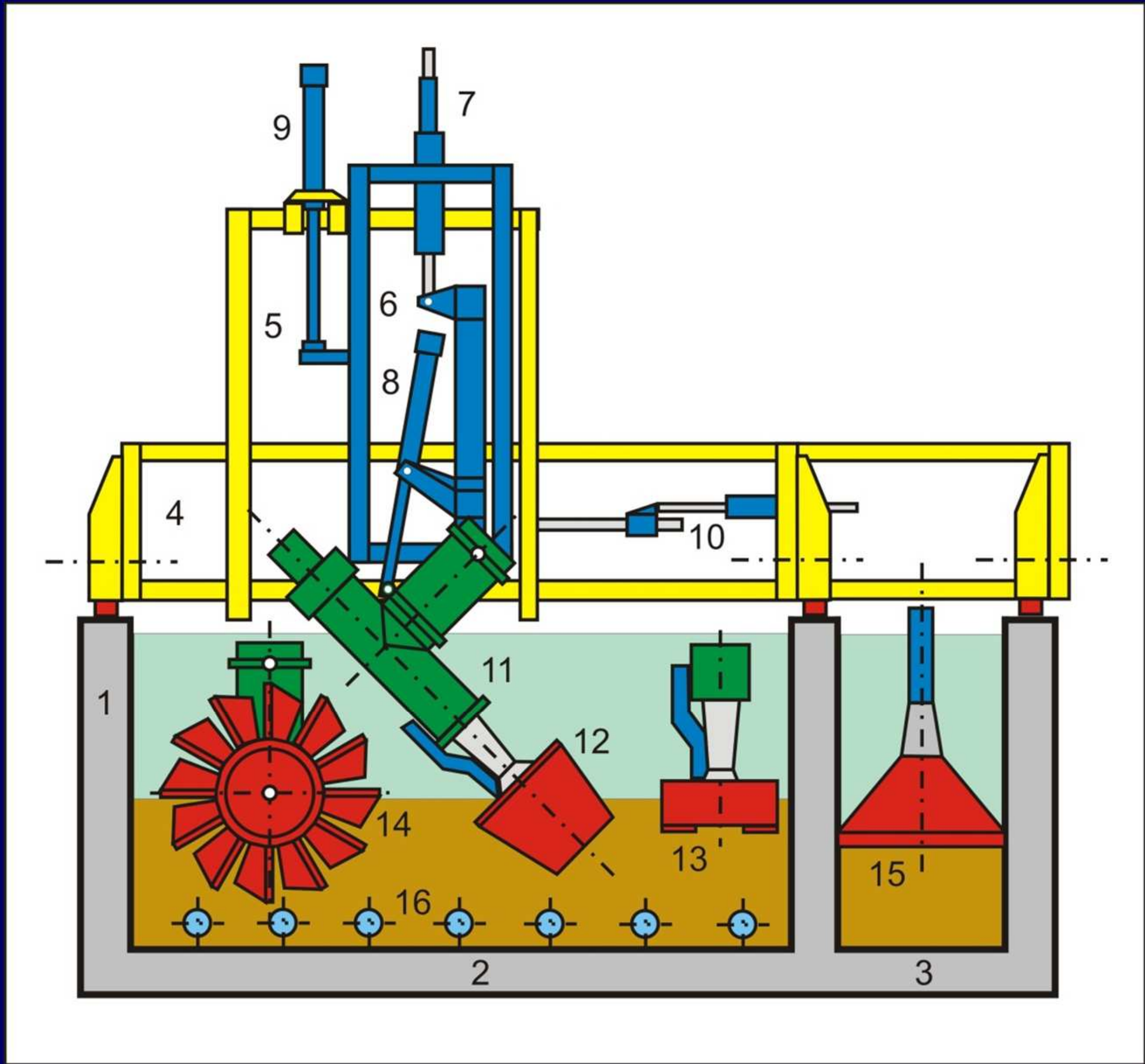
Laboratory Side View



Dredging Technology Research Lab.



1. Concrete Tank
2. Cutting Tank
3. Spoil Tank
4. Main Carriage
5. Transversal Carriage
6. Frame
7. Vertical Positioning
8. Ladder Angle Adjustment
9. Vertical Oscillation
10. Horizontal Oscillation
11. Cutter Ladder
12. Crown Cutter Head
13. Disc Bottom Cutter Head
14. Dredging Wheel
15. Dustpan Spoil Removal
16. Drainage System

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Dredging Technology Research Lab.

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A Model Rock Cutterhead

[1]

Model Cutter Heads

[1]

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Cutting Blade Mounted

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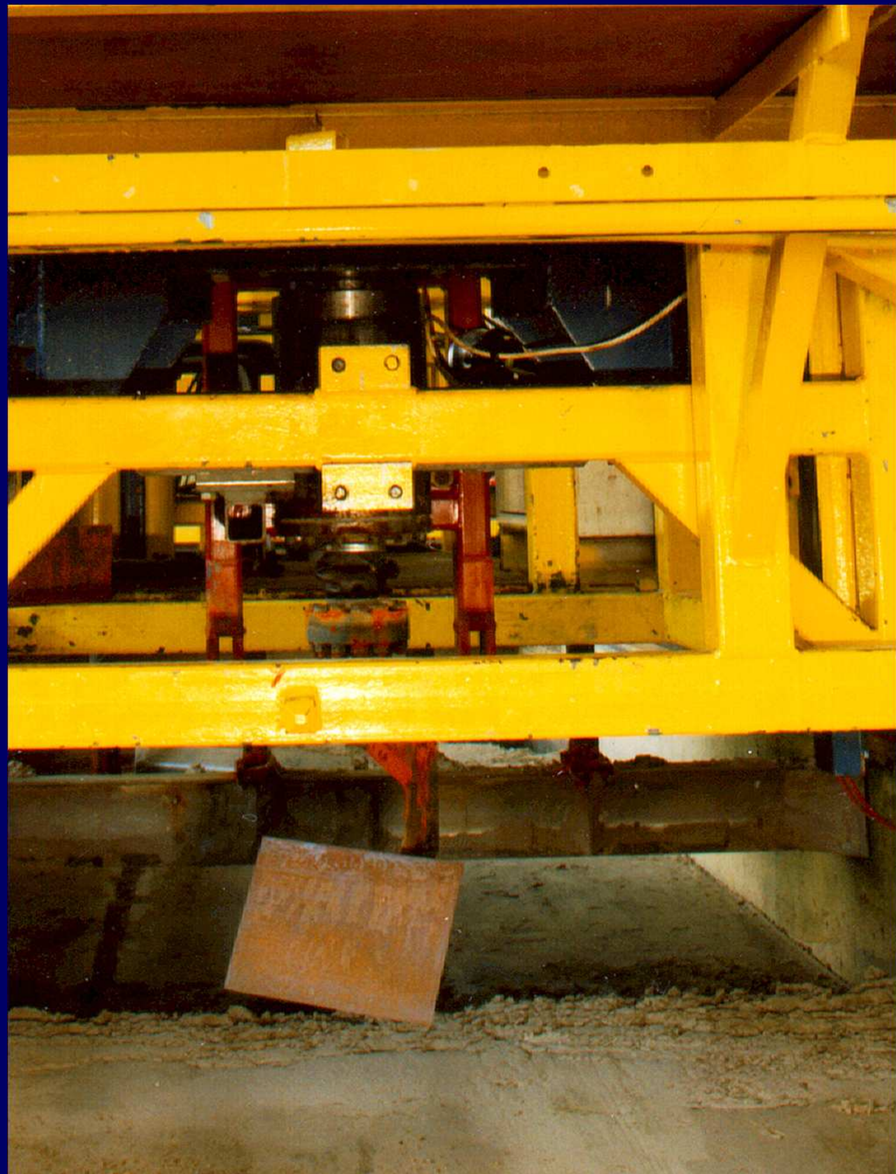
The Inclined Blade



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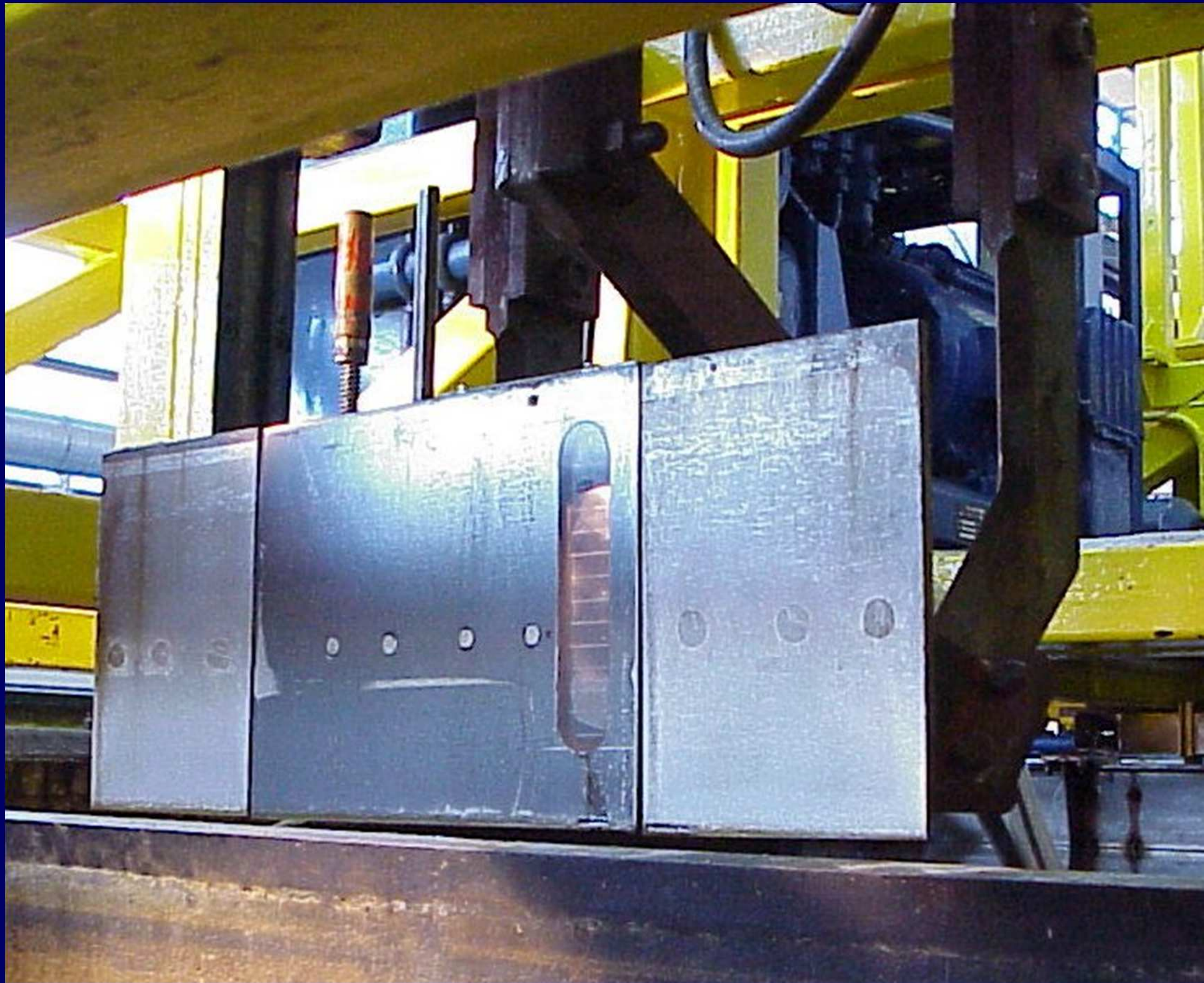
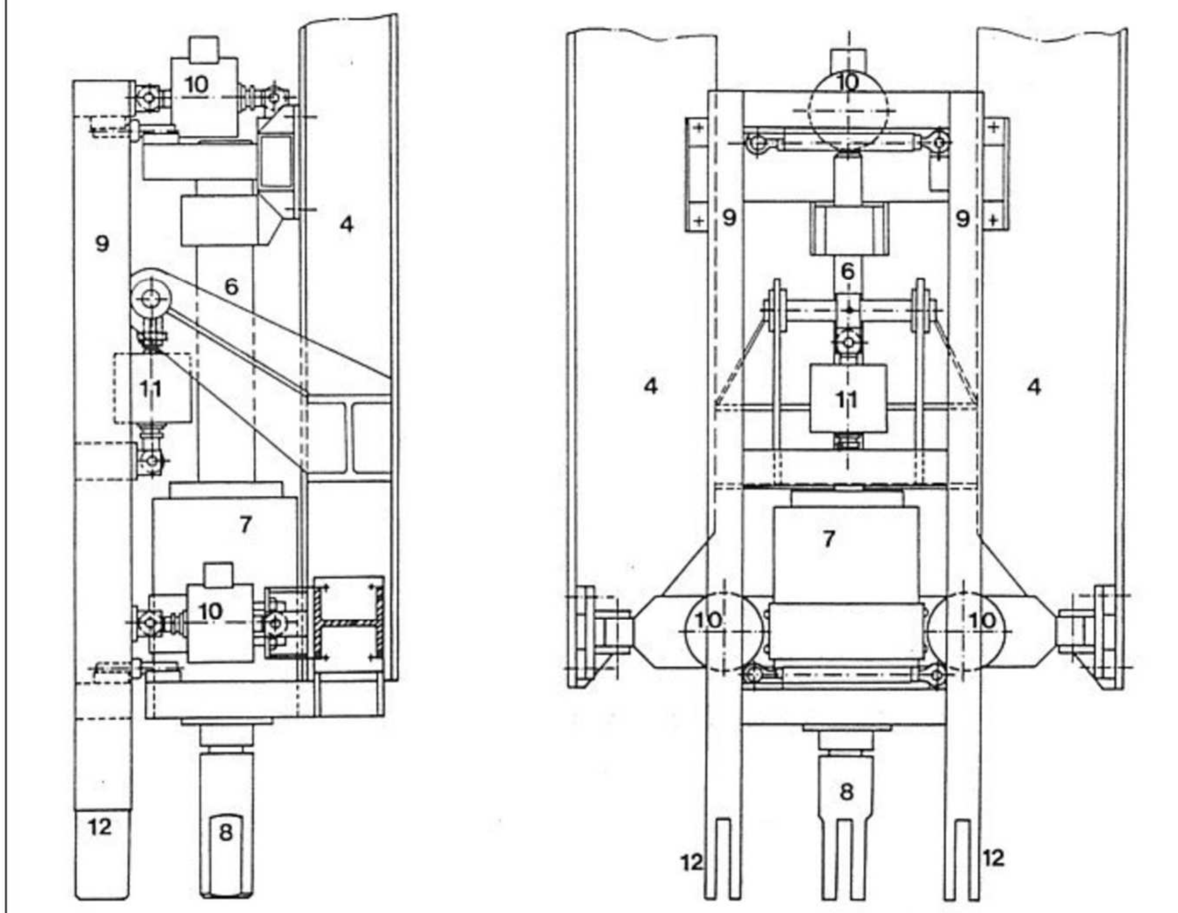
Blades Mounted



Mounting System



4. Auxiliary Frame
6. Middle Blade Mounting
7. Dynamometer Middle Blade
8. Mounting Point Middle Blade
9. Side Blade Mounting
10. Dynamometers Horizontal Force Side Blades
11. Dynamometer Vertical Force Side Blades
12. Mounting Point Side Blade

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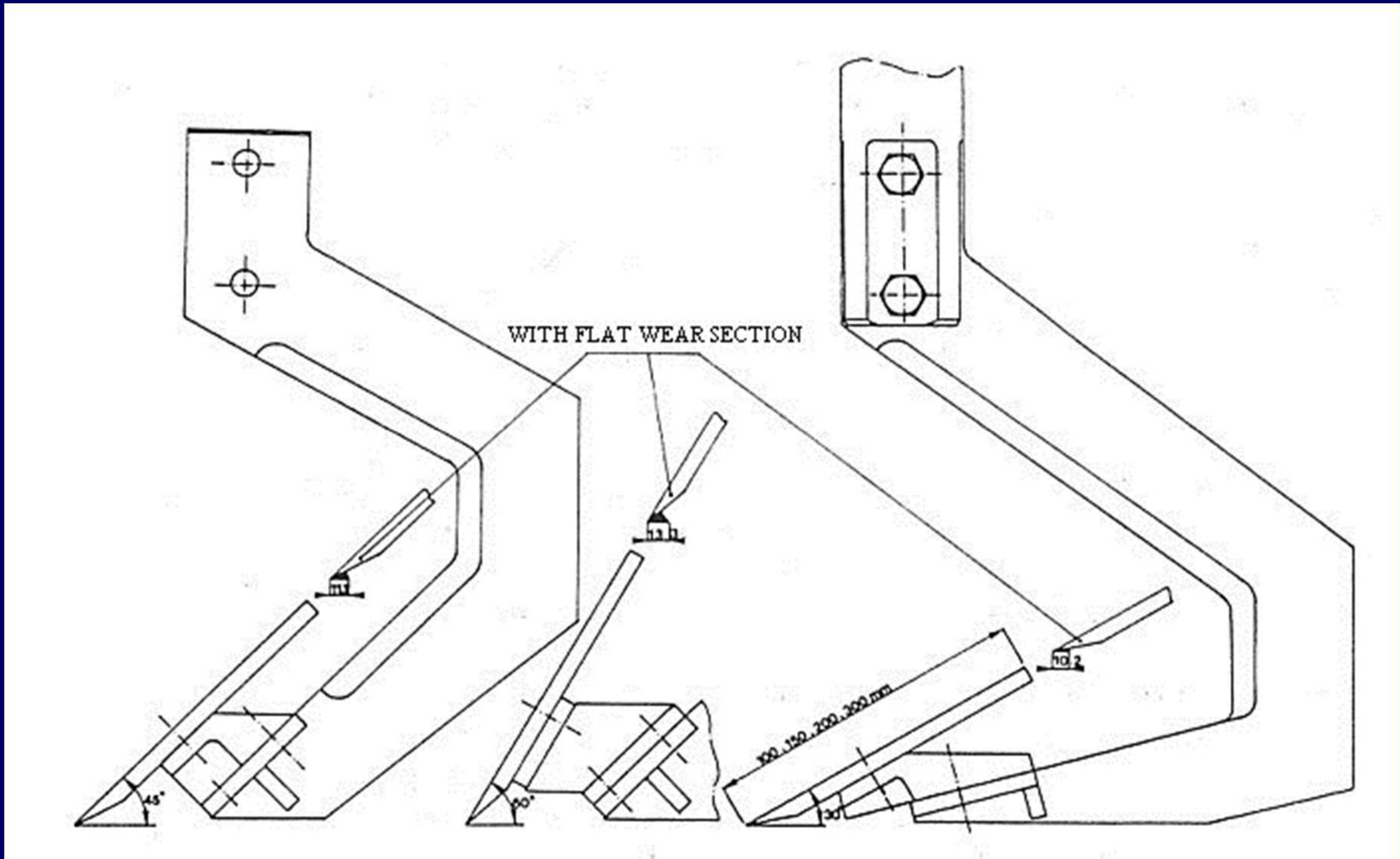
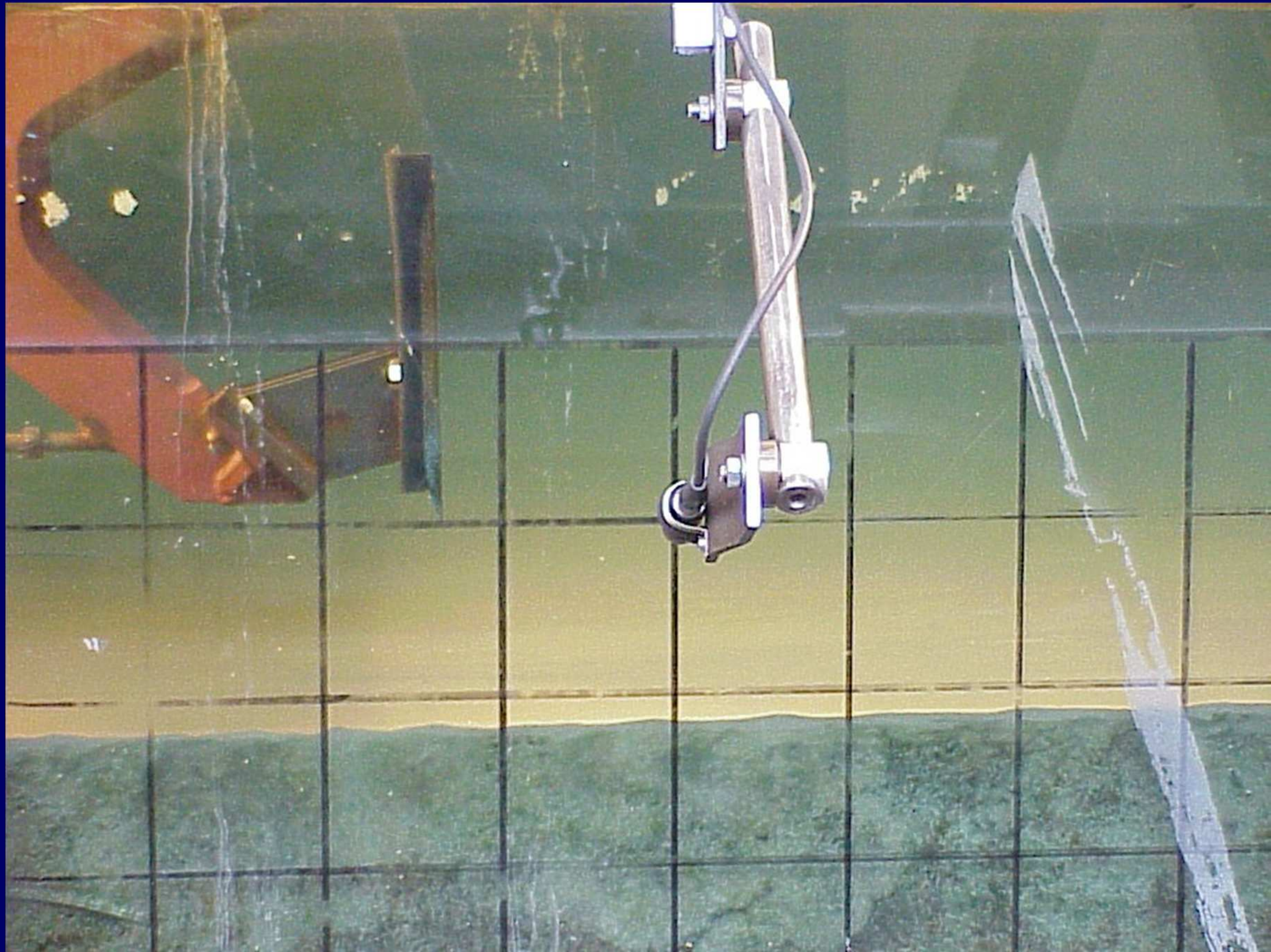
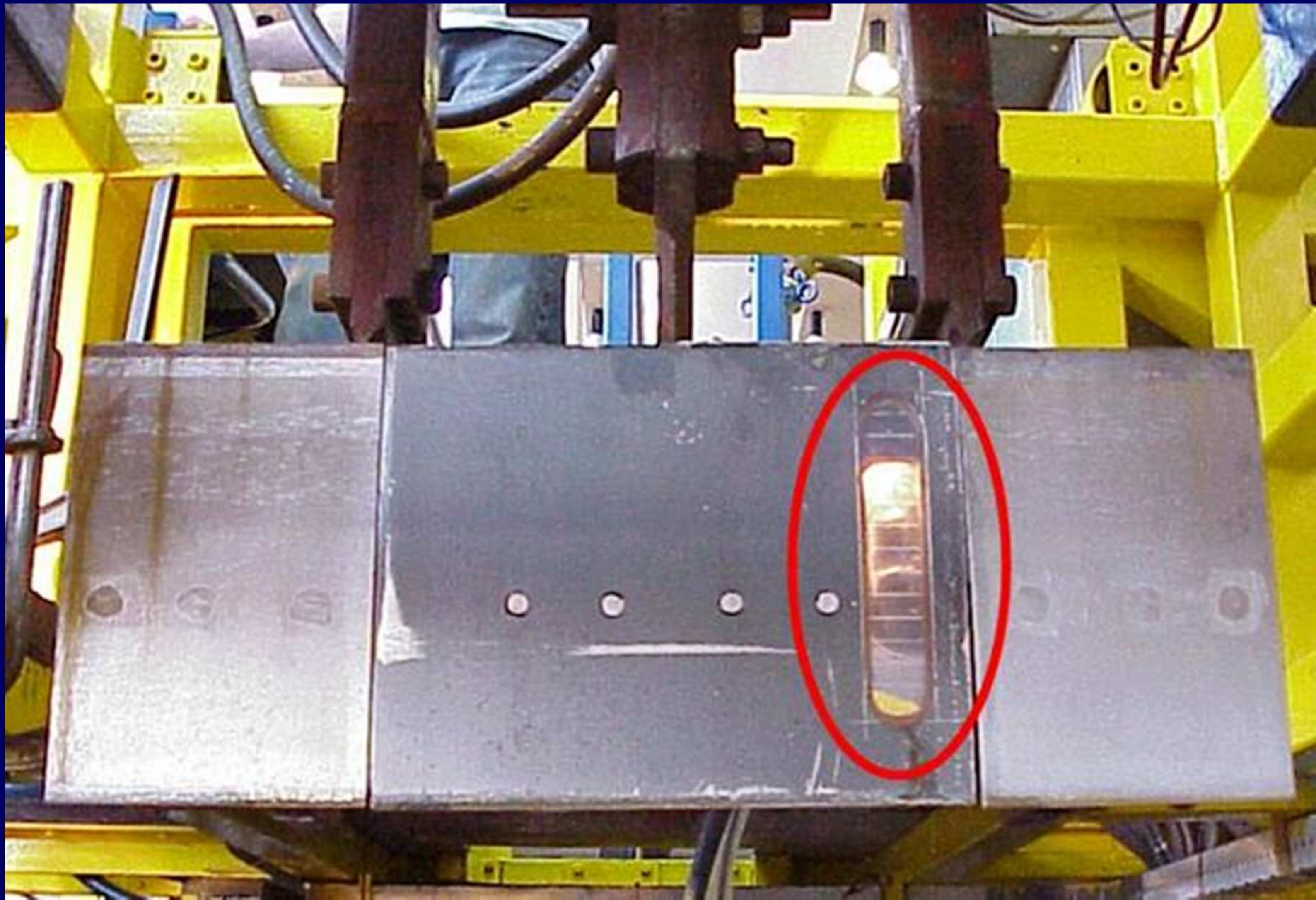
Dimensions



Camera



Window in Blade



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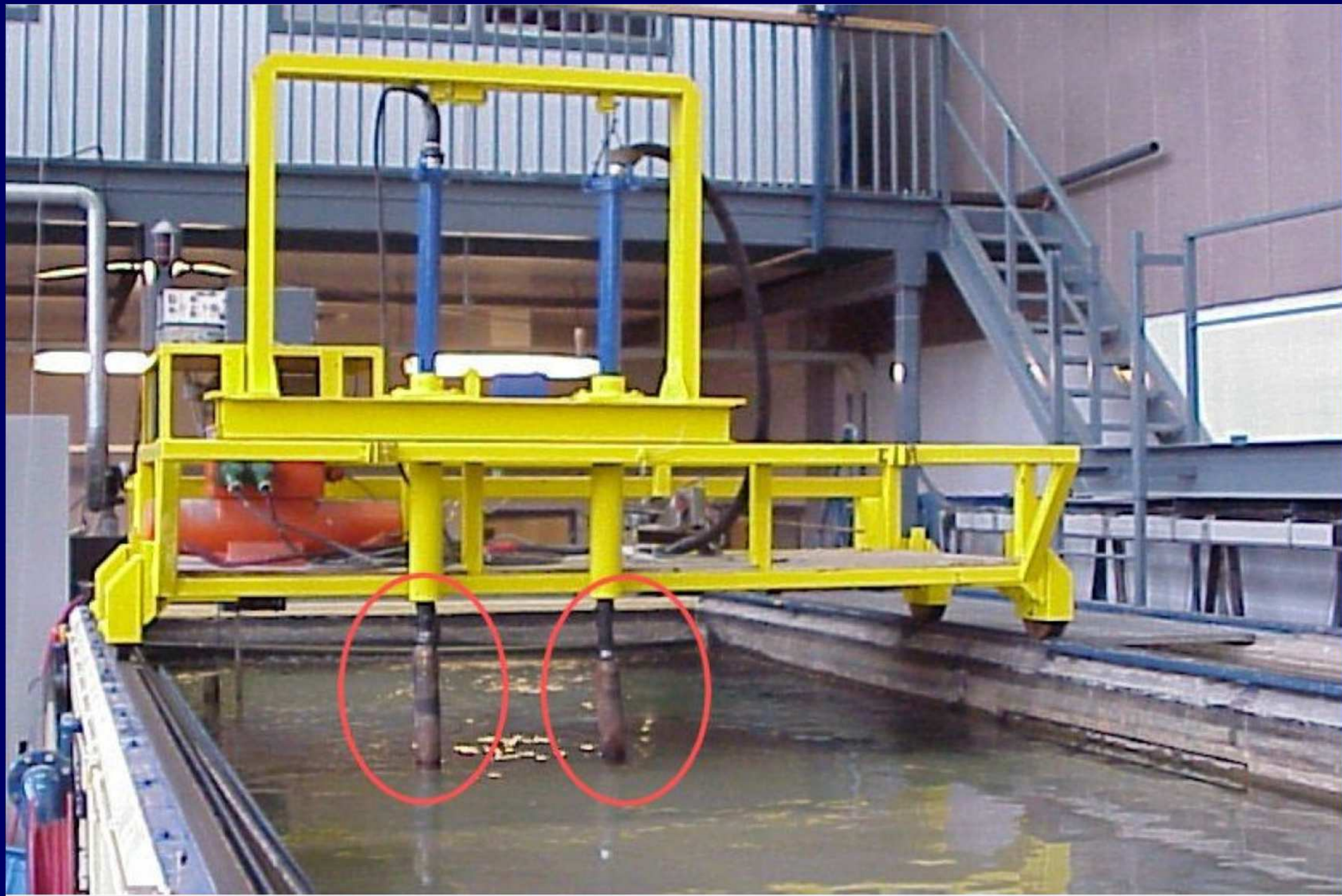
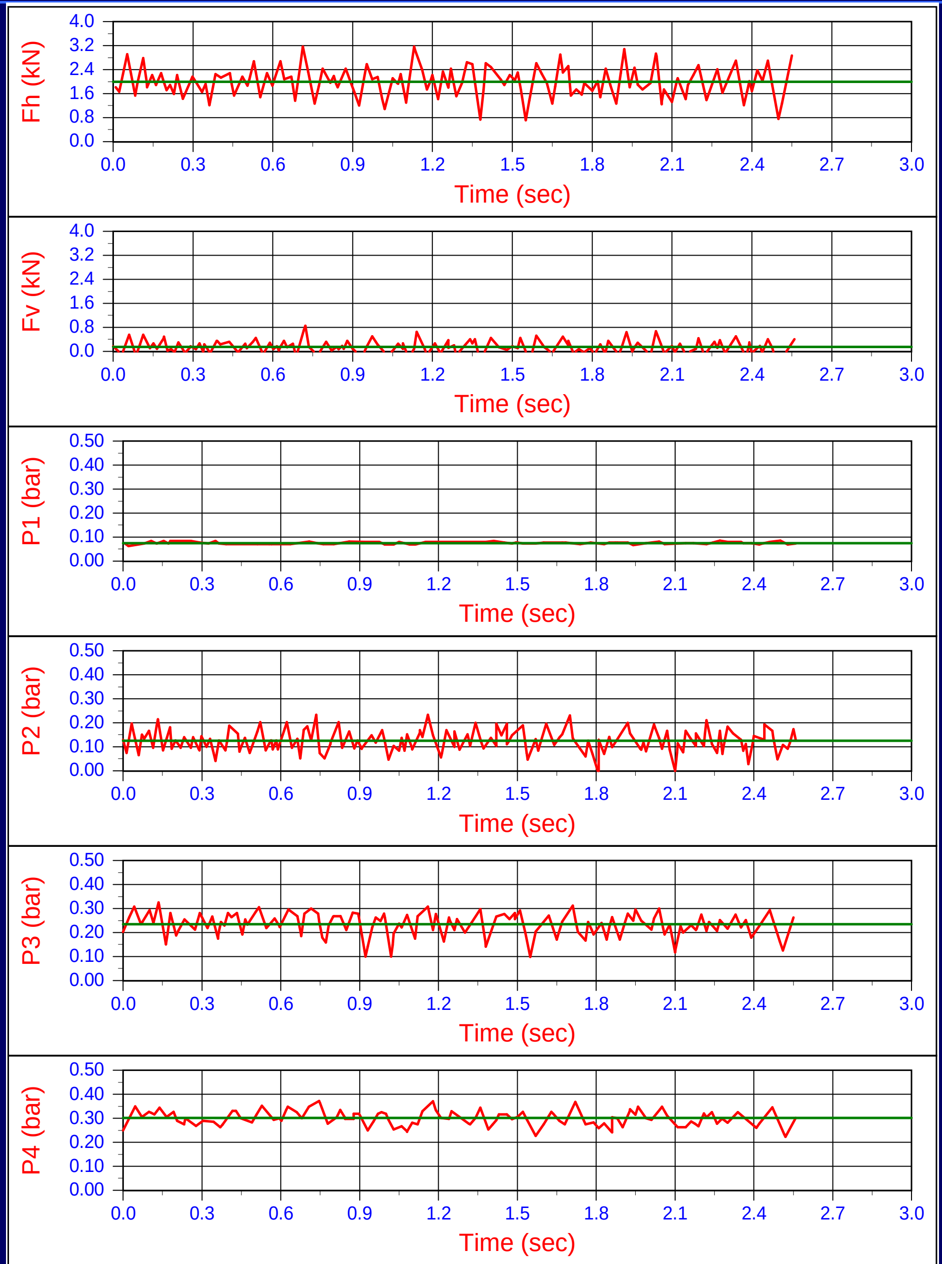
Egaliser

Vibration Devices



Raw Data



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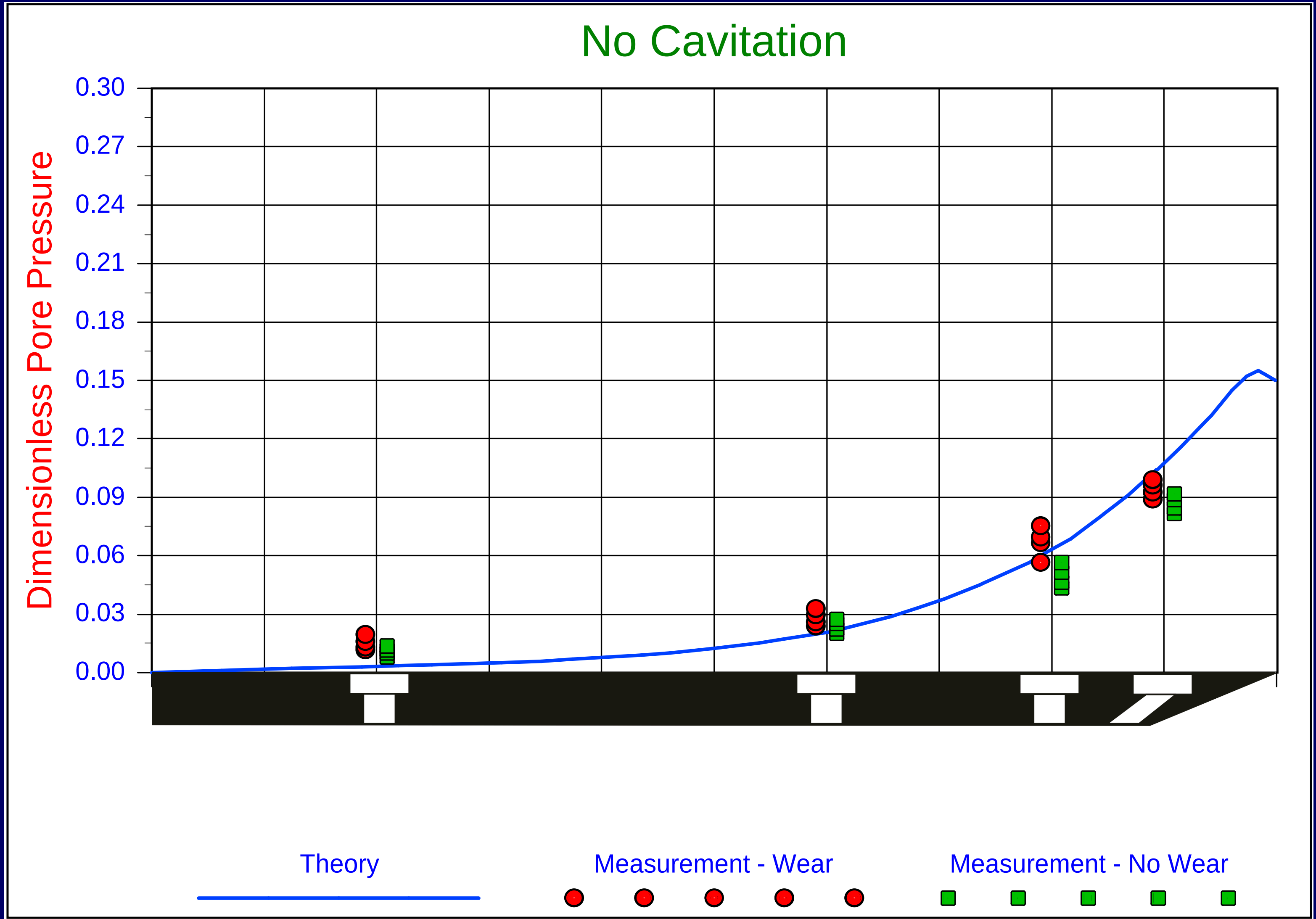
Pore Pressures Long Blade



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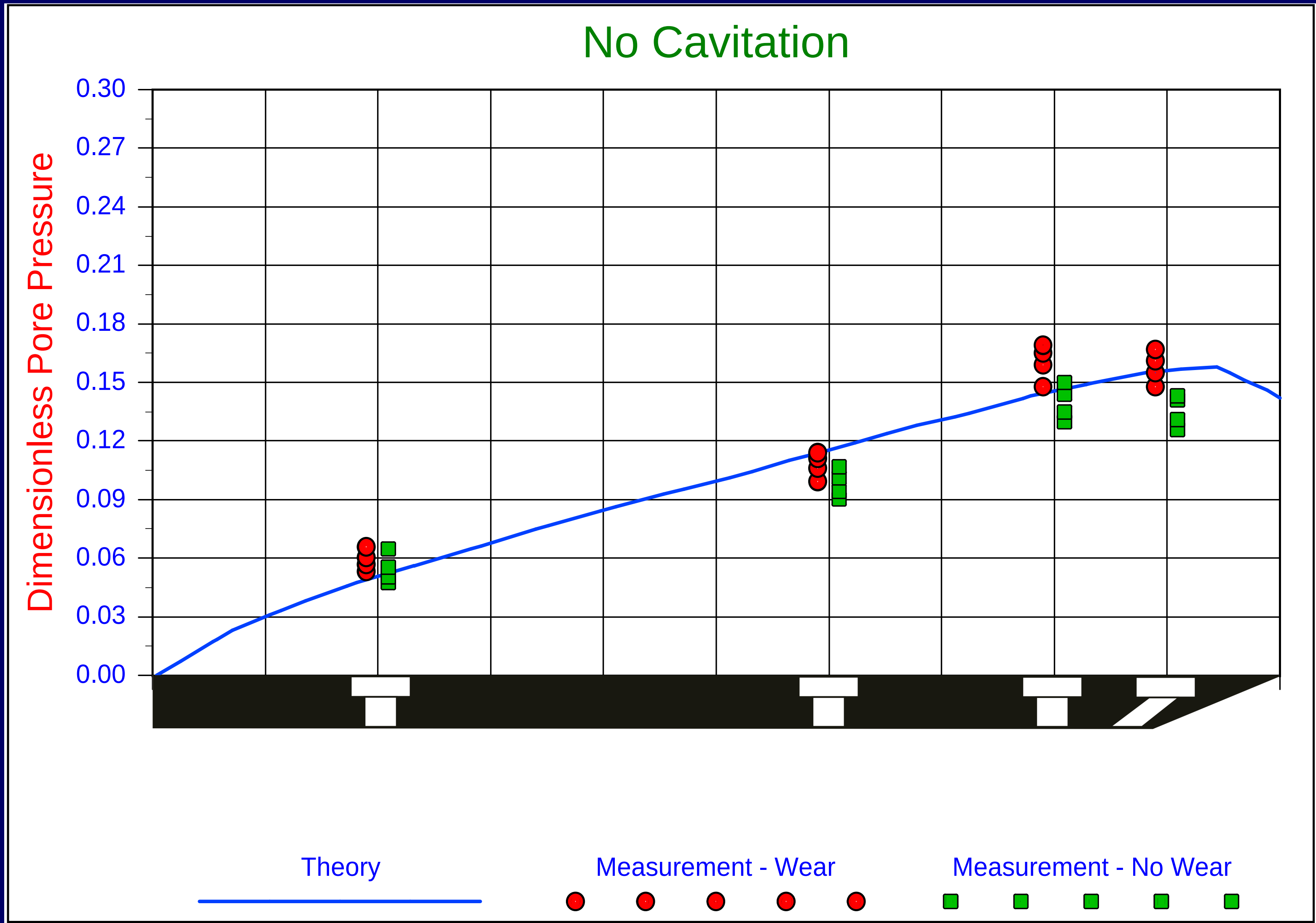
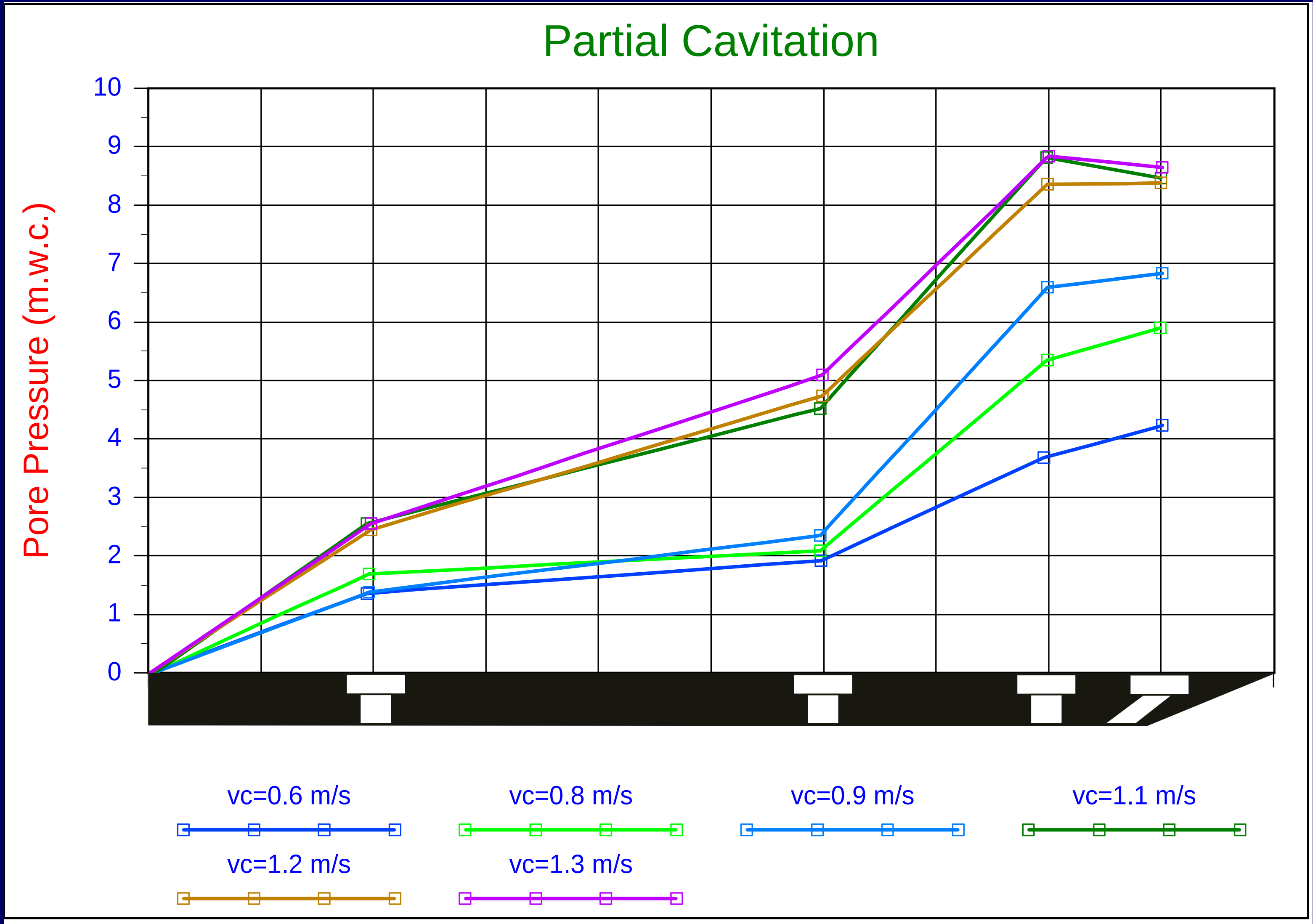
Pore Pressures Short Blade



Pore Pressures Start Cavitation



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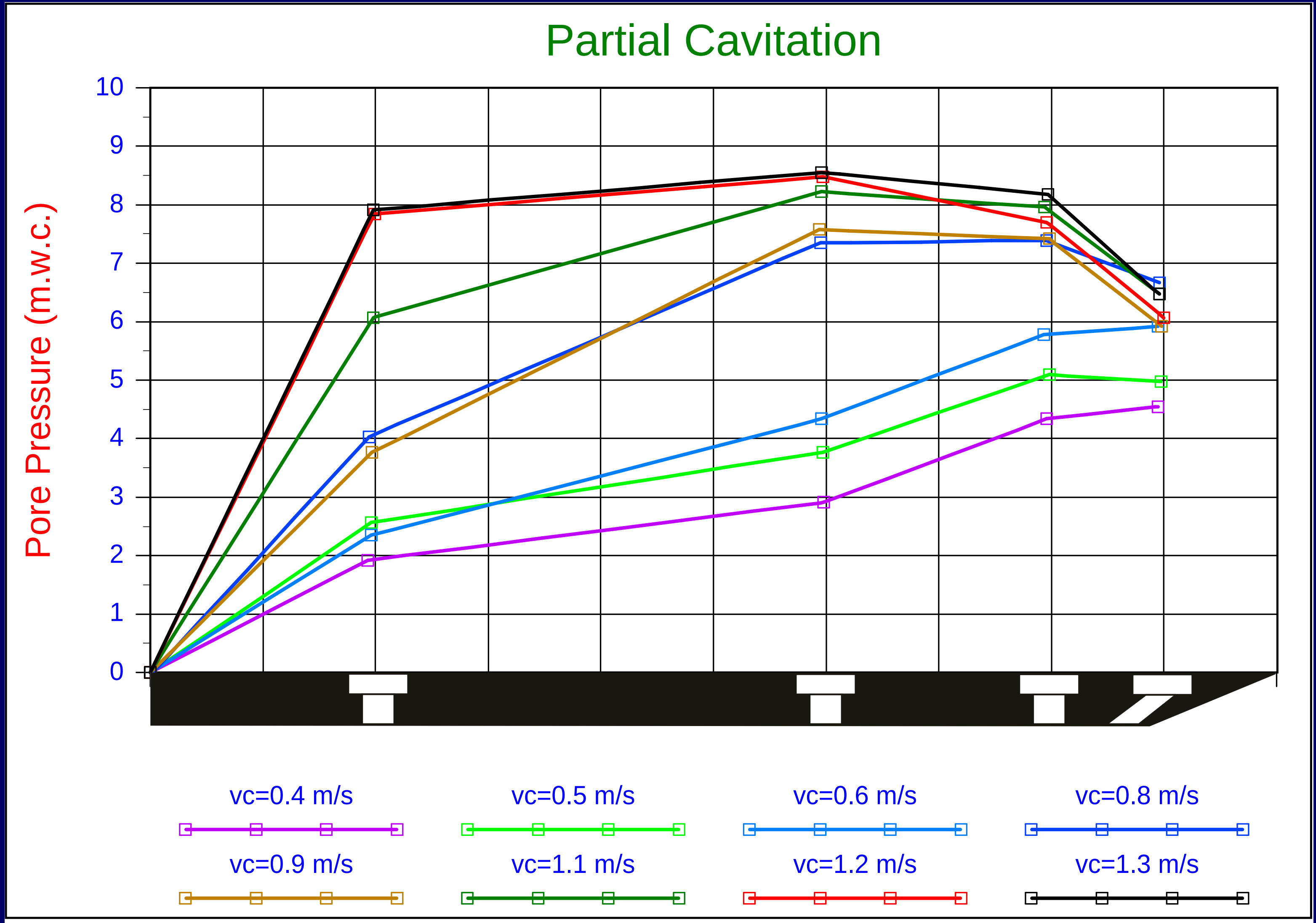
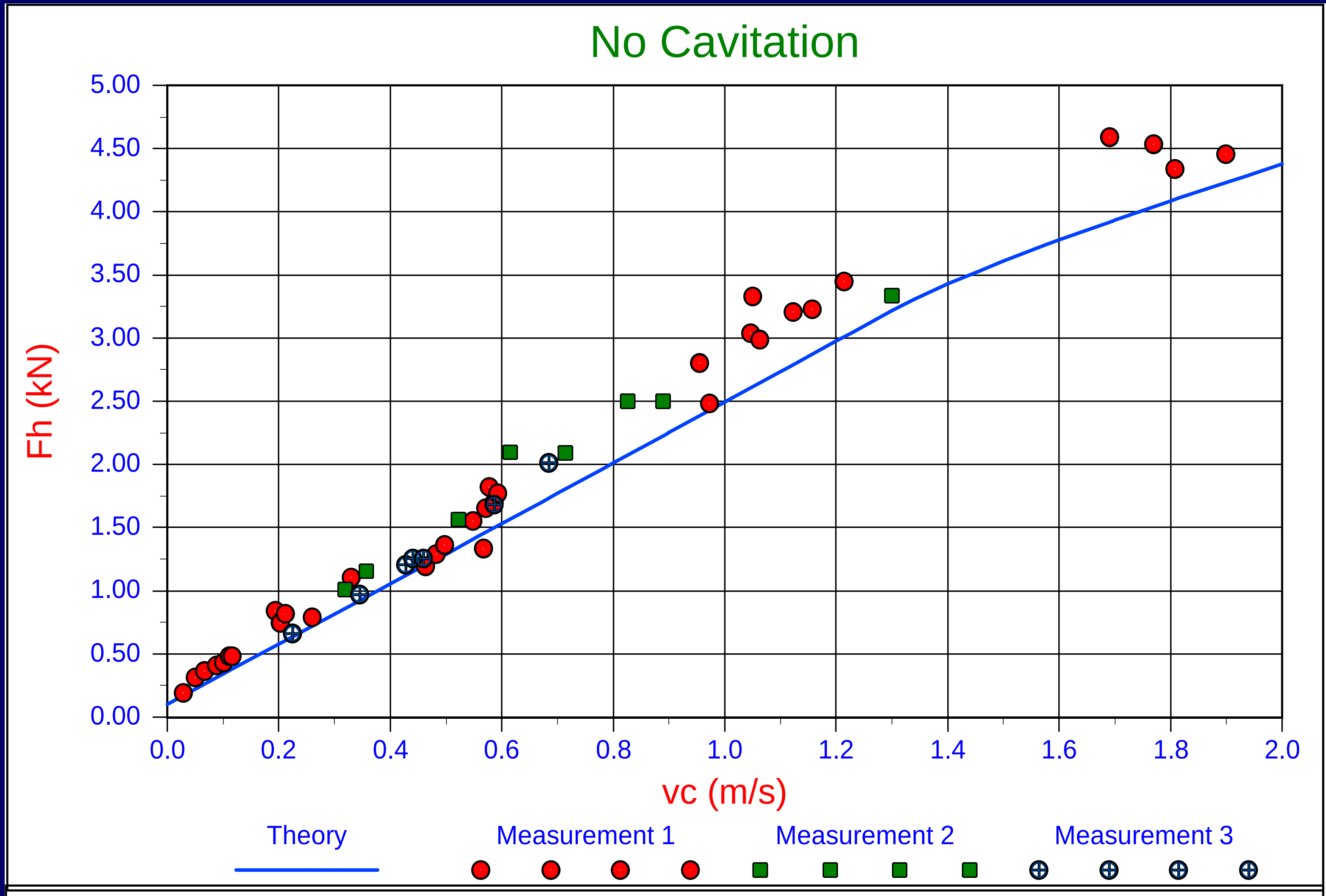
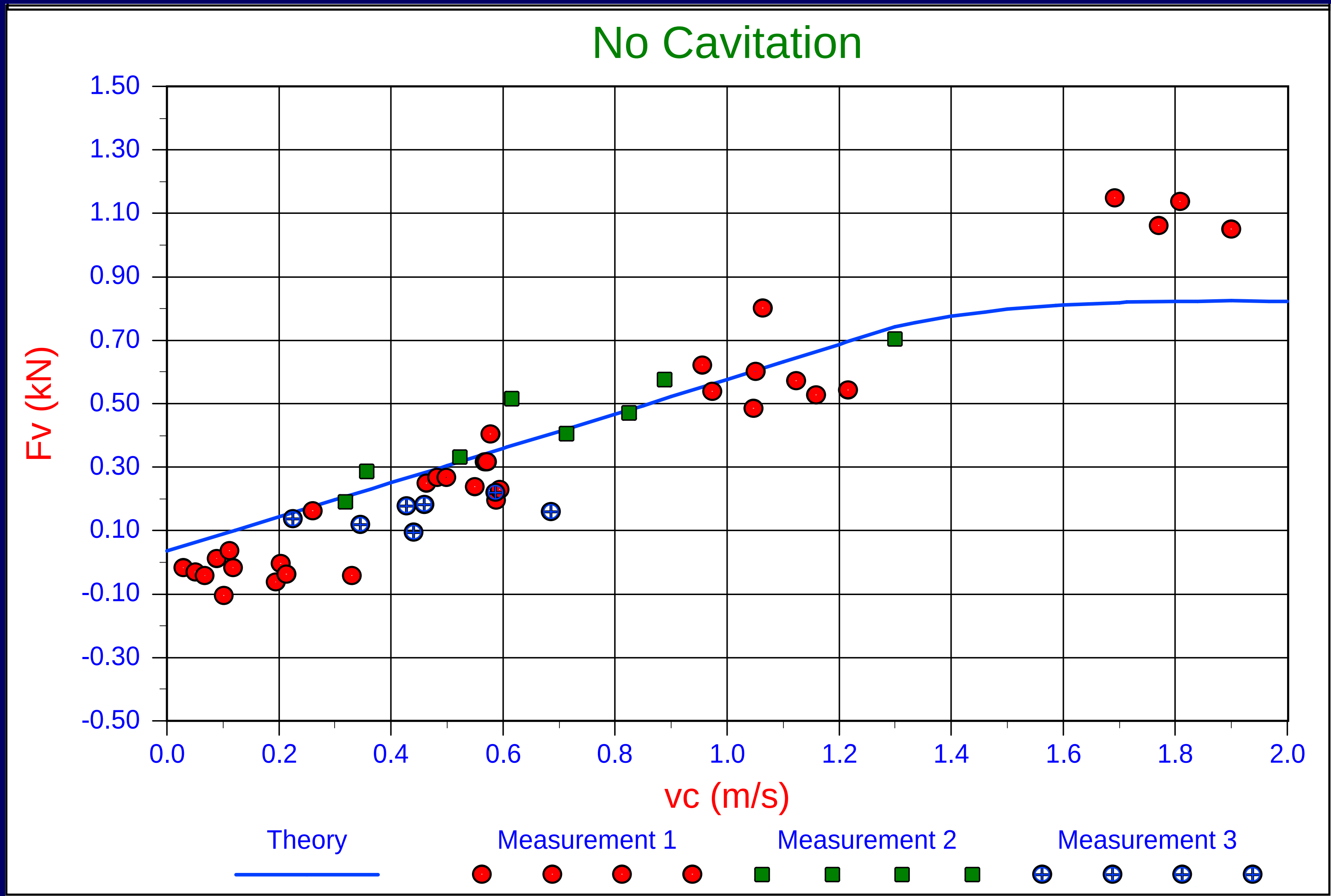
Pore Pressures Cavitation



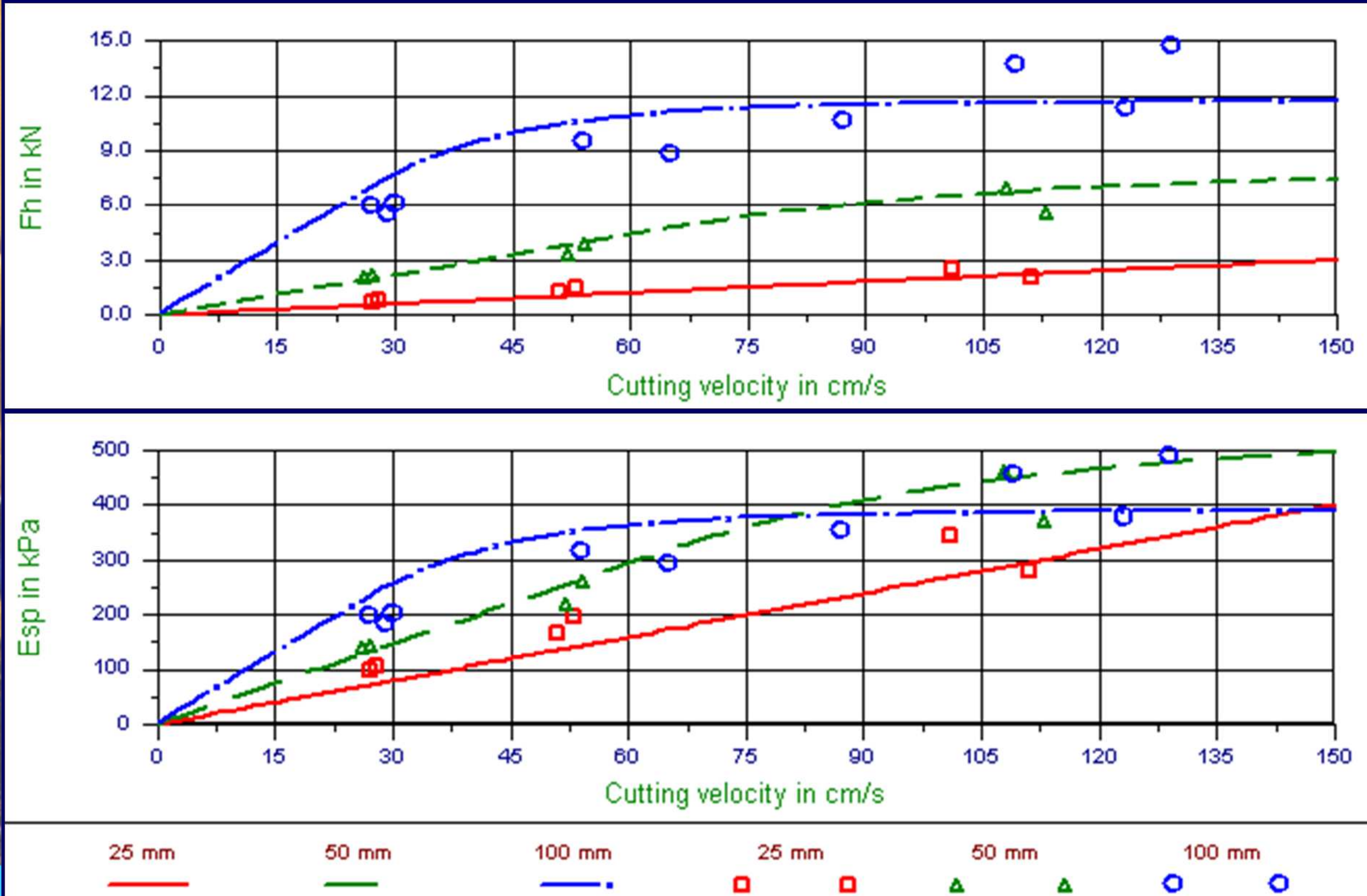
Cutting Forces Horizontal Force



Cutting Forces Vertical Force



Verification of Cutting Theory



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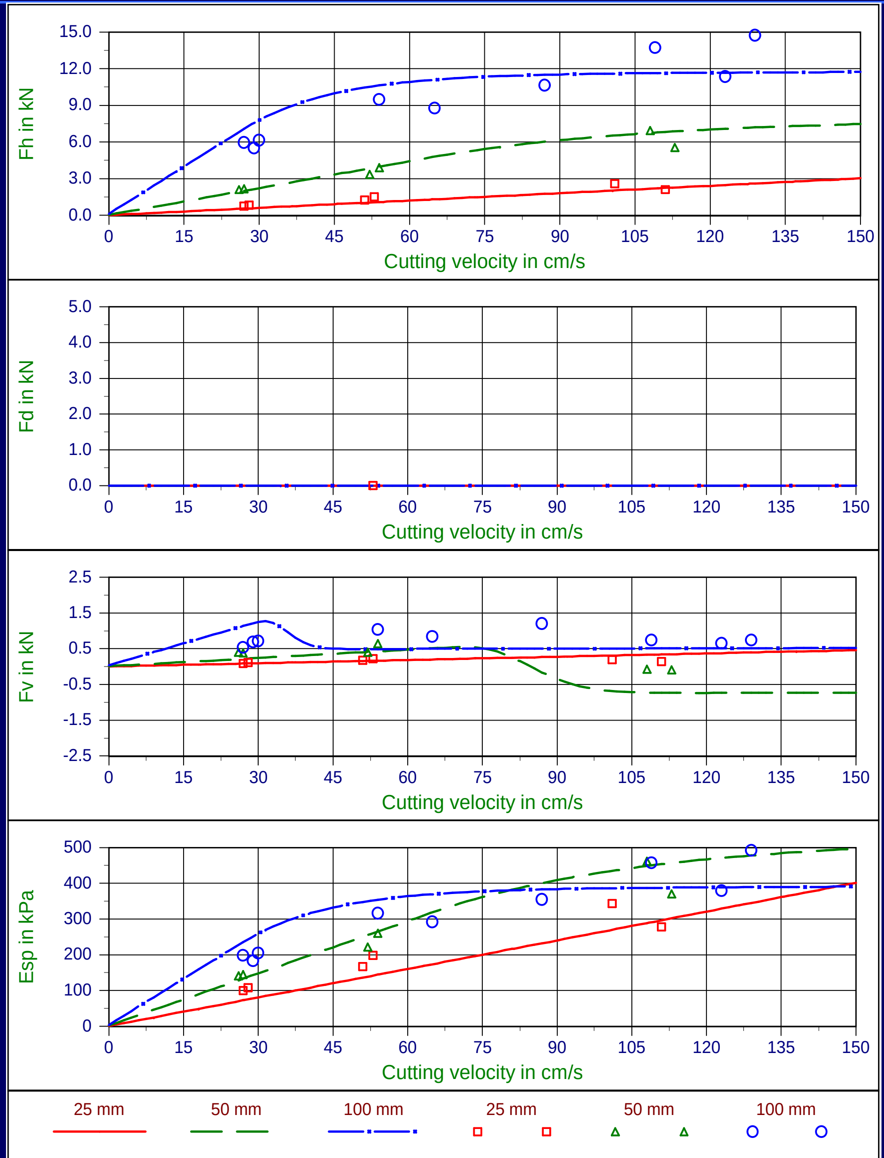
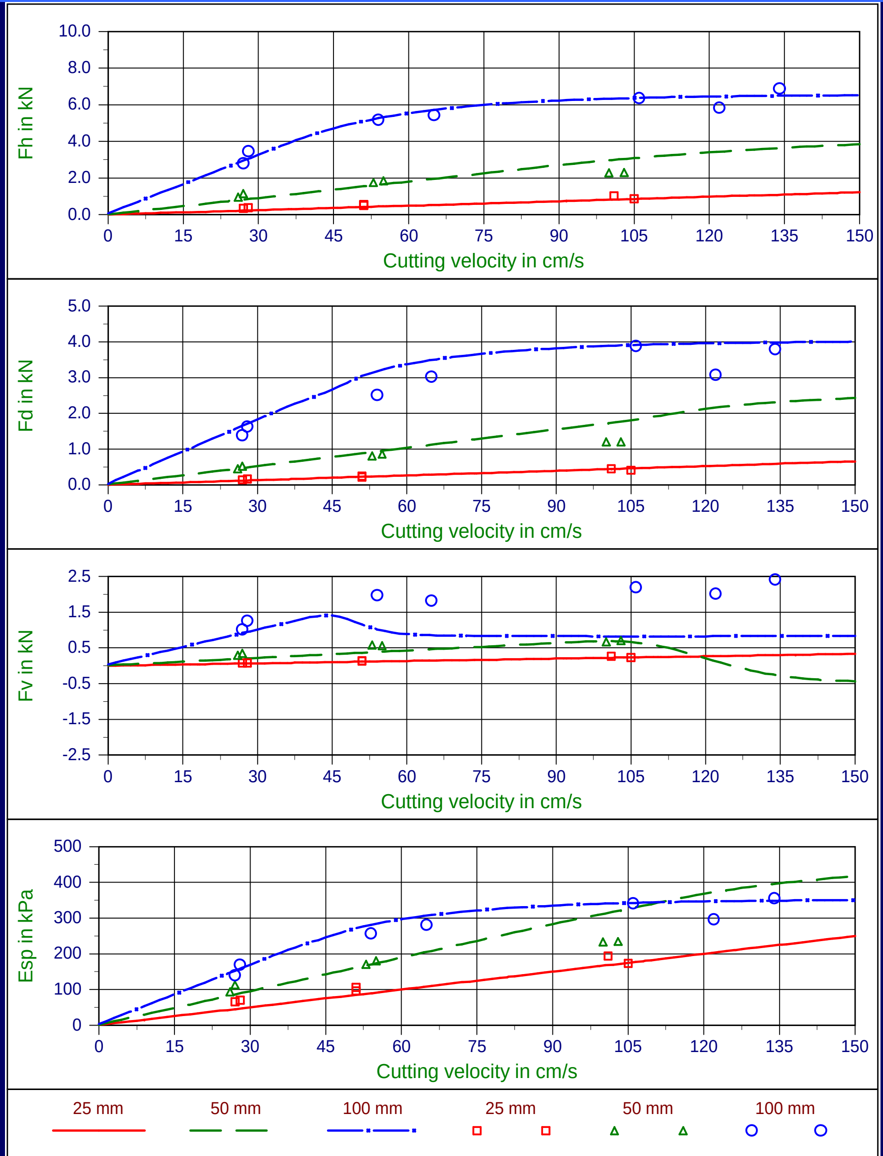
Snow Plough Effect 0 Degrees



Snow-plough effect research, theory versus measurements.
Blade width 0.3 m, blade height 0.2 m, cutting angle 45 degrees, deviation angle 0 degrees.

Snow Plough Effect 45 Degrees



Snow-plough effect research, theory versus measurements.
Blade width 0.3 m, blade height 0.2 m, cutting angle 45 degrees, deviation angle 45 degrees.

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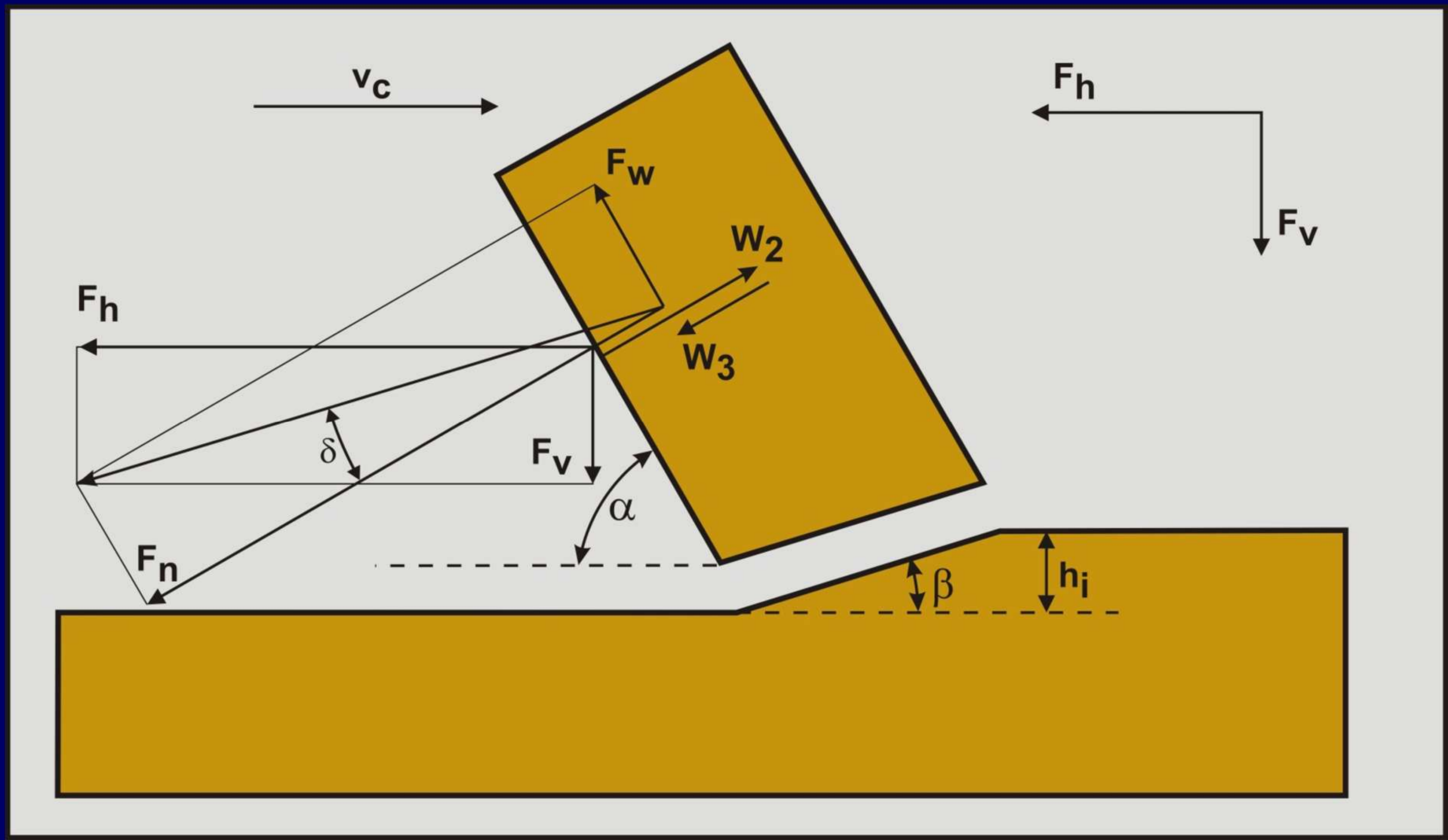
How to determine friction



Saturated Sand With Wedge

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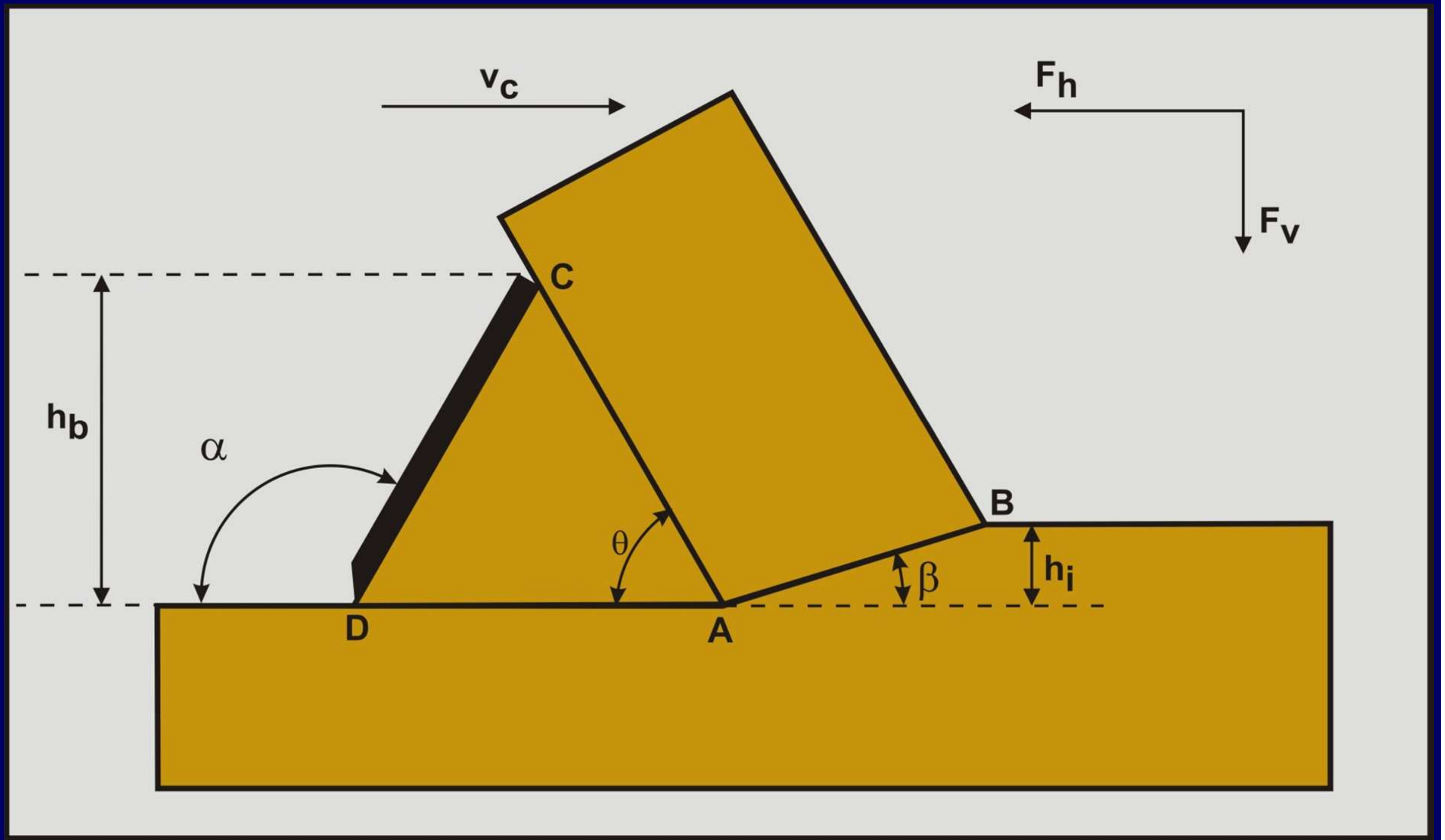
Definitions



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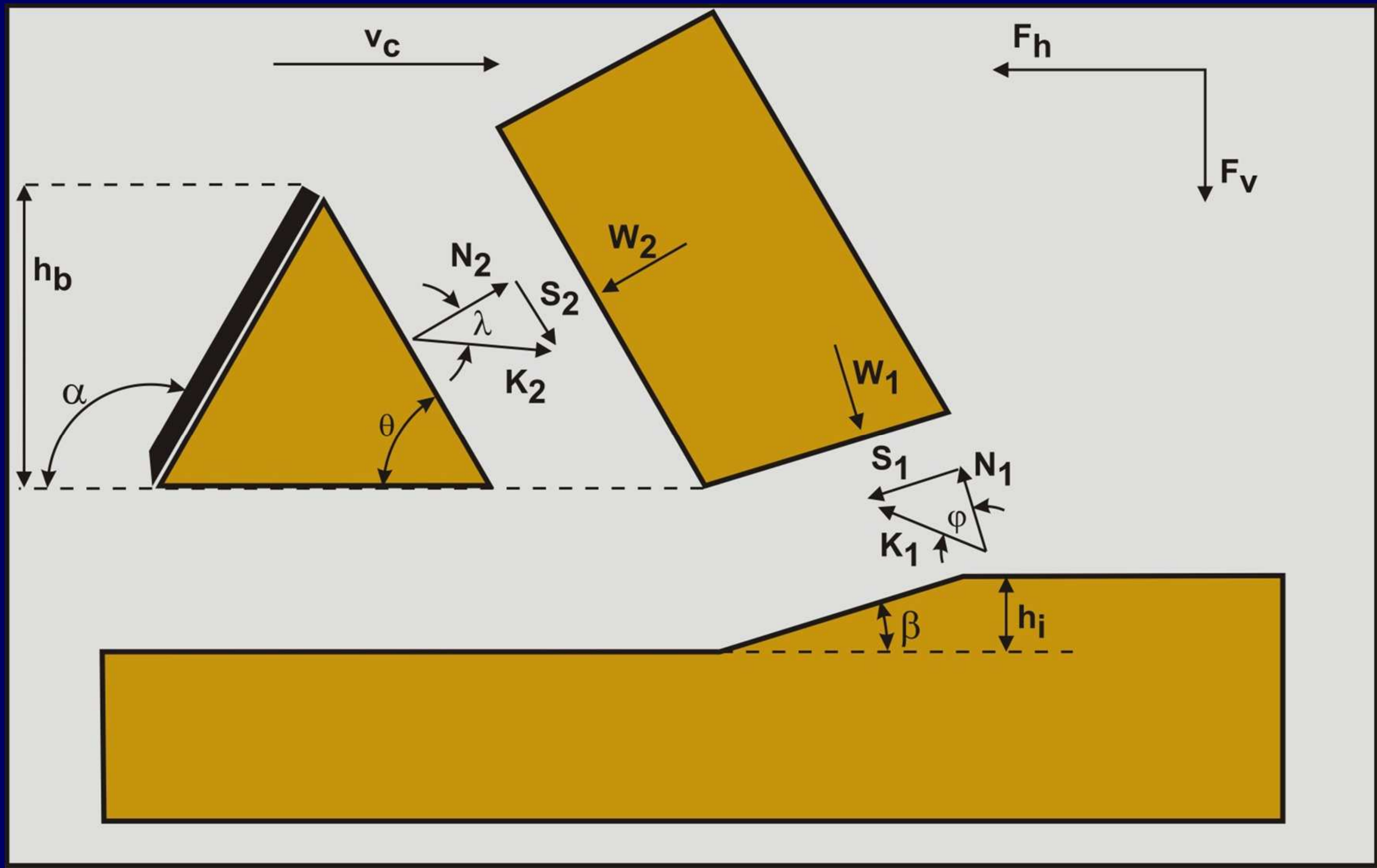
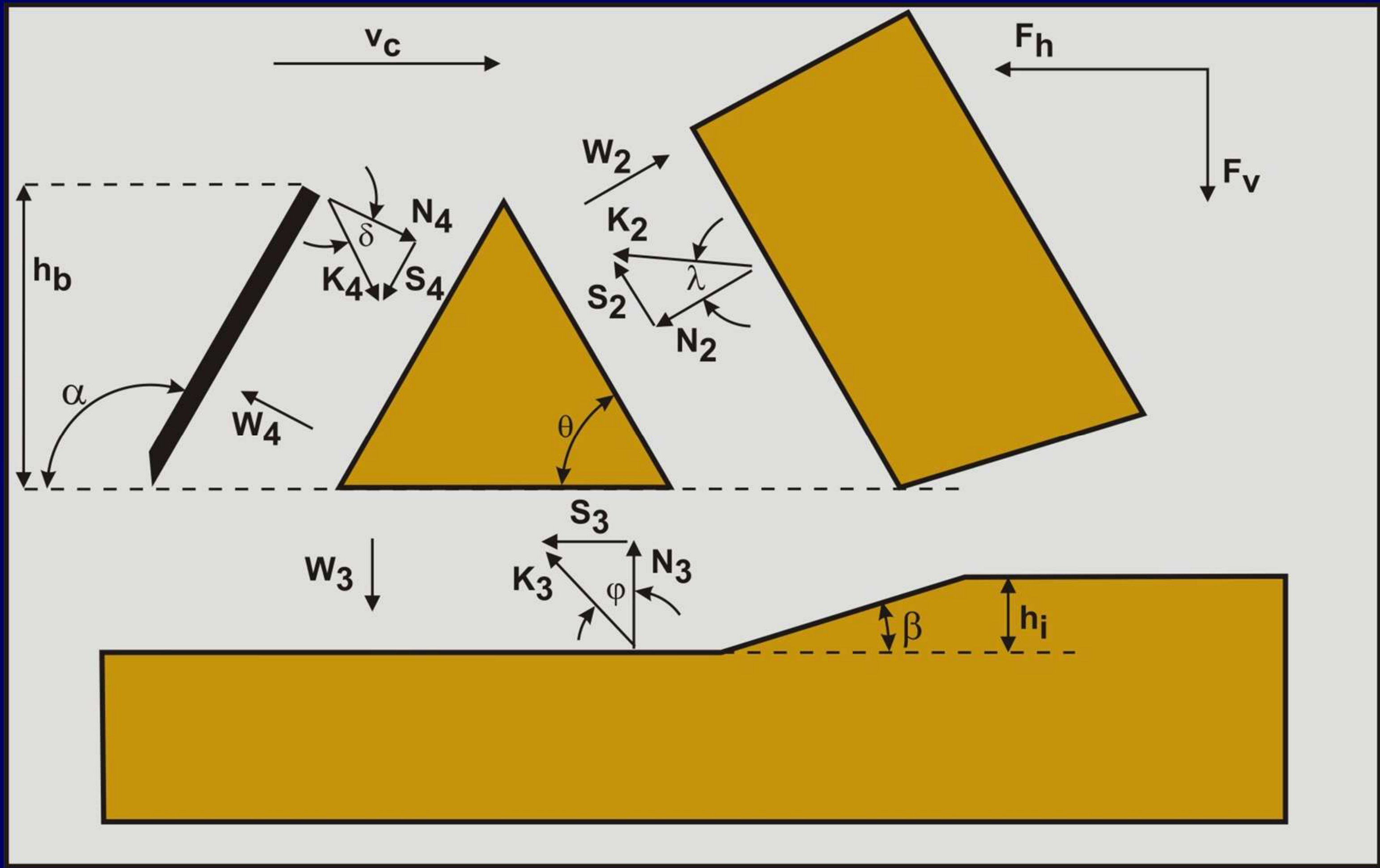
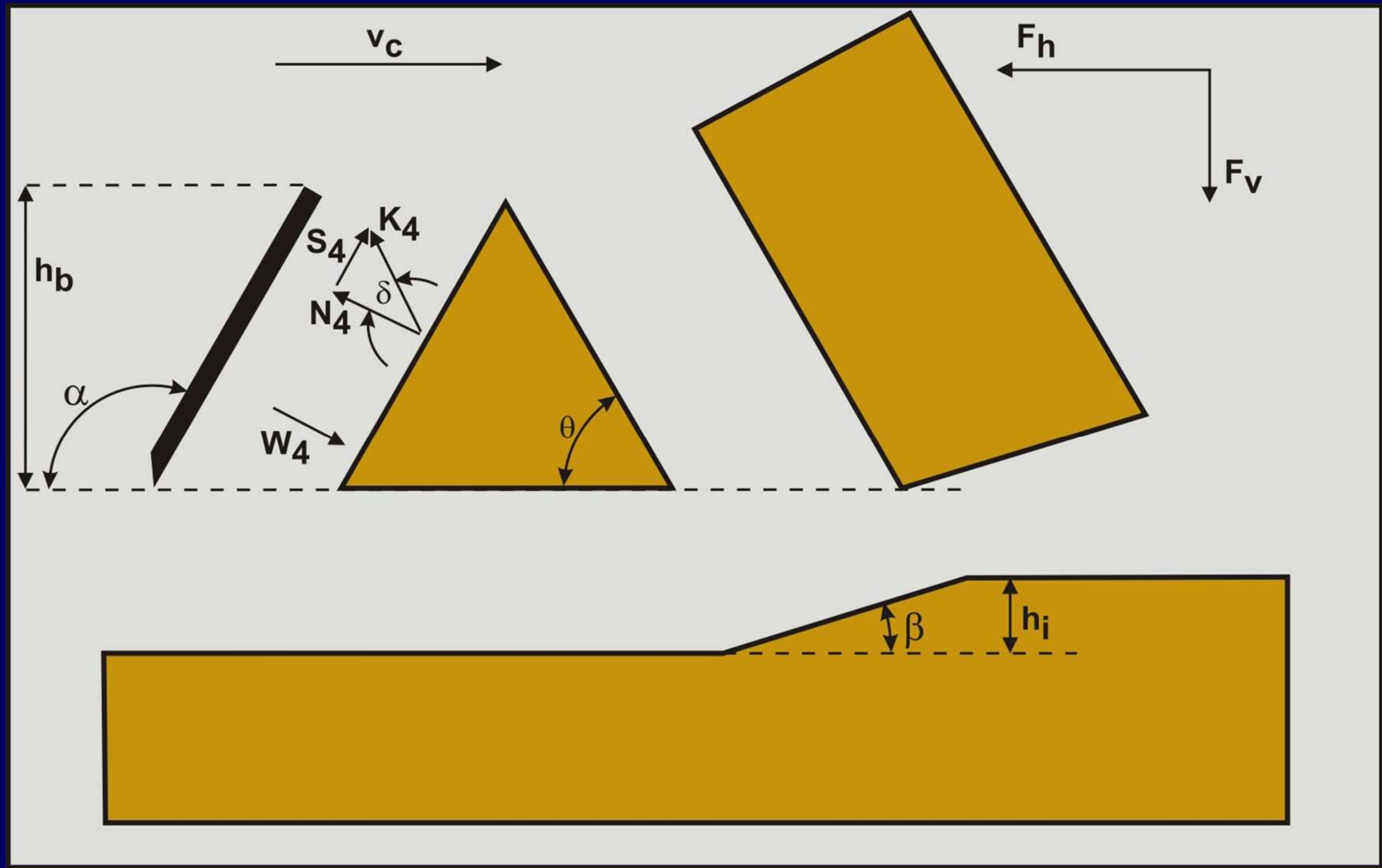
Forces on the Layer Cut



Forces on the Wedge



Forces on the Blade



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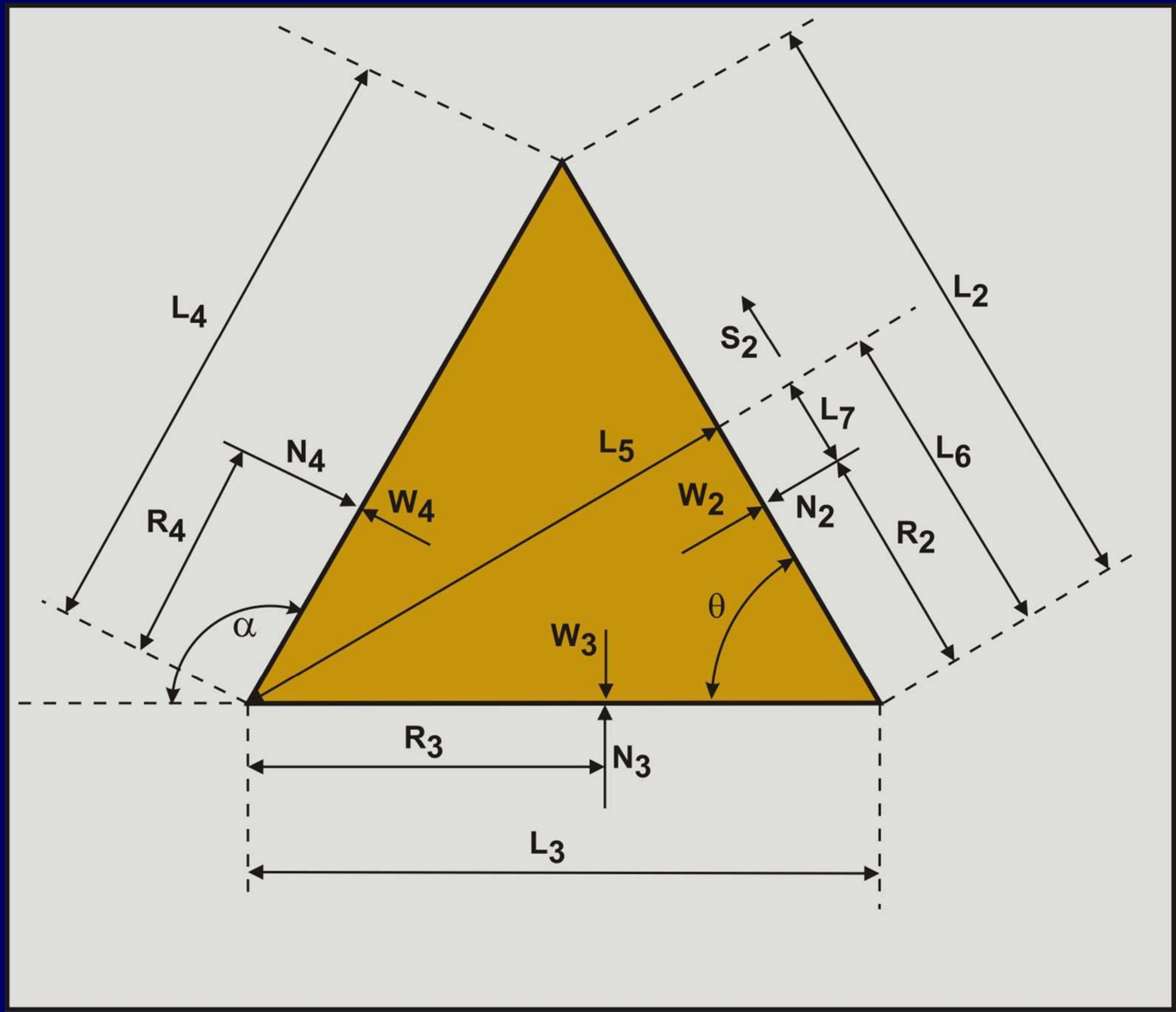
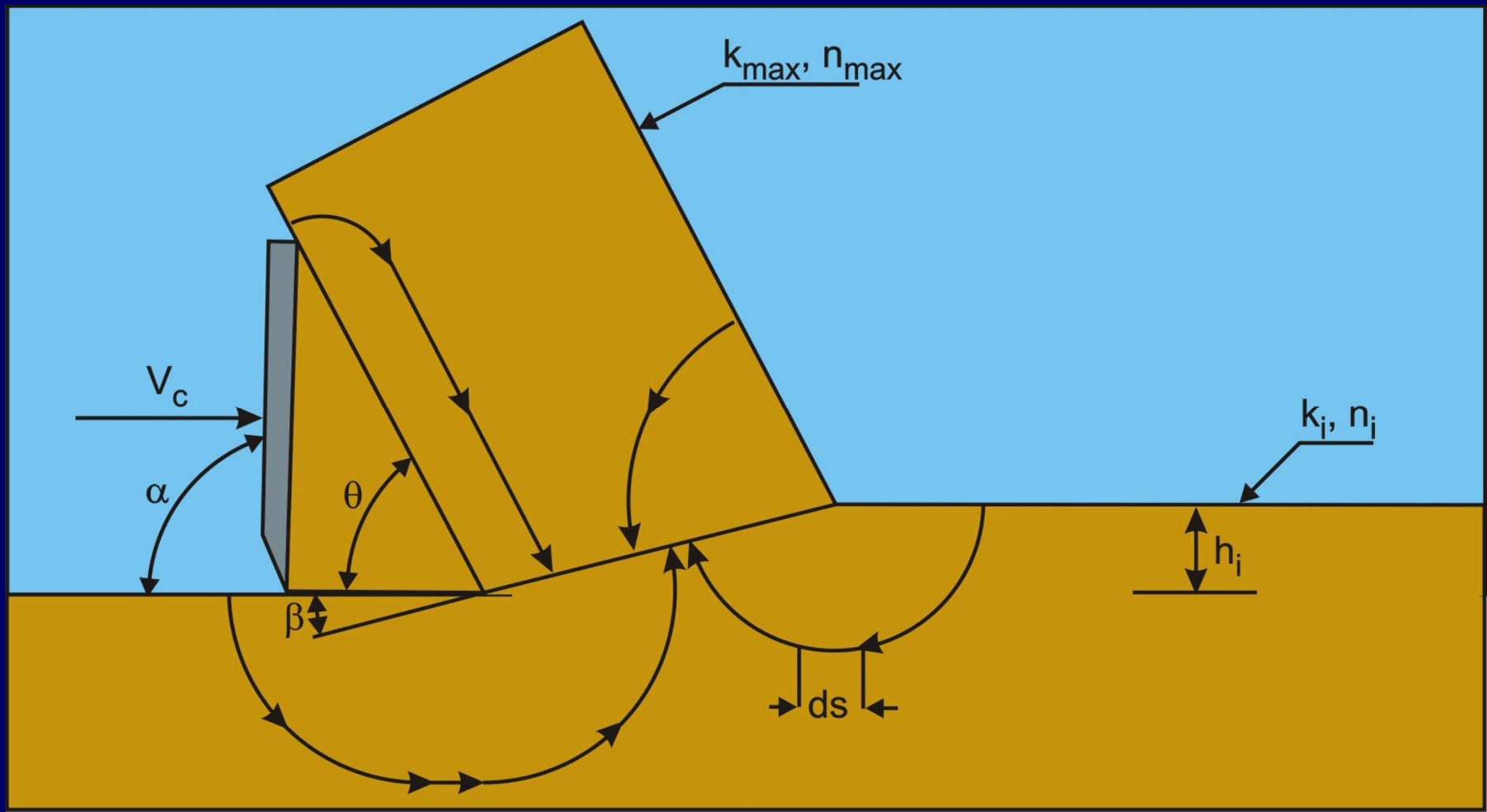
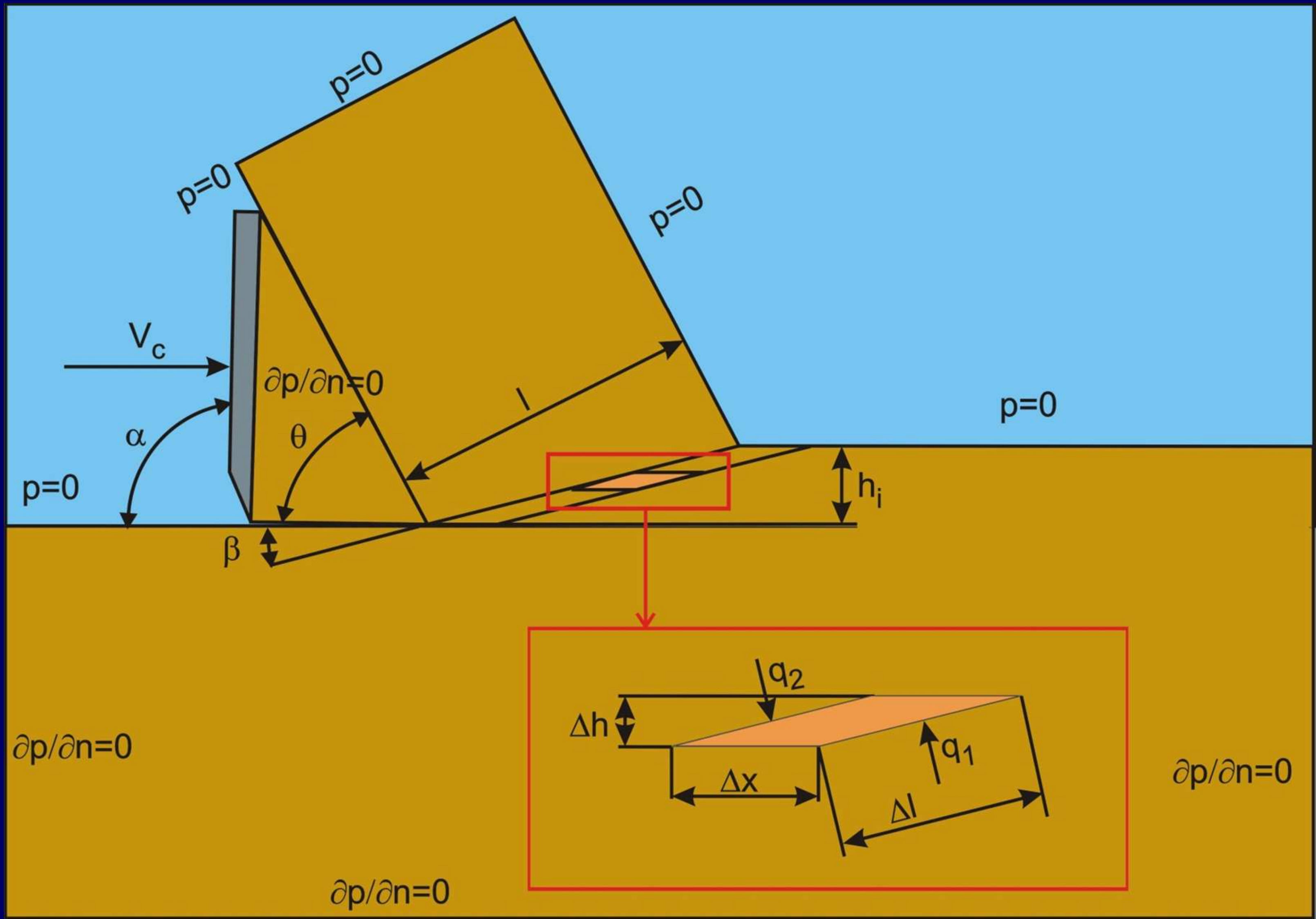
Moments on the Wedge



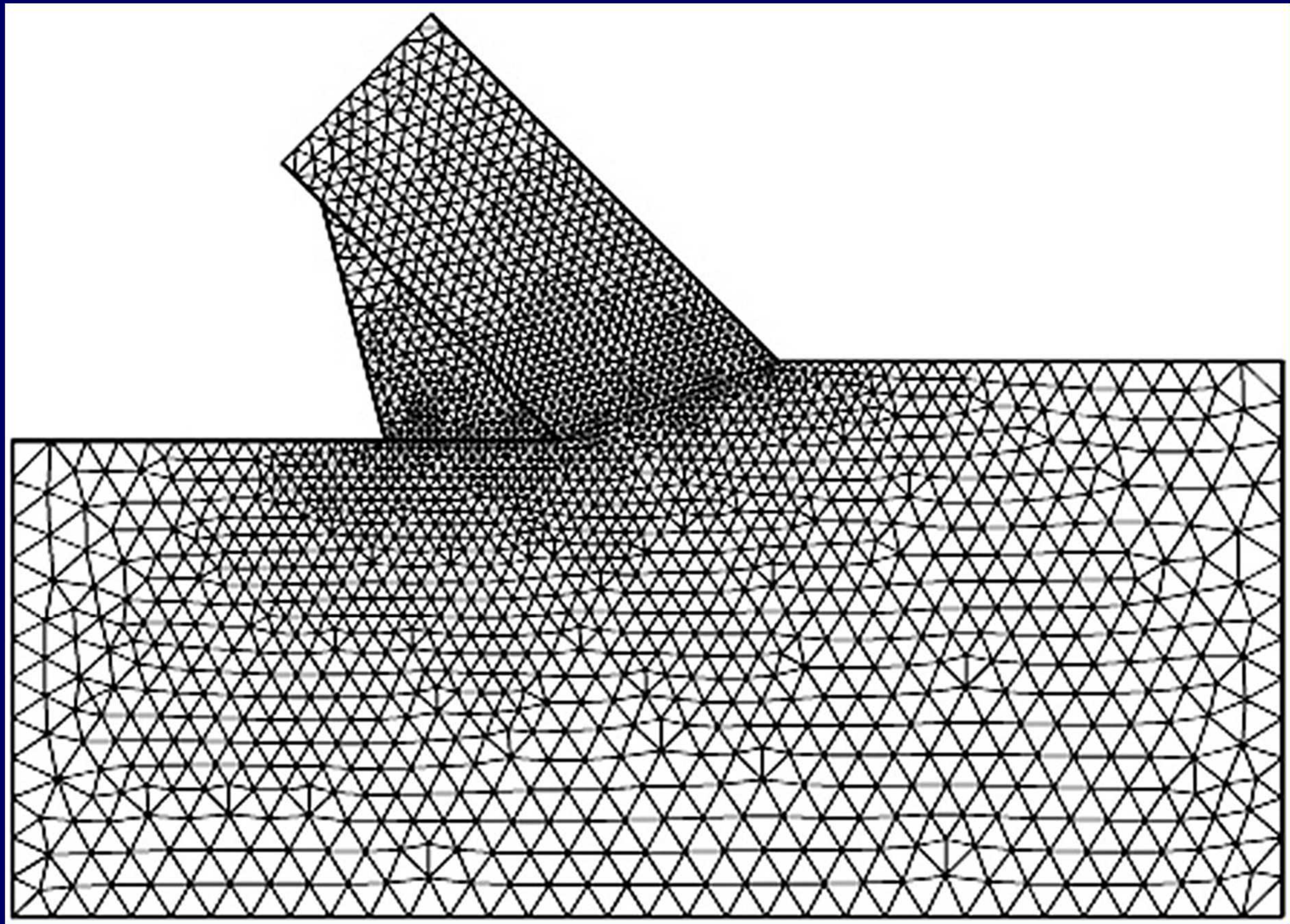
Path of Pore Water Flow



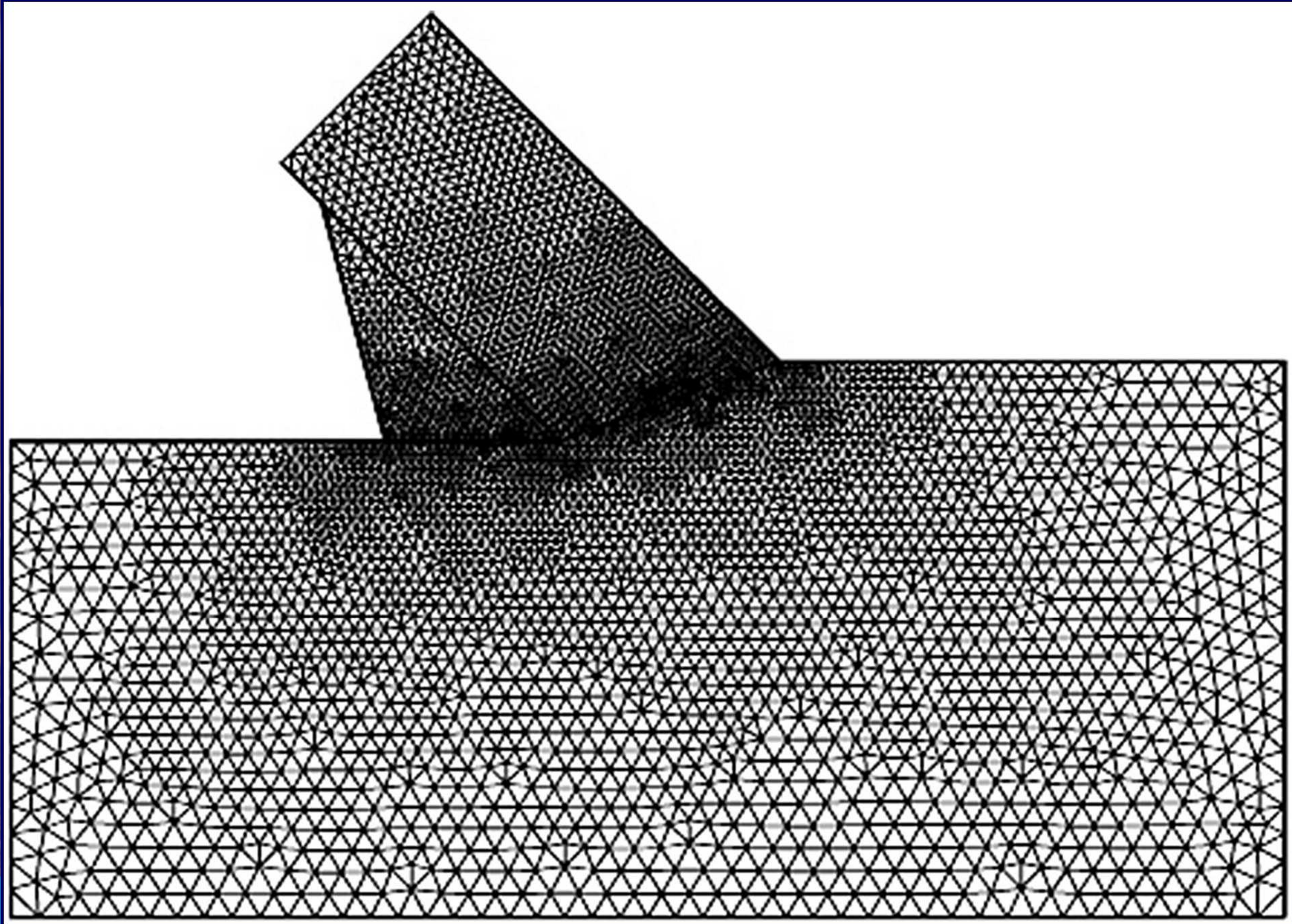
Specific Flow



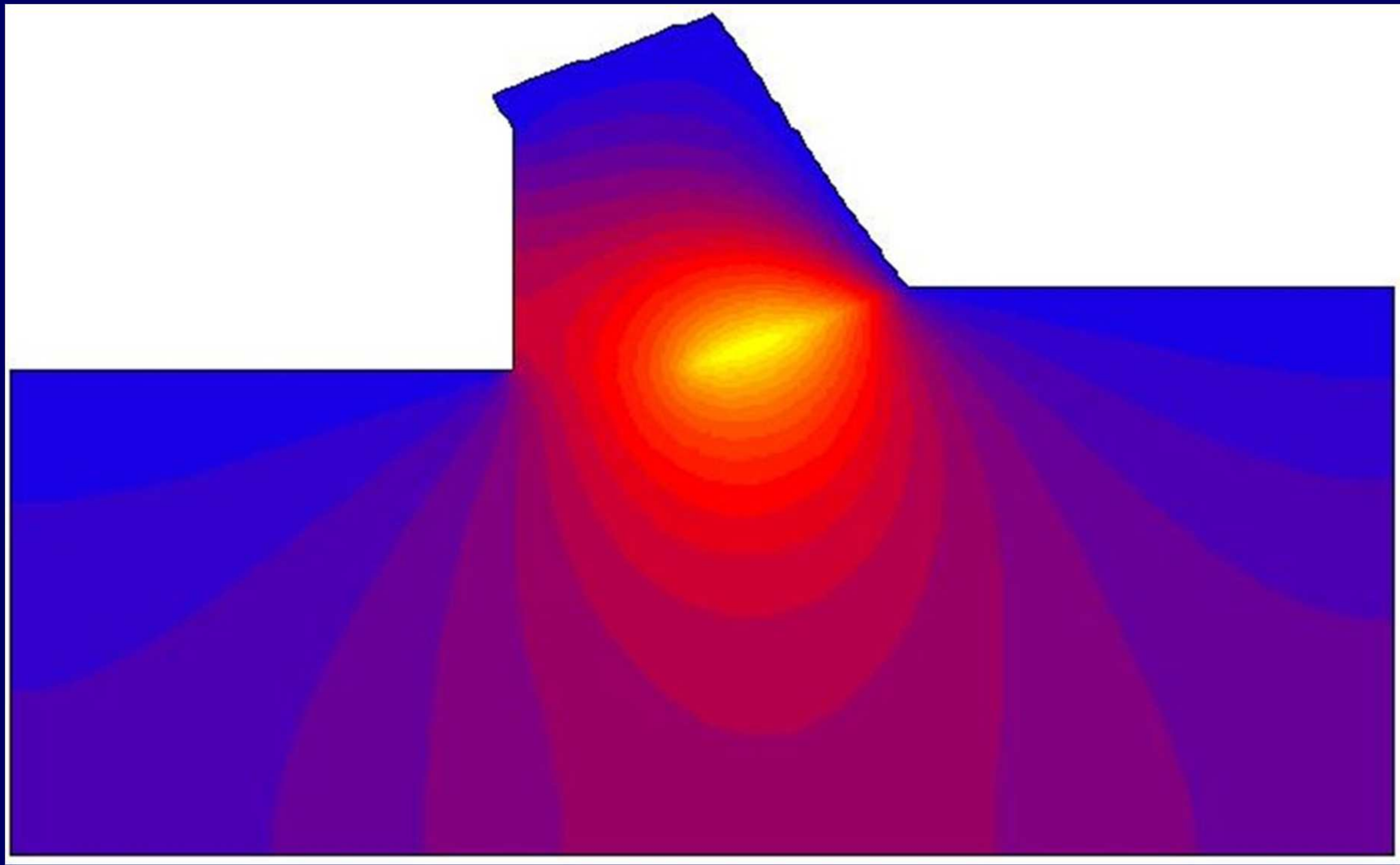
Mesh Coarse



Mesh Fine



Equi Potential Lines



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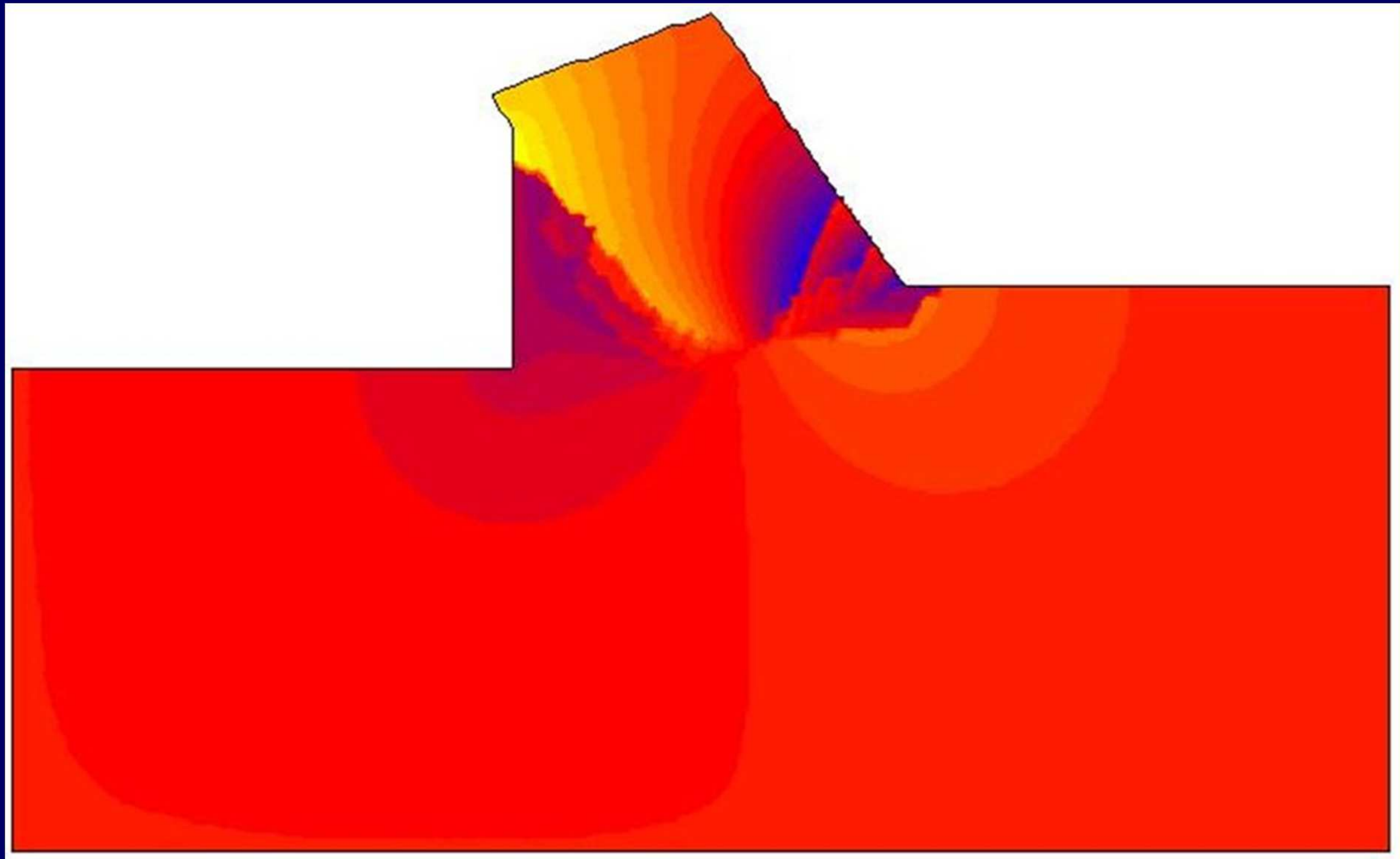
Flow Lines



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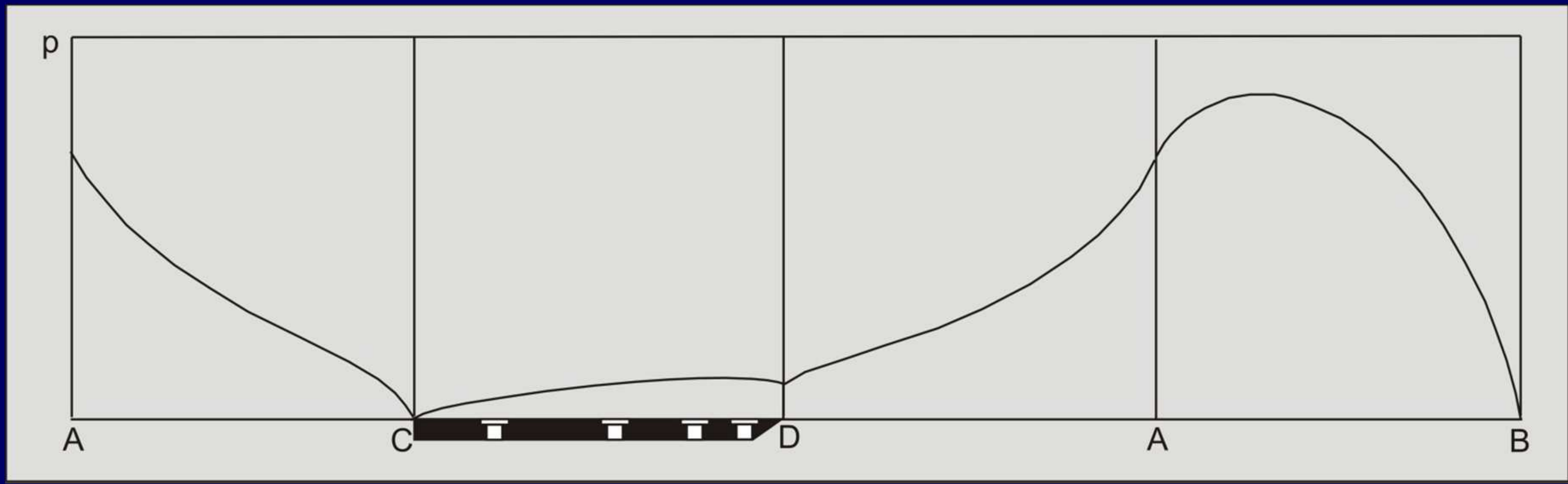
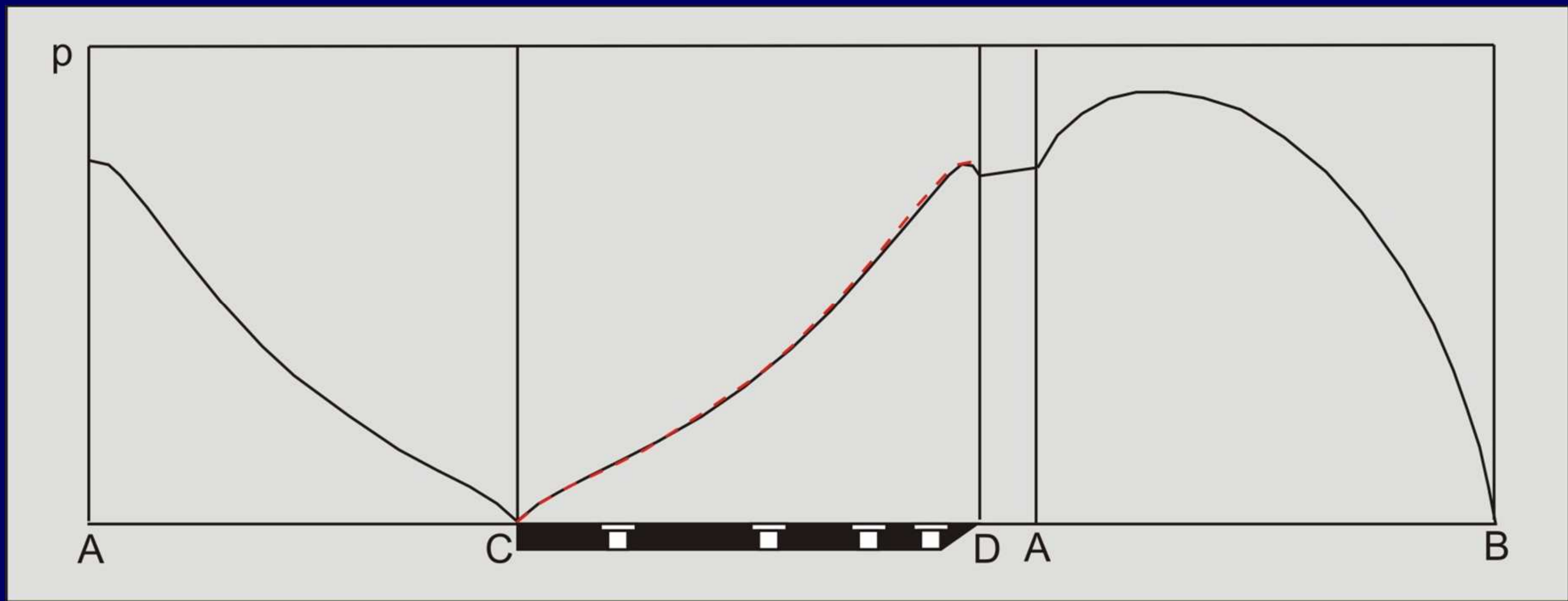
Pore Pressure Distribution





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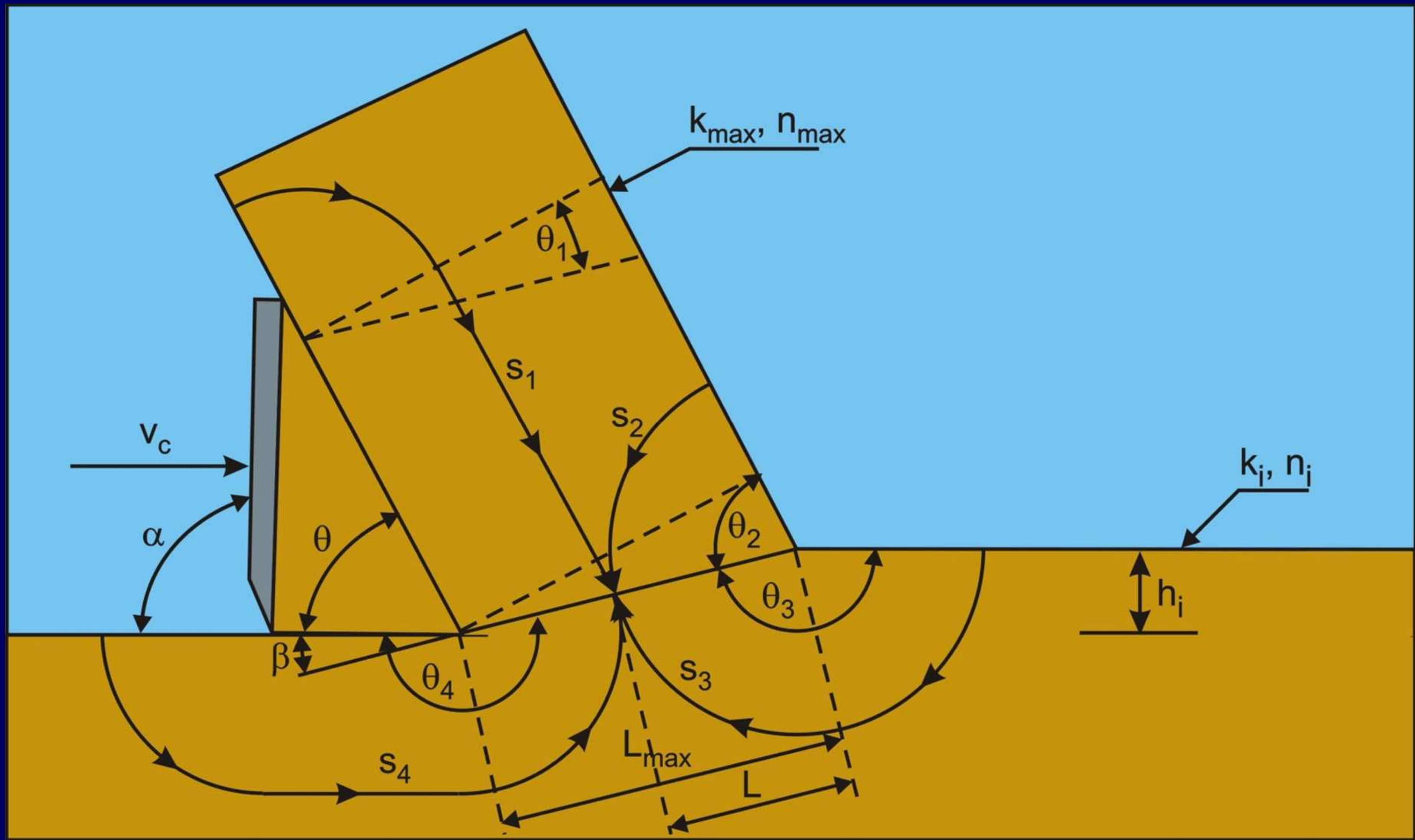
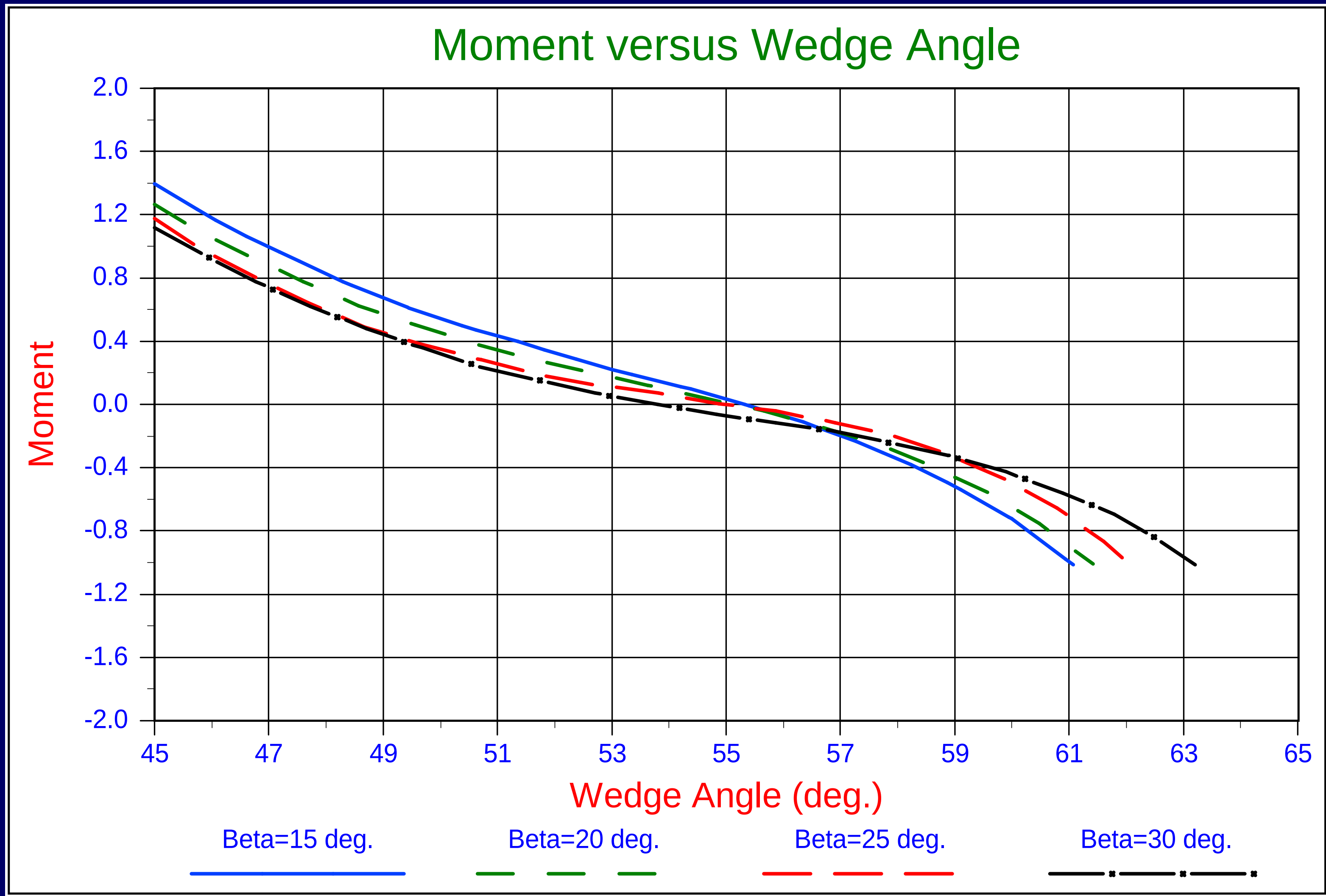
Parallel Resistors



Moment as Function of the Wedge Angle



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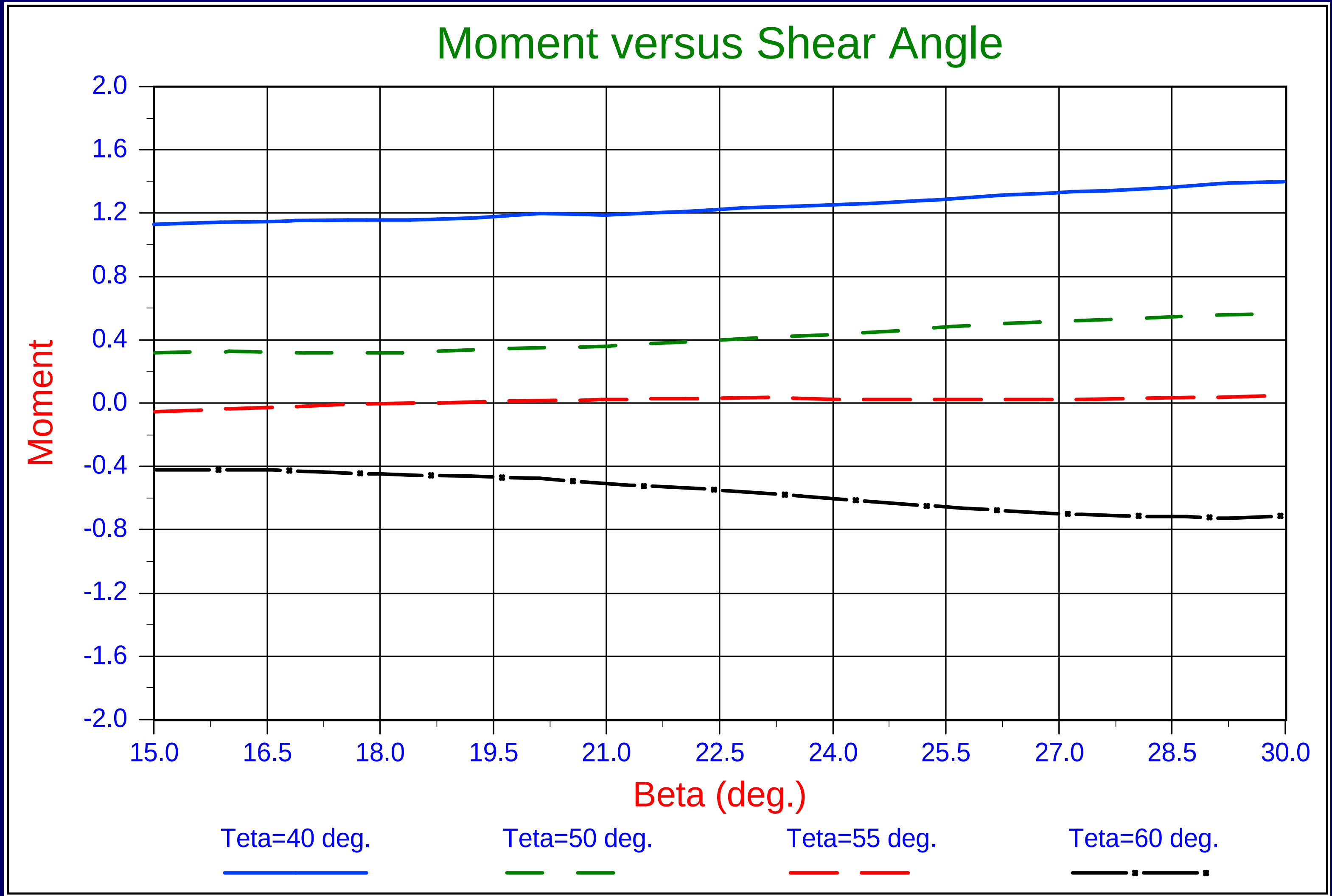
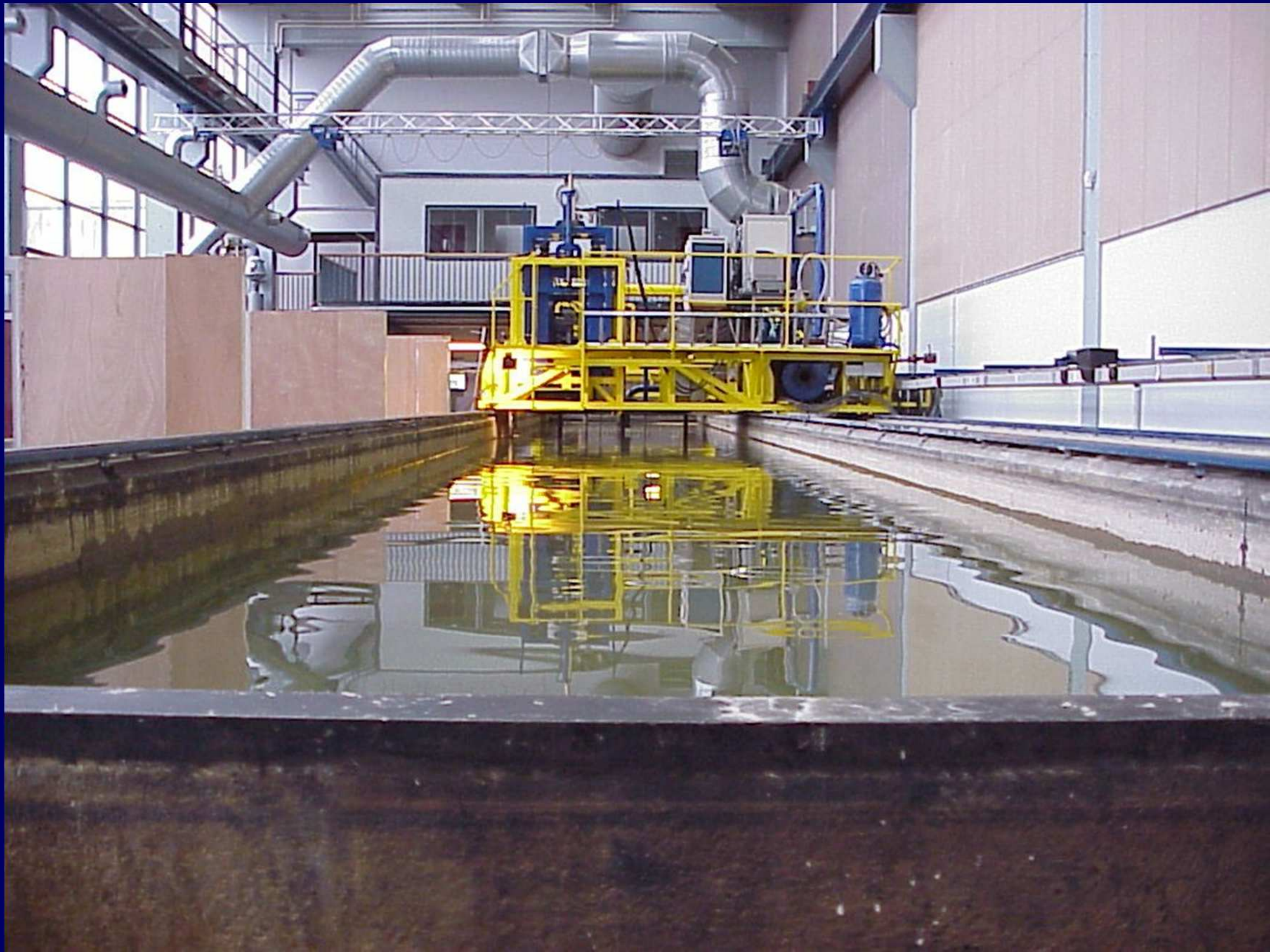
Moment as Function of the Shear Angle



Front view of the carriage.



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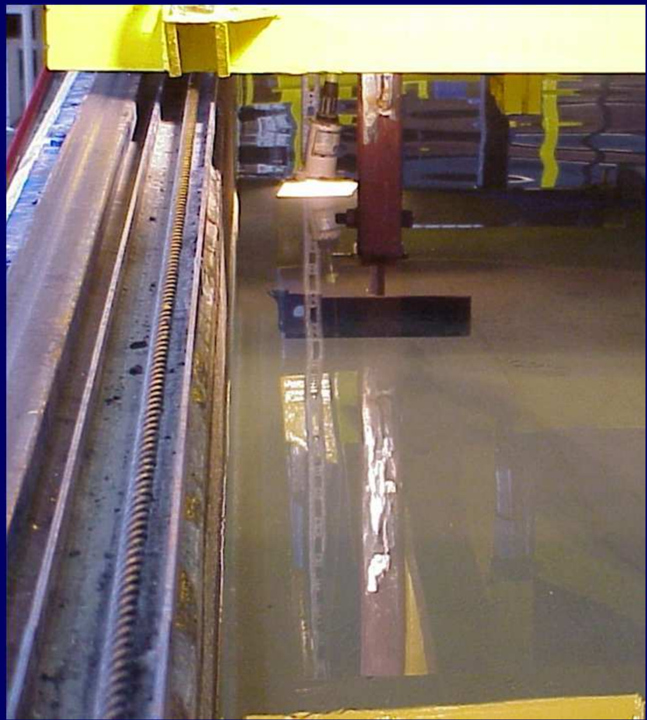
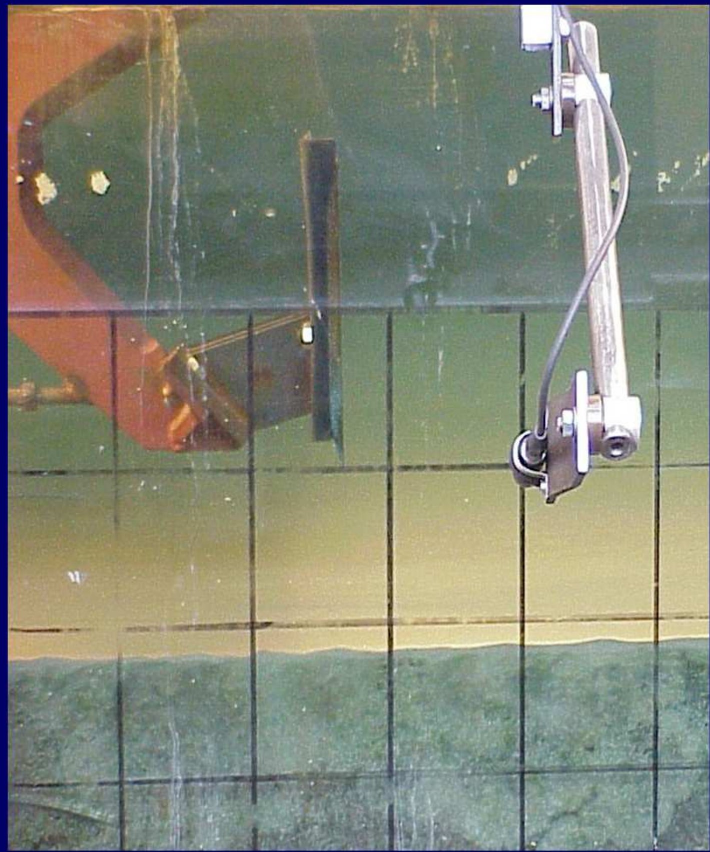
The blade mounted with the camera outside.





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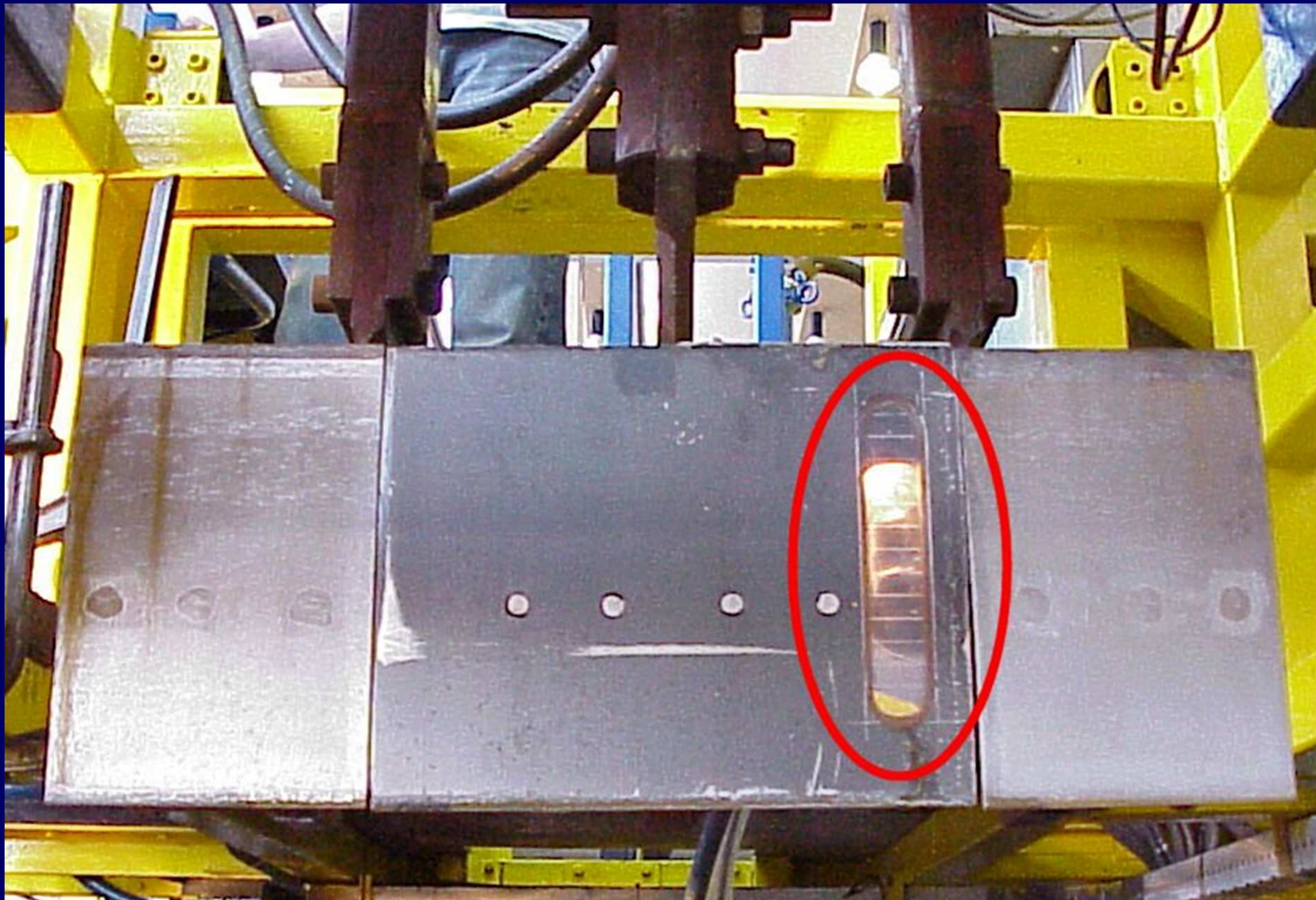
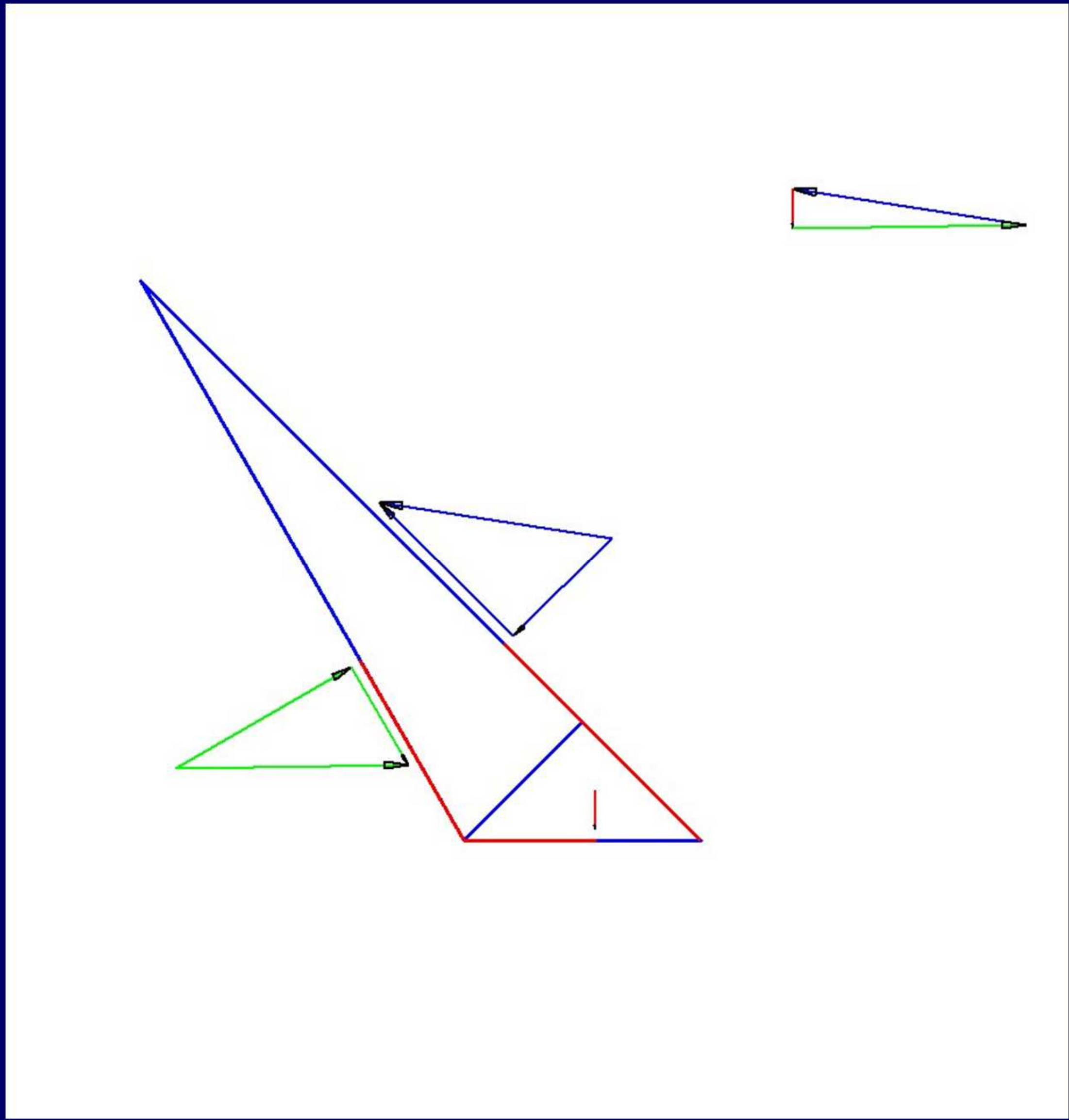
The window in the blade.



The camera behind the blade.

The forces on the wedge at 60 degrees.



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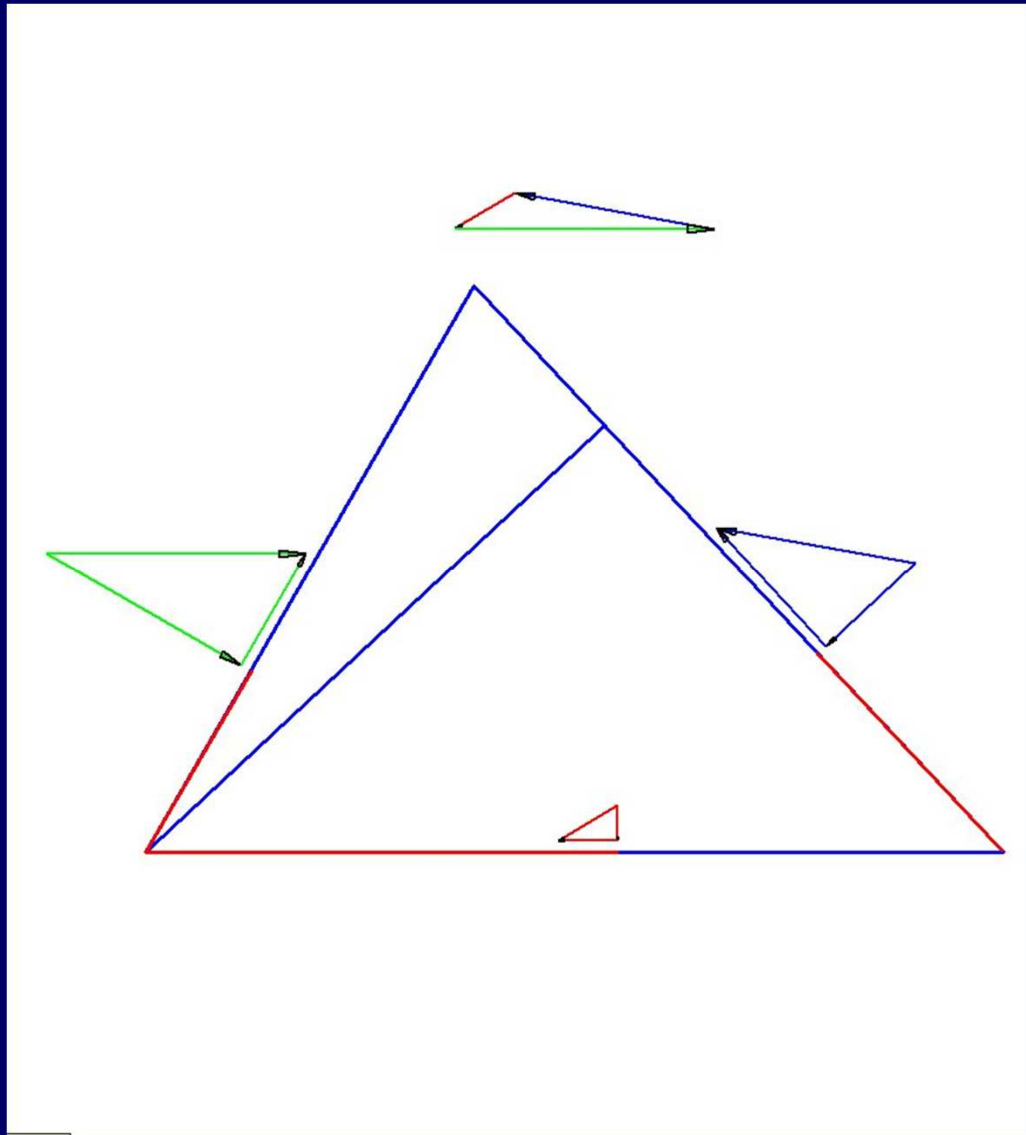
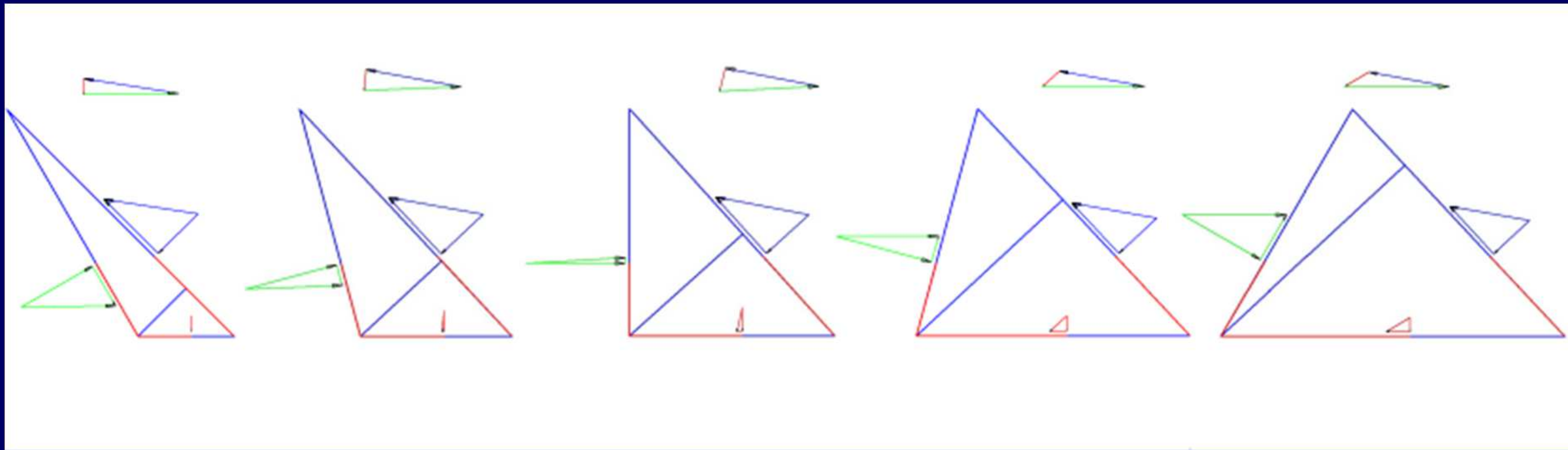
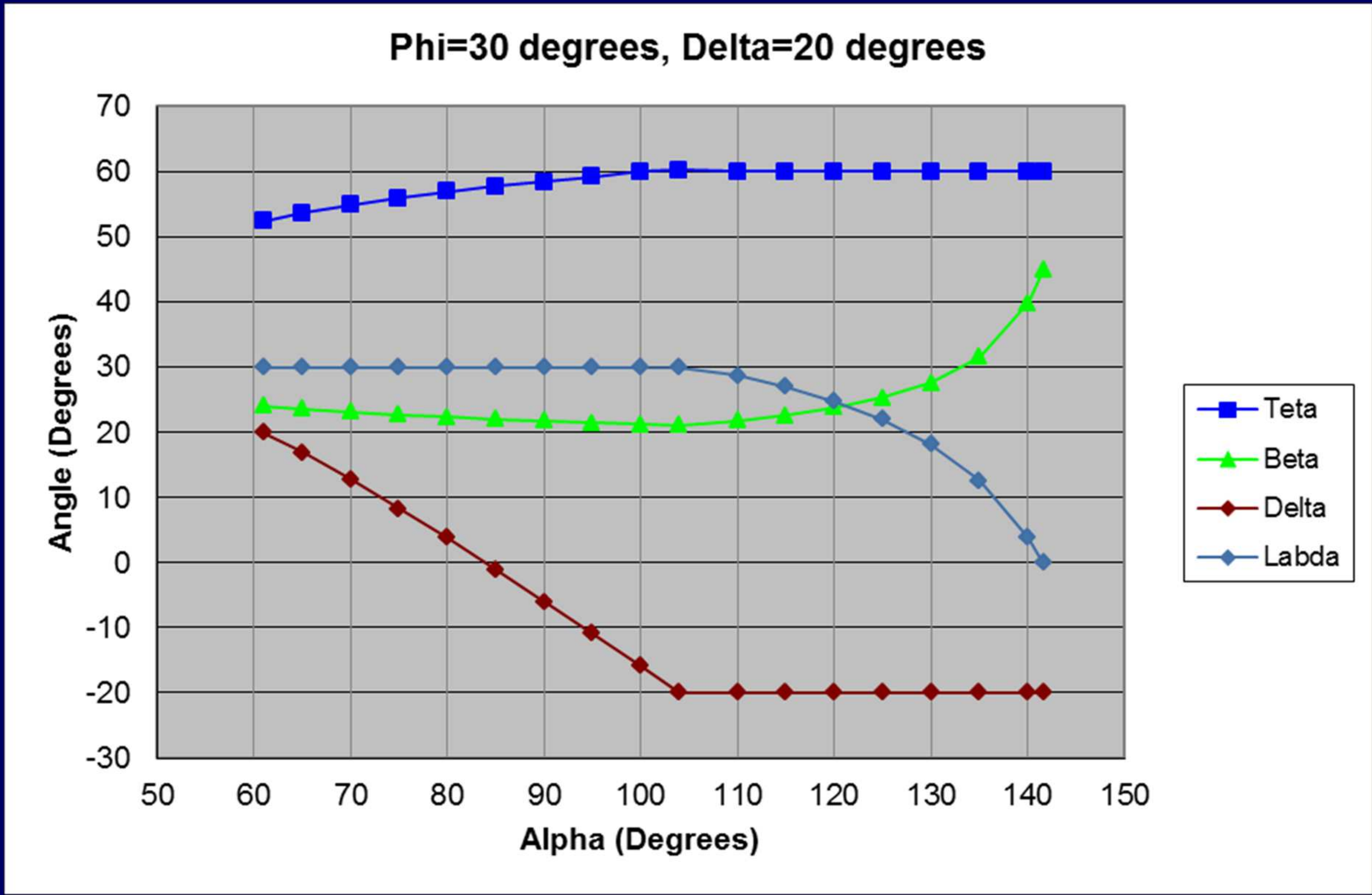
The forces on the wedge at 120 degrees



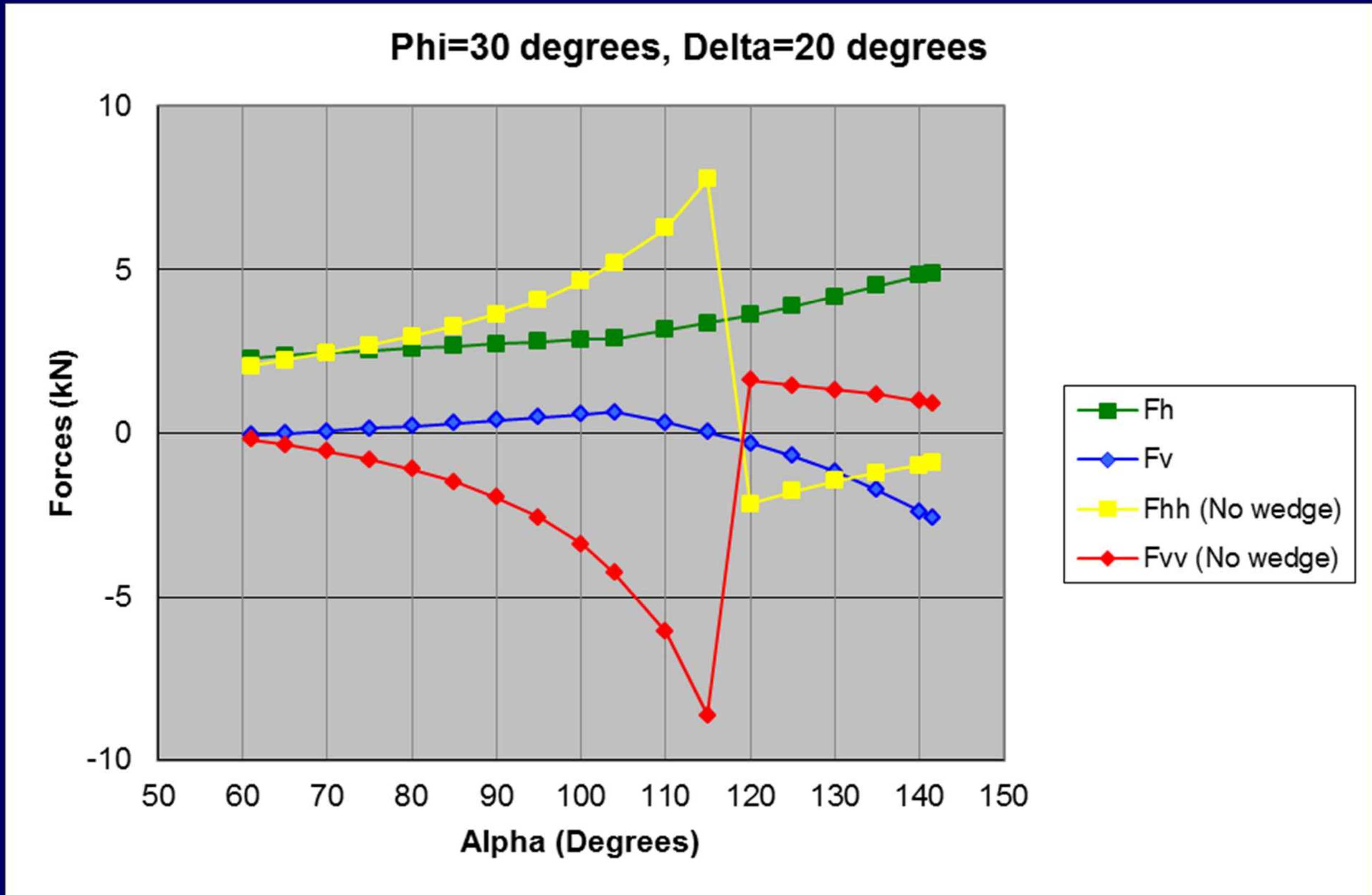
The force diagrams at different blade angles (non-cavitating).



The wedge angle Teta and the shear angle Beta versus the blade angle Alpha (Phi=30 deg., non-cavitating)



The horizontal and vertical forces versus the blade angle Alpha (Phi=30 deg, non-cavitating)



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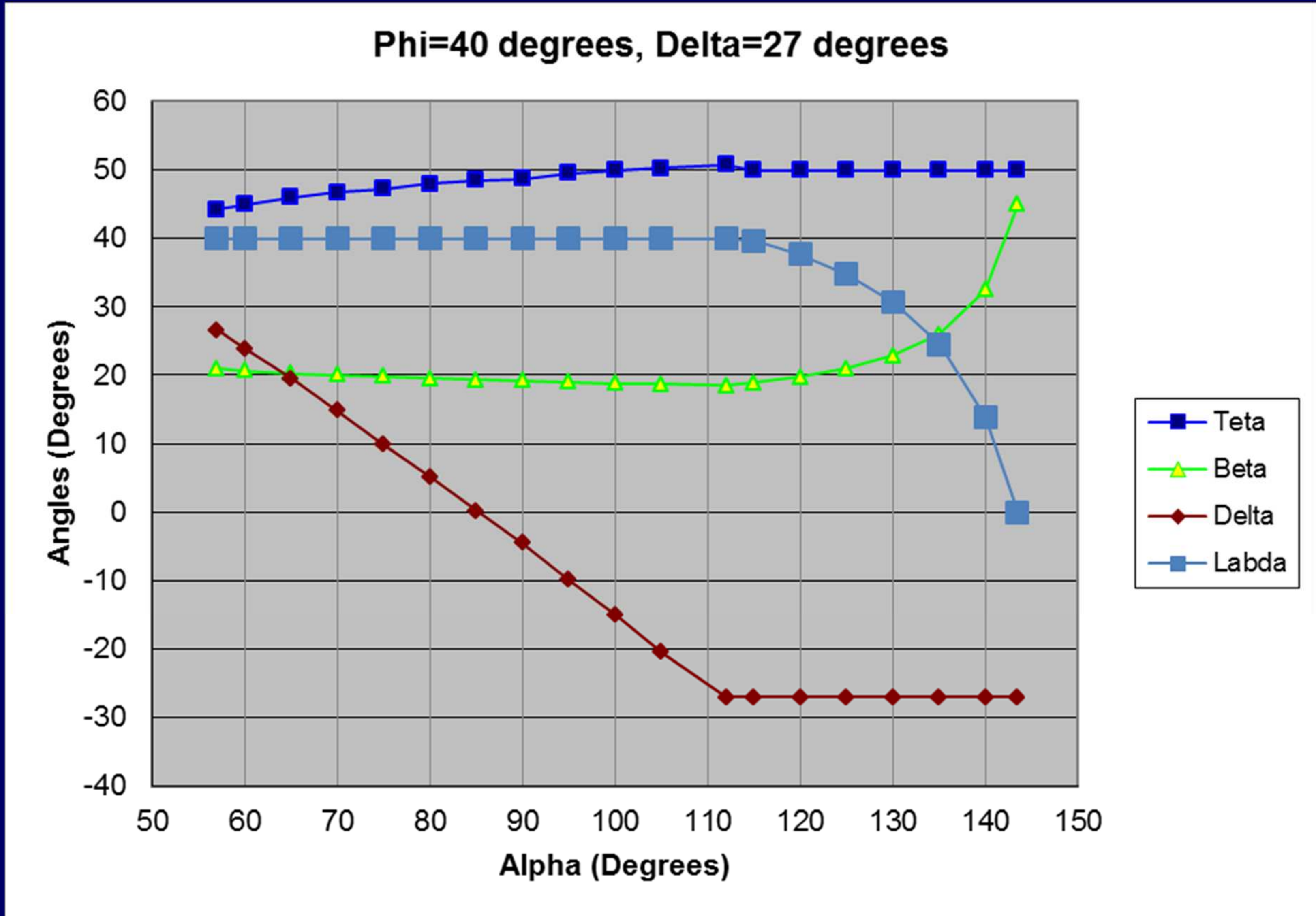
The wedge angle Teta and shear angle Beta versus the blade angle Alpha (Phi=40 deg., non-cavitating)



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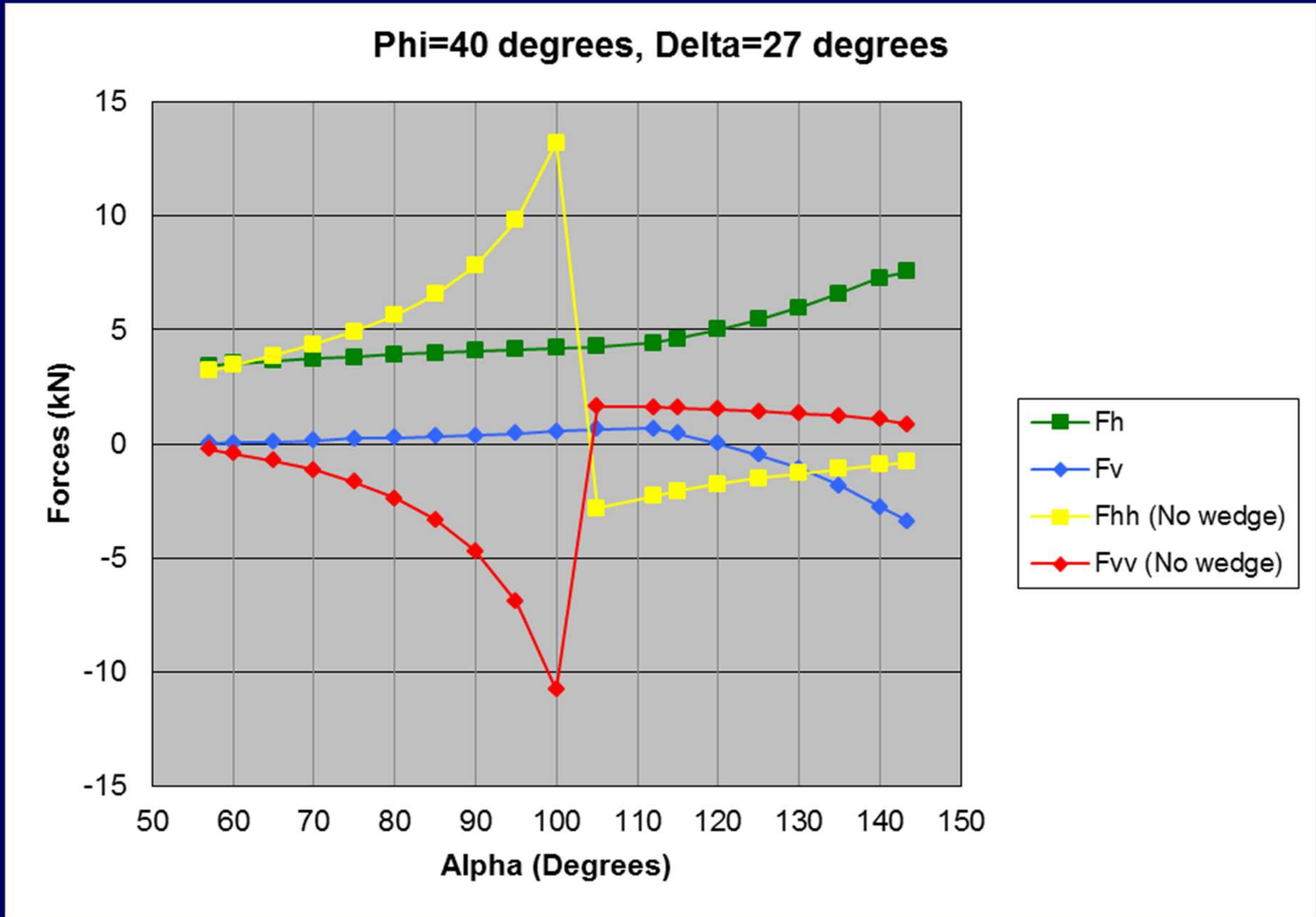
The horizontal and vertical forces versus the blade angle Alpha (Phi=40 deg., non-cavitating)



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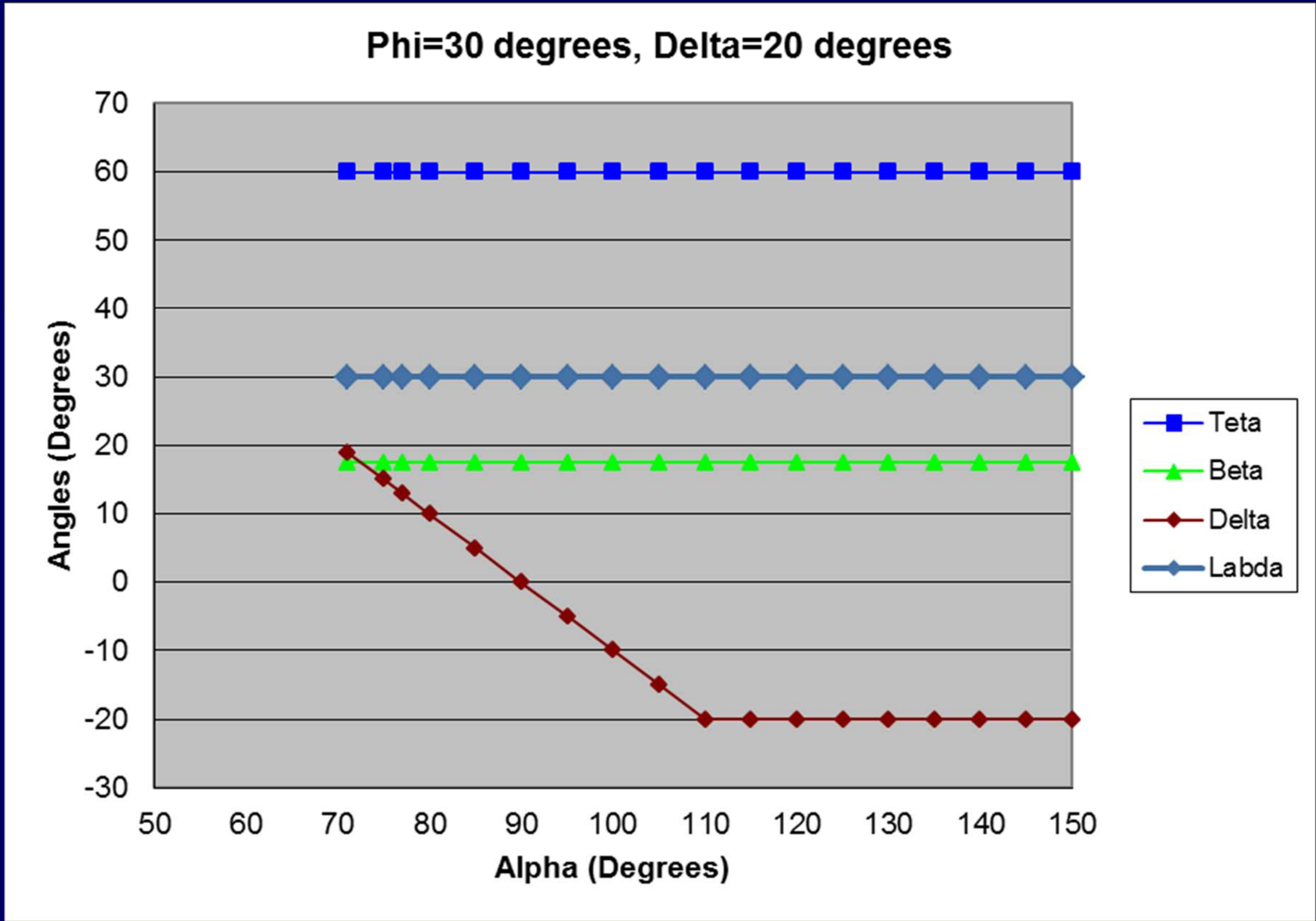
The wedge angle Alpha, shear angle Beta and soil/interface friction angle Delta (Phi=30 deg., cavitating).



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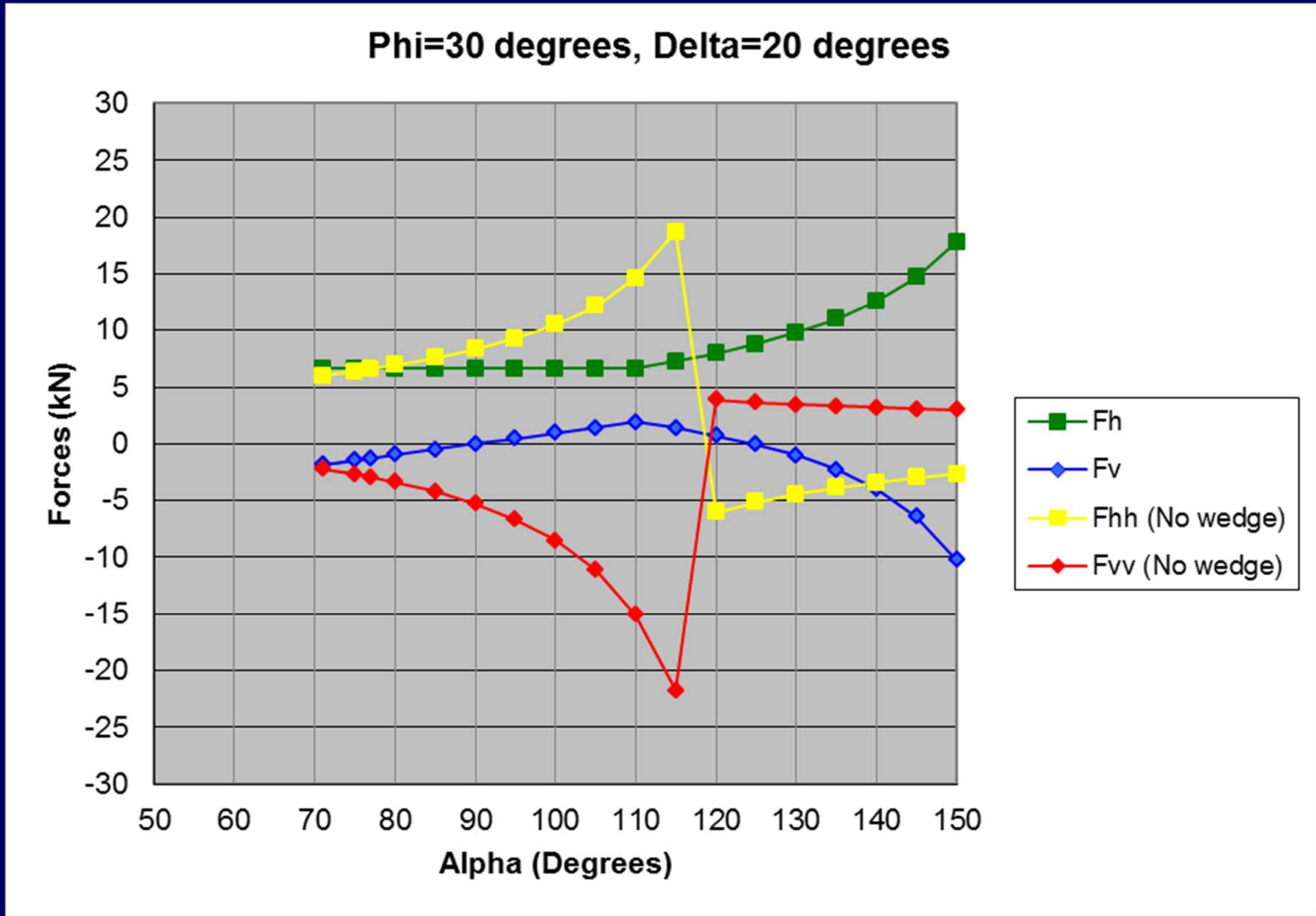
The cutting forces with and without the wedge (Phi=30 deg., cavitating).



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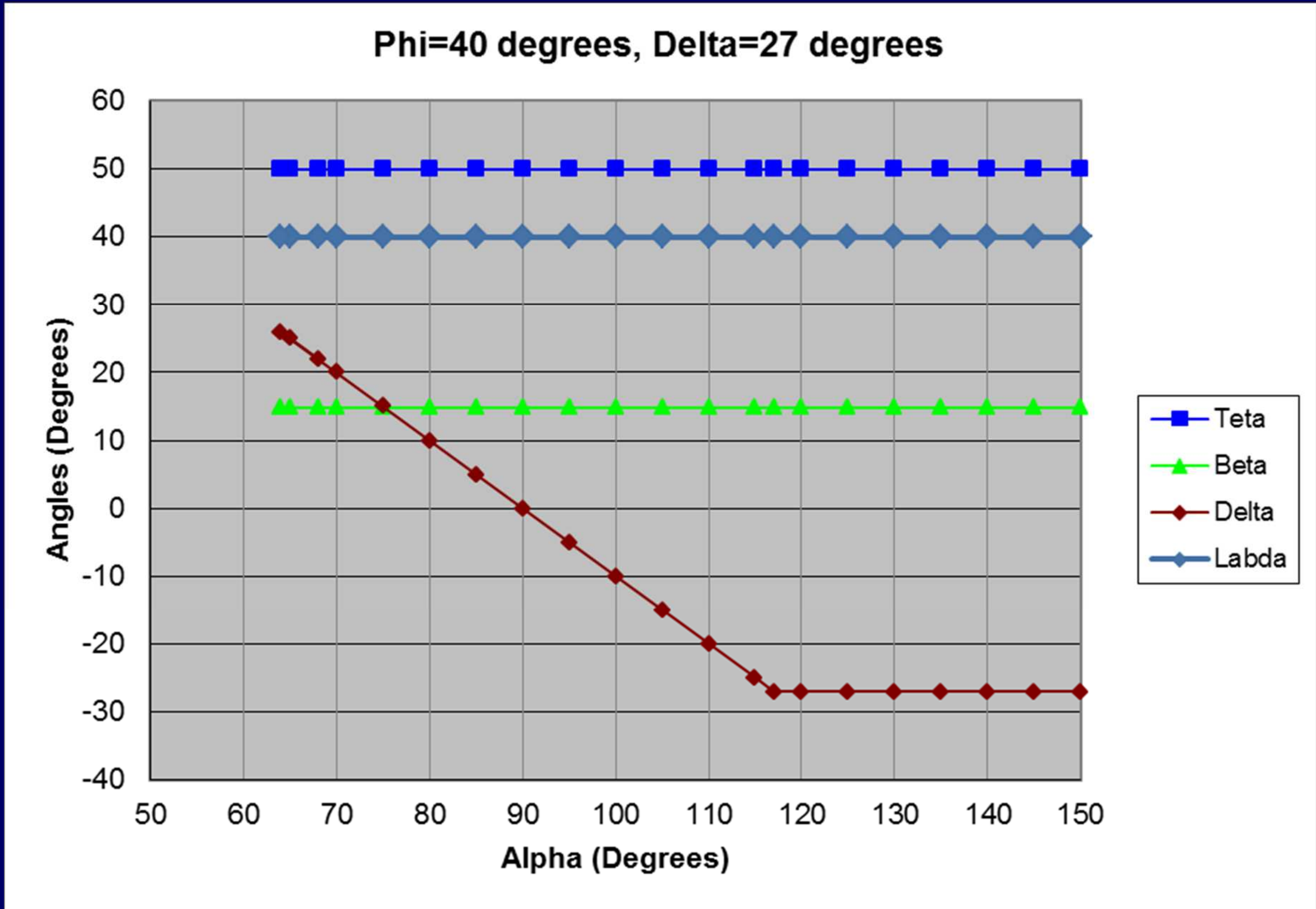
The wedge angle Teta, shear angle Beta and soil/interface friction angle Delta (Phi=40 deg., cavitating).



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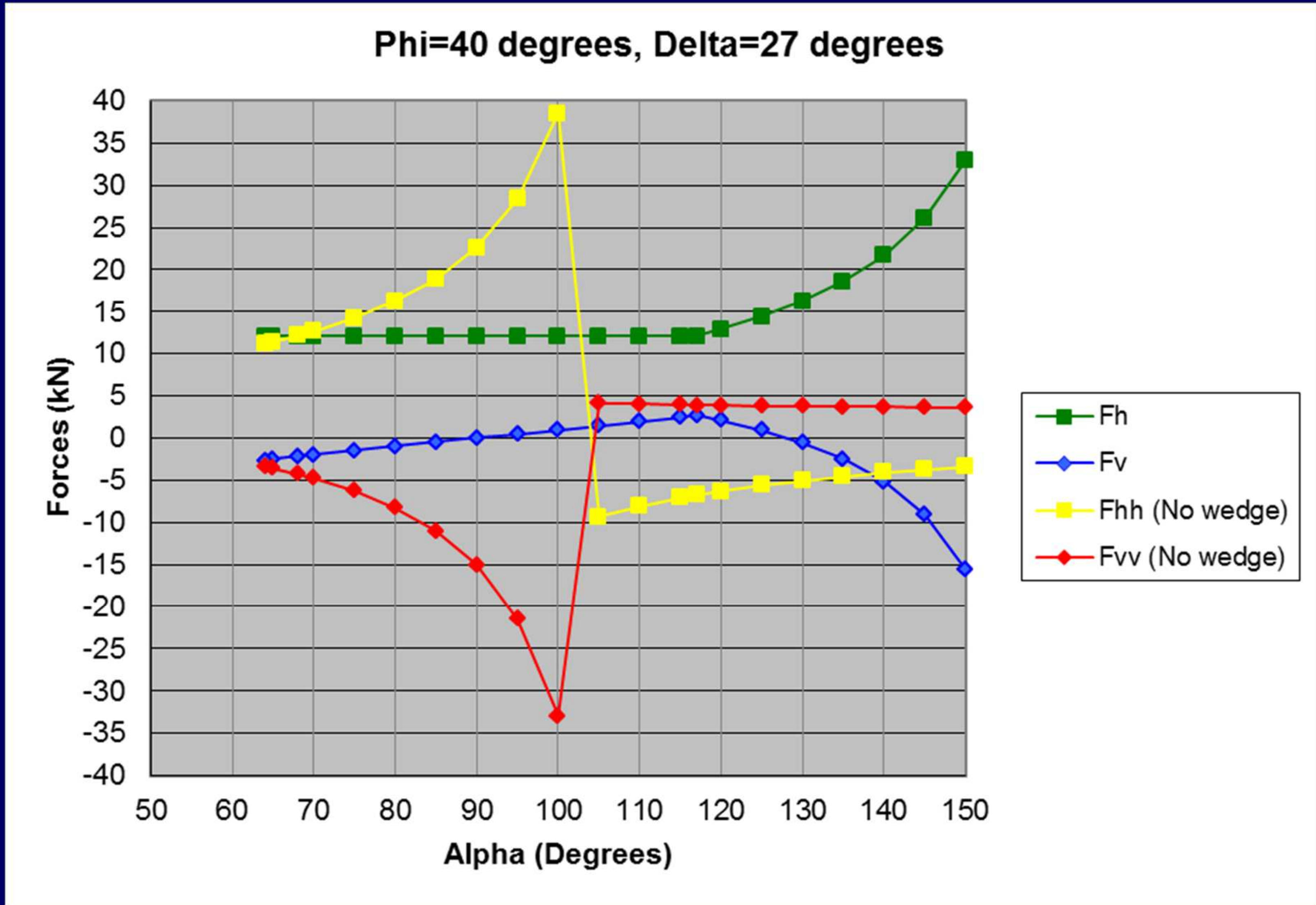
The cutting forces with and without the wedge (Phi=40 deg., cavitating).



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The transition of cutting forces with and without the wedge.

No cavitation:

$$\alpha = 90 - \frac{2}{3} \cdot \varphi$$

Cavitation:

$$\alpha = 90 - 0.014 \cdot \varphi^2$$

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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