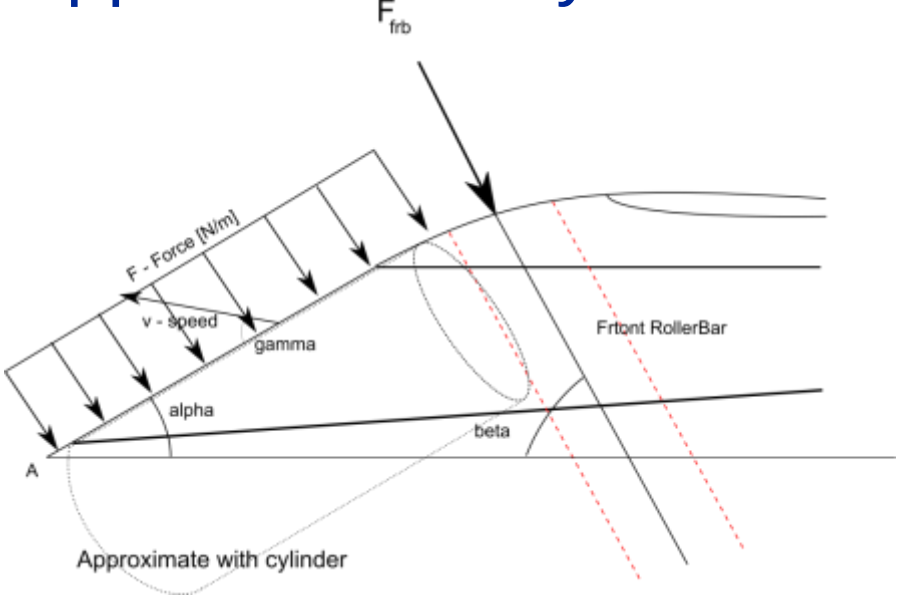
2011-03-27

Cockpit Fluid & Solid mechanics considerations

Approximation by Potential flow



Uniform steem + Dipole

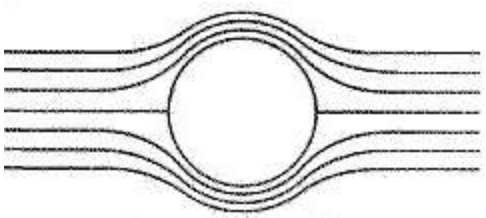
$$kar2pol := [x = r\cos(\theta), y = r\sin(\theta)]$$

$$\phi us := V_\infty r\cos(\theta)$$

$$\psi us := V_\infty r\sin(\theta)$$

$$\phi d := \frac{C\cos(\theta)}{r}$$

$$\psi d := -\frac{C\sin(\theta)}{r}$$



Velocity on the surface (r=R) & some math

$$U_R := 2\sqrt{V_\infty^2 \sin(\theta)^2}$$

Example data from Hydrocat cockpit

$V_b = 45\,m/s = 87\,knots$ $\qquad$ $\rho = 1025\,kg/m^3$

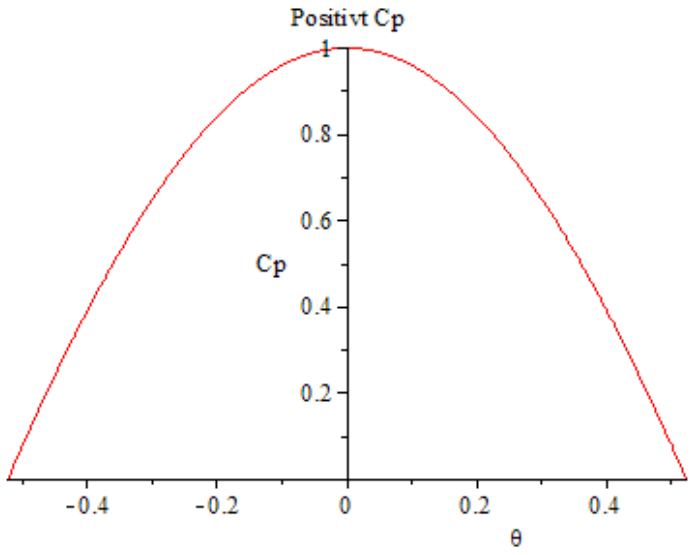
$R = 0.32\,m$ $\qquad$ $L = 0.8\,m$

From Bernoulli equation we get Pressure Coefficient

$$Cp := 1 - \frac{U_R^2}{V_\infty^2} \qquad Cp := 1 - 4\sin(\theta)^2$$

Calculating θ-values and solving for zero Cp to get integration boundaries (pressure -> dilatation)

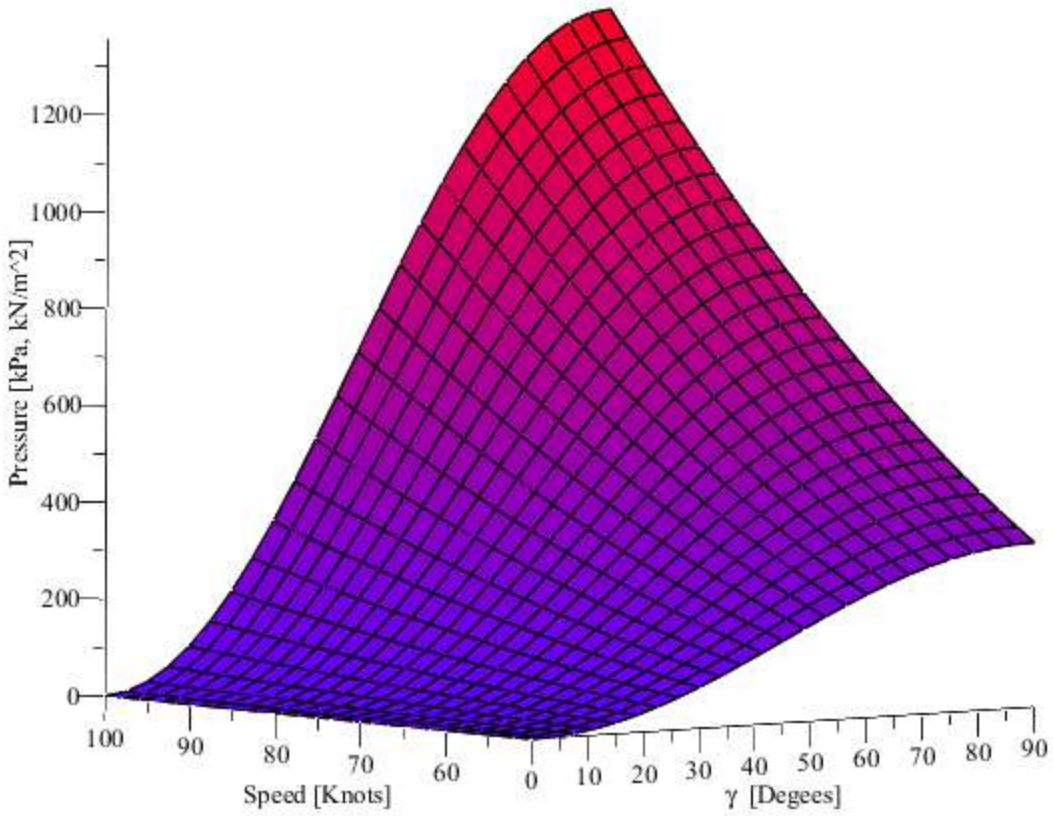
$$\theta_{rv} := \frac{1}{6}\pi, -\frac{1}{6}\pi$$



Boat kinematics

Velocity V and dynamic pressure $p := \frac{V^2 \cdot \mathrm{rho}}{2};$

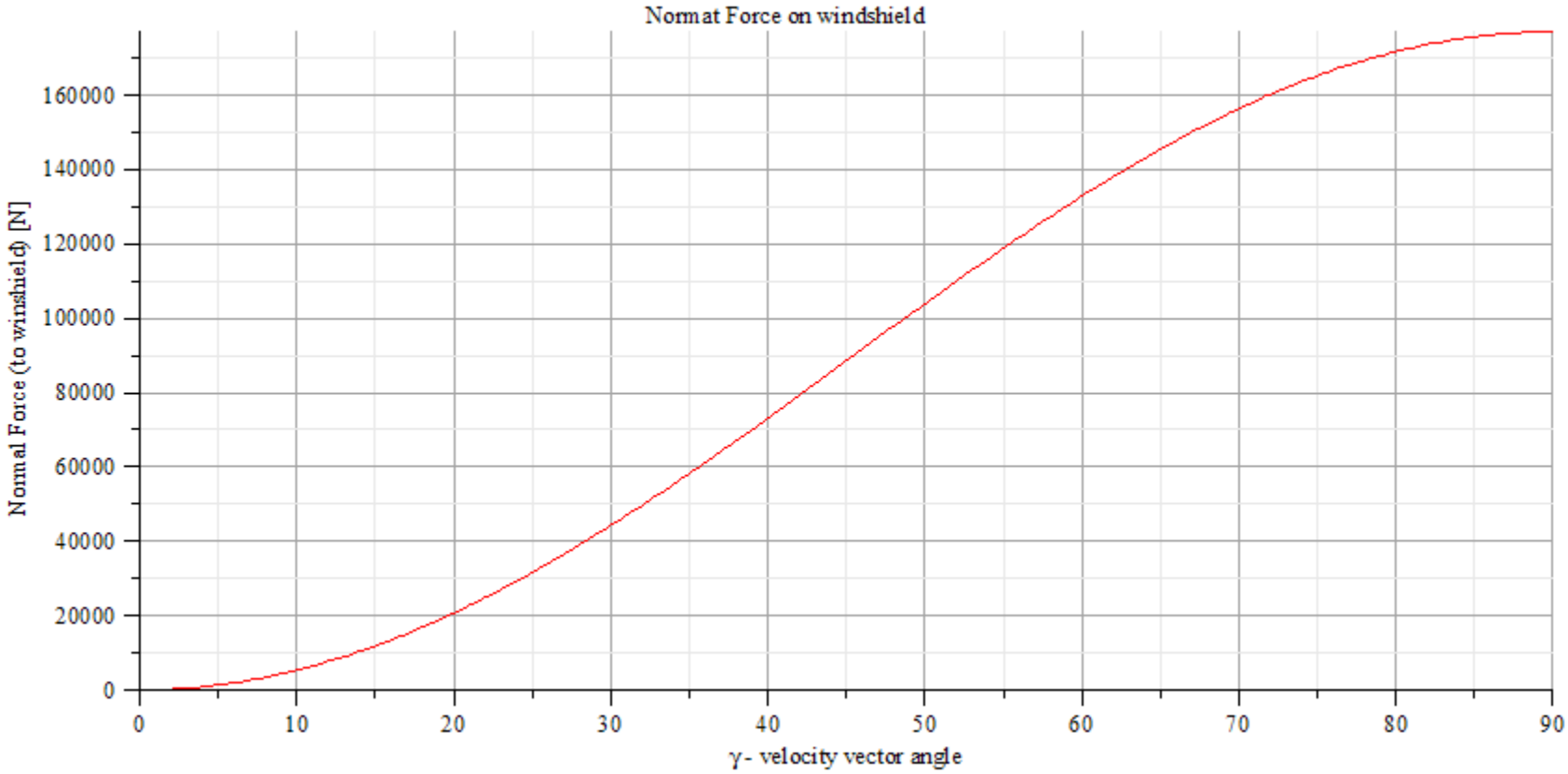
$V := Vb \sin(\gamma)$ $p := \frac{1}{2} Vb^2 \sin(\gamma)^2 \rho$



Forces from the impact

$F = \int p\, Cp\, dA = \int p\, Cp\, L\, R \cos(\theta)\, d\theta$

$$F := \frac{1}{3} L R Vb^2 \sin(\gamma)^2 \rho$$

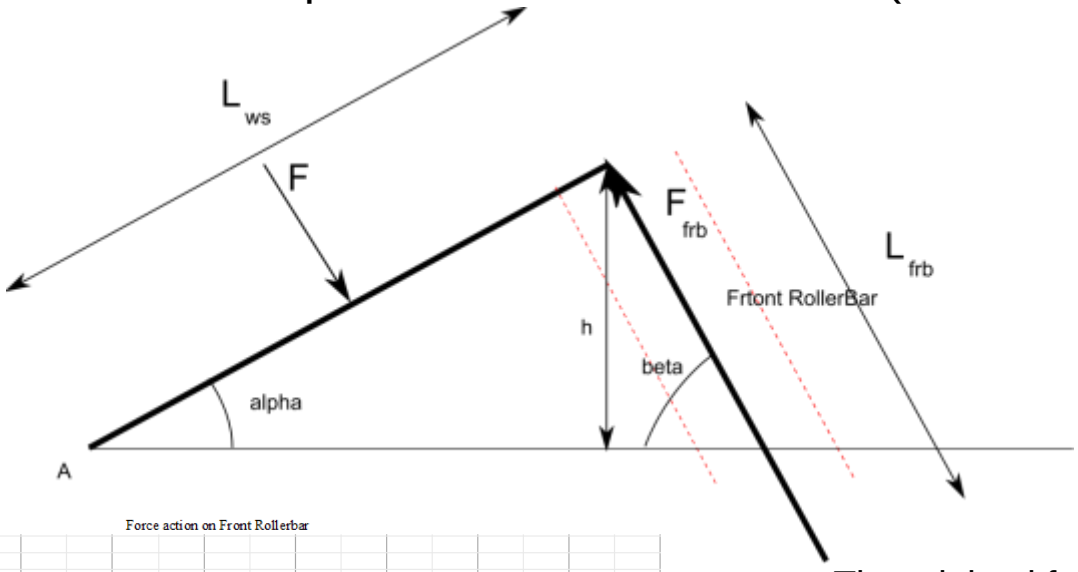


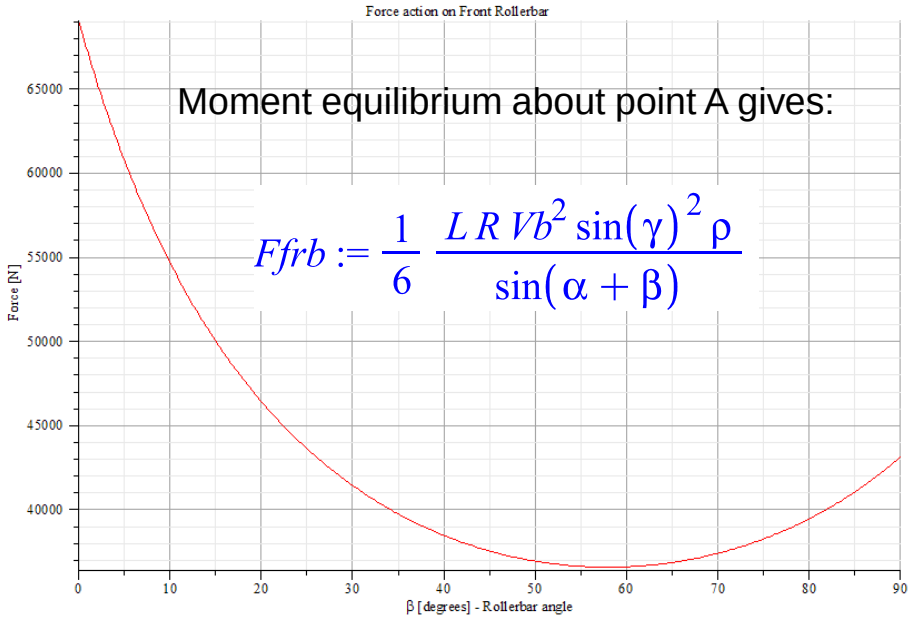
Crash type “Roll“ in 45 m/s = 87 knots

Here we assume that the boat rotates 180 degrees around the x-axis (speed direction) and the whole of CP penetrates the water, this case can give γ = 40 degrees → Force ~ 74 kN

More types of impact analysis for example dives, roll, loop, etc. ...

Distribution of impact forces at the structure (ie front rollerbar)





Moment equilibrium about point A gives:

$$Ffrb := \frac{1}{6}\,\frac{L\,R\,Vb^2\,\sin(\gamma)^2\,\rho}{\sin(\alpha+\beta)}$$

The minimal force in Rollerbar is at β = 58 degrees, which means that the RB should preferably be orientated perpendicular windshield to minimize structural loads.

Due to other circumstances (vision field for the driver) it is not a good idea to choose this optimum β -value. For our geometry the most appropriate angle is β = 70-80 degrees.

Ffrb ~ 37 kN

FEM analysis on front roll bar

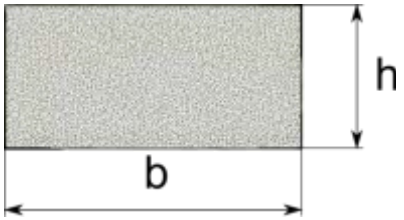
Roll bar with rectangular cross section, homogeneous (without core material) made of uni-axial E-glass and iso-polyester as matrix.

Fn = -37000/0.5; Distributed load [N/m]

Ft = -37000/0.36/2; Distributed load (half of Fn) [N/m

Element stiffness and element load matrices

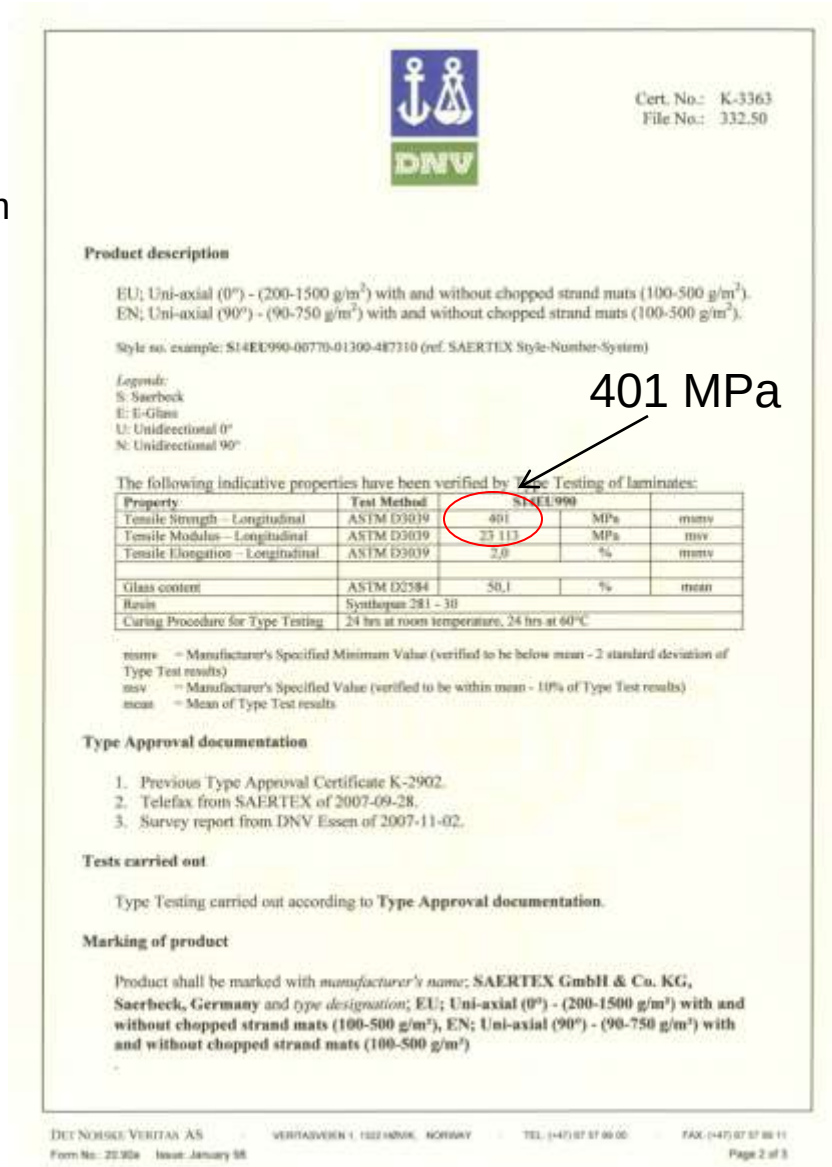
- E=23e9; From ud_01.pdf
- b = 0.1; h = 0.025;
- A1 = b*h; A2 = A1;
- I1 = b*h^3/12; I2 = I1;



ISO 12 215-5

$$w_f = 0.5 \text{ fibre content by weight}$$

$$\sigma = 1800 w_f^2 - 1400 w_f + 510 = 260 \text{ MPa}$$



Cert. No.: K-3363
File No.: 332.50

Product description

EU; Uni-axial (0°) - (200-1500 g/m²) with and without chopped strand mats (100-500 g/m²).
EN; Uni-axial (90°) - (90-750 g/m²) with and without chopped strand mats (100-500 g/m²).

Style no. example: S14EU990-00770-01300-487310 (ref. SAERTEX Style-Number-System)

Legends:
S: Saerbeck
E: E-Glass
U: Unidirectional 0°
N: Unidirectional 90°

401 MPa

The following indicative properties have been verified by Type Testing of laminates:

Property	Test Method	S14EU990		
Tensile Strength – Longitudinal	ASTM D3039	401	MPa	mmv
Tensile Modulus – Longitudinal	ASTM D3039	23 113	MPa	msv
Tensile Elongation – Longitudinal	ASTM D3039	2,0	%	mmv
Glass content	ASTM D2584	50,1	%	mean
Resin	Synthopan 281 - 30			
Curing Procedure for Type Testing	24 hrs at room temperature, 24 hrs at 60°C			

mmv = Manufacturer's Specified Minimum Value (verified to be below mean - 2 standard deviation of Type Test results)
msv = Manufacturer's Specified Value (verified to be within mean - 10% of Type Test results)
mean = Mean of Type Test results

Type Approval documentation

1. Previous Type Approval Certificate K-2902.
2. Telefax from SAERTEX of 2007-09-28.
3. Survey report from DNV Essen of 2007-11-02.

Tests carried out

Type Testing carried out according to **Type Approval documentation**.

Marking of product

Product shall be marked with *manufacturer's name*; **SAERTEX GmbH & Co. KG, Saerbeck, Germany** and *type designation*; **EU; Uni-axial (0°) - (200-1500 g/m²) with and without chopped strand mats (100-500 g/m²), EN; Uni-axial (90°) - (90-750 g/m²) with and without chopped strand mats (100-500 g/m²)**

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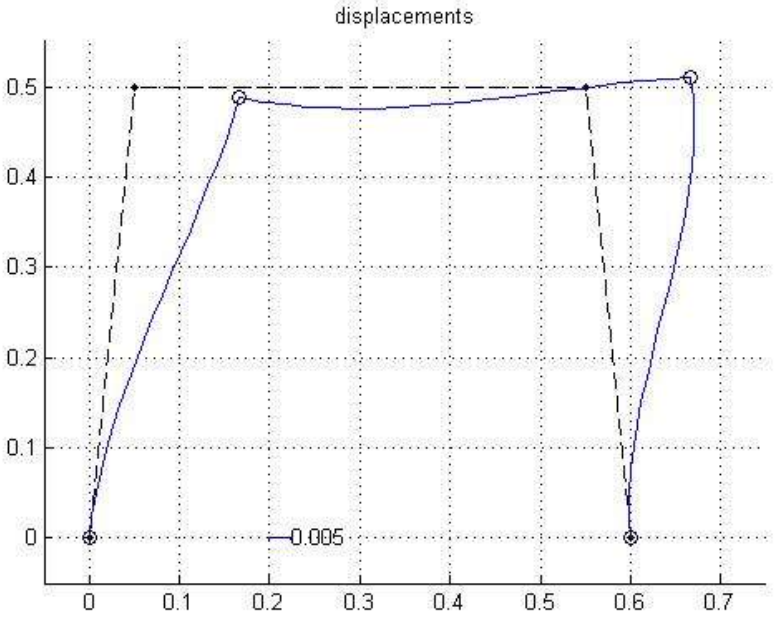
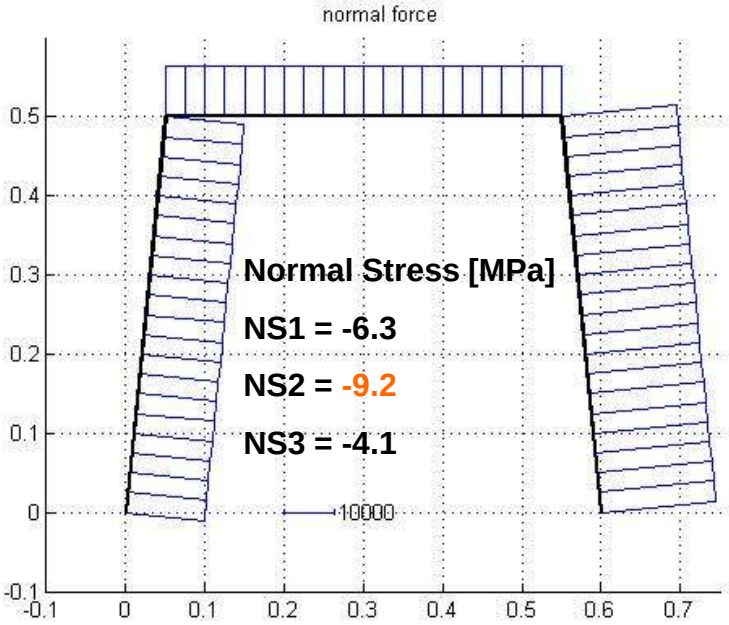
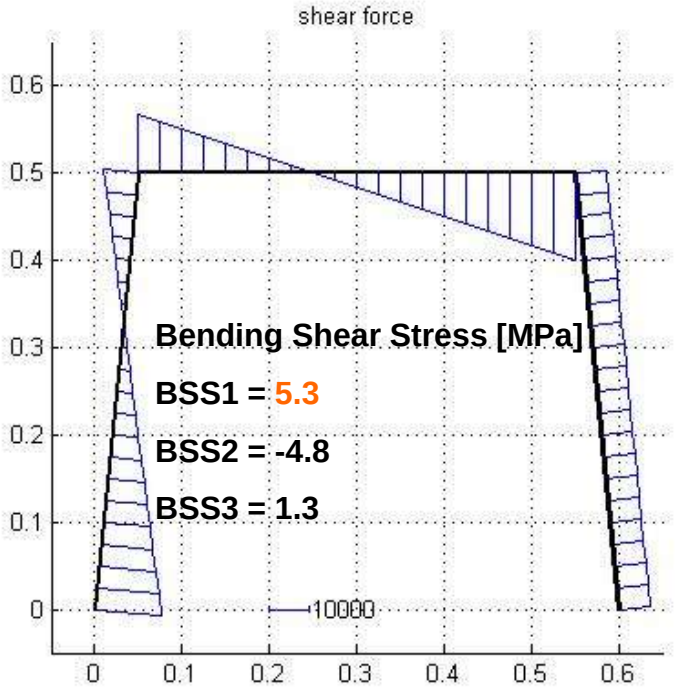
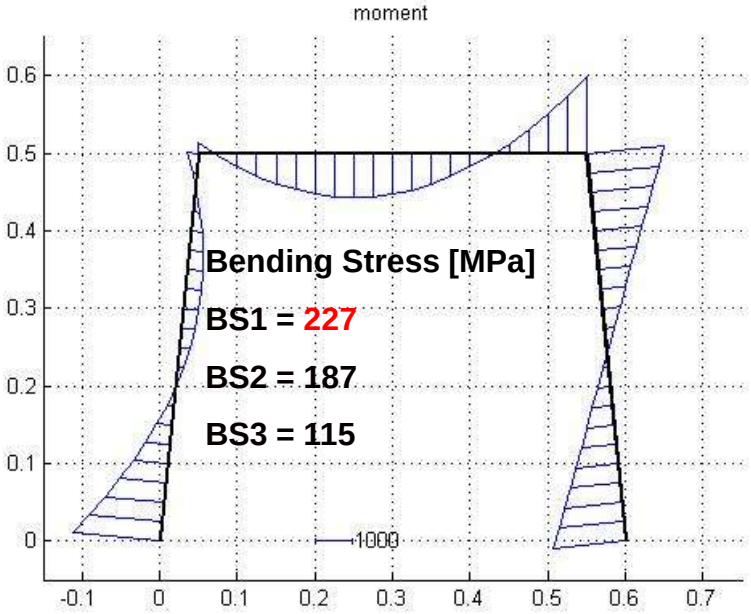
Form No.: 22.92a Issue: January 98 — Page 2 of 3


displacements
0.005


normal force
Normal Stress [MPa]
NS1 = -6.3
NS2 = -9.2
NS3 = -4.1
10000


shear force
Bending Shear Stress [MPa]
BSS1 = 5.3
BSS2 = -4.8
BSS3 = 1.3
10000


moment
Bending Stress [MPa]
BS1 = 227
BS2 = 187
BS3 = 115
1000

Some thoughts about hatches