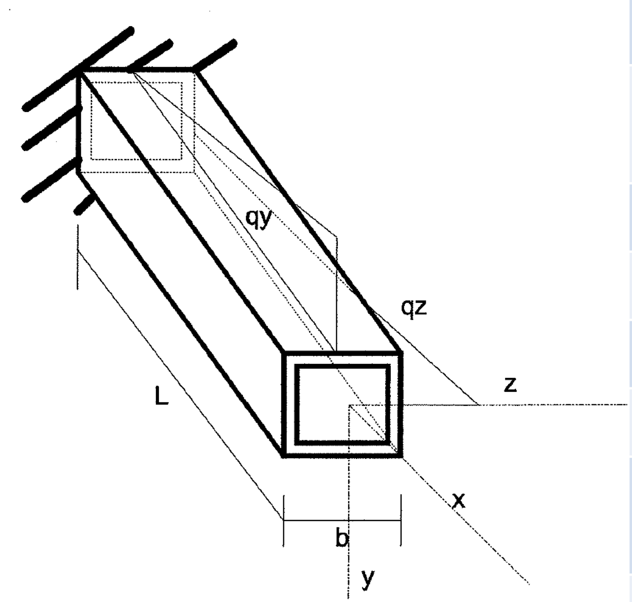
Design project

Evaluation criteria

- Topic and approach
  - How do you transfer your problem from the complex structure to the infinitesimal element for the stress/strain analysis
  - Intermediate steps (not evaluated) – load estimation/simplifications
  - Intermediate steps (evaluated) – assumptions
  - MUST: include hand calculations of CLT
- Report
  - Concise and clear Correctness
  - Clarity of group involvement
- Presentation
  - Clarity – conveying the message without being chatty
  - Group performance

Objective

- Design the beam of Fig. 1 under the given loads, by using CFRP T300/5208.



Data			Control:
L=12m			principal tensile strain less than 0.3%
B=0.7m (square section)			principal compressive strain less than -0.2%
qy=0.694 x kN/m			
qz=0.046 x kN/m			Use
T=200kNm			$[0_n/(\pm45_m)]_s$ laminate
Layer thickness 200µm			Define n, m so that no failure happens
Use the quadratic failure criterion			
Safety factor 1.5			

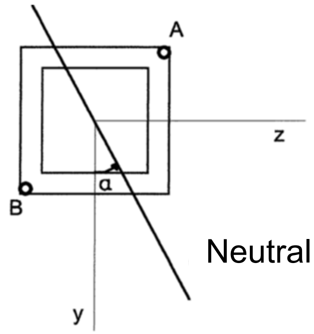
Static analysis

- The critical region is at the fixed point. There we have bending moments, shear forces, and torsional moment.

Mz	400 kNm
My	26.67 kNm
T	200kNm
Qy	50 kN
Qz	3.33 kN

$$M_{tot} = \sqrt{M_y^2 + M_z^2} = 400.89 kNm$$

$$\text{with } \tan a = \frac{M_z}{M_y} = 14.89, \text{ and therefore having an angle of } 86.88^o \text{ with y-axis}$$



Neutral axis (Iz=Iy)

Points A, B the most critical

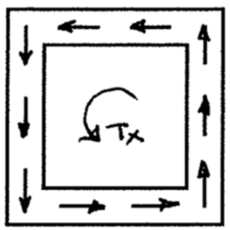
Stress calculation

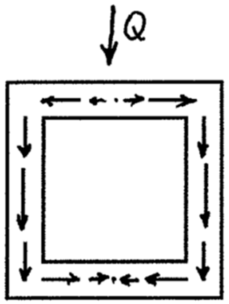
- Point A: $\sigma_x = \frac{M_y}{I_y} z - \frac{M_z}{I_z} y$

- Point B: opposite normal stress due to symmetry

Shear stresses: Due to torsion and due to shear

Torsion





$$\sigma_s = \sigma_s^T + \sigma_s^Q$$

$$\sigma_s^T = \frac{T}{2b^2 h}$$

$$\sigma_s^{Q_i} = \frac{Q_i}{2I_i} b^2$$

Design

- Considering point A – because of the thickness (low) we can assume that the stresses are constant through the thickness of the laminate.

Plate symmetry and no bending moments!

$$N_x = h\sigma_x$$
$$N_y = h\sigma_y = 0$$
$$N_s = h\sigma_s$$

$$\begin{Bmatrix} \varepsilon_x^o \\ \varepsilon_y^o \\ \varepsilon_s^o \end{Bmatrix} = A' \begin{Bmatrix} N_x \\ N_y \\ N_s \end{Bmatrix}$$

When **laminate midplane** strain is calculated, the strain of each **ply** can be calculated by using the **CLT**

Results

- Using stress ratios
- I have created a software (Matlab/fortran etc) that calculates the stress ratio of each ply when the number of plies is changing (n,m are the variables)
- For n=10, m=1, (total 24 layers, total thickness of 4.8 mm) the following values are estimated:

$$R^{0} = 21.5, R^{45} = 1.72, R^{-45} = 15.76$$

- For these values, the principal normal strains are ε_{I}=0.079%, ε_{II}=0.076% well below the limits.
  - The same could be done without the use of the stress ratios (iterative procedure)

Optimization – one step

- Optimal material use can be achieved if the beam is designed with a gradual section. For example if we split it in two parts along its length (see figure) and repeat the aforementioned process for each part we can reduce the number of used layers.