Università di Catania

Digital twins for intelligent production of submarine optical fibers

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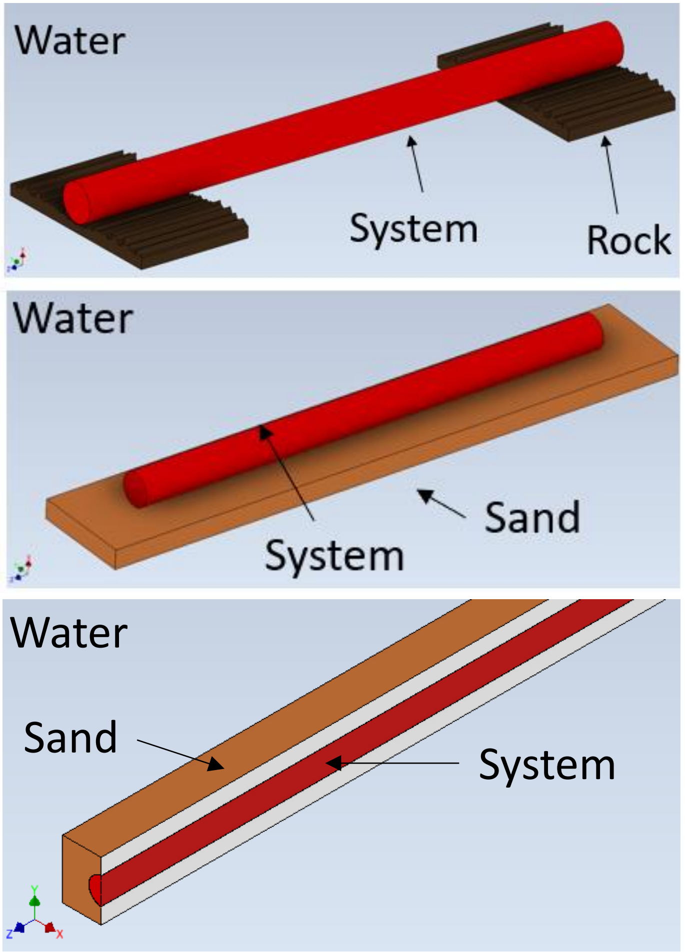
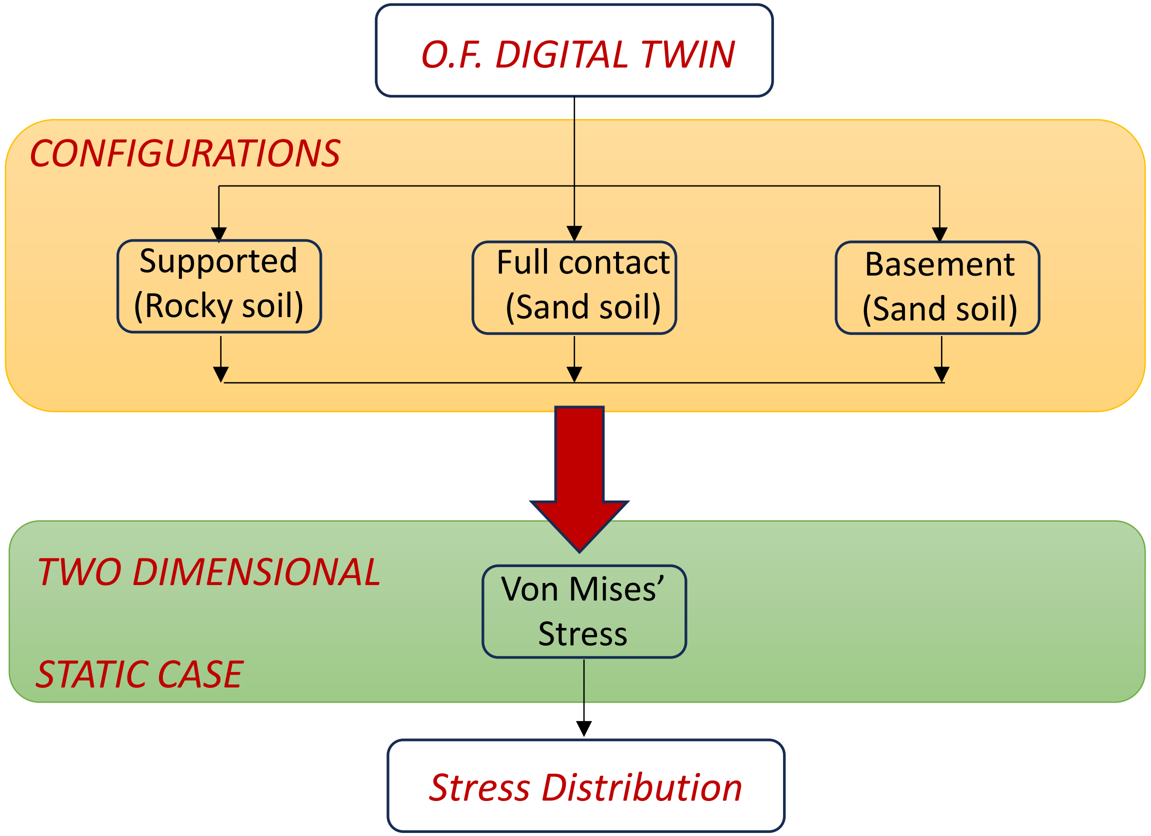
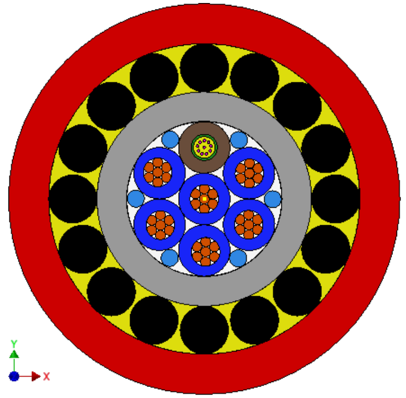
INFN LNS

Study methodology

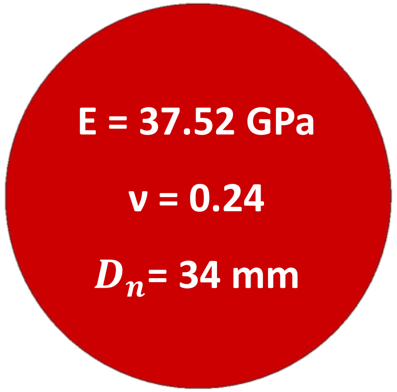




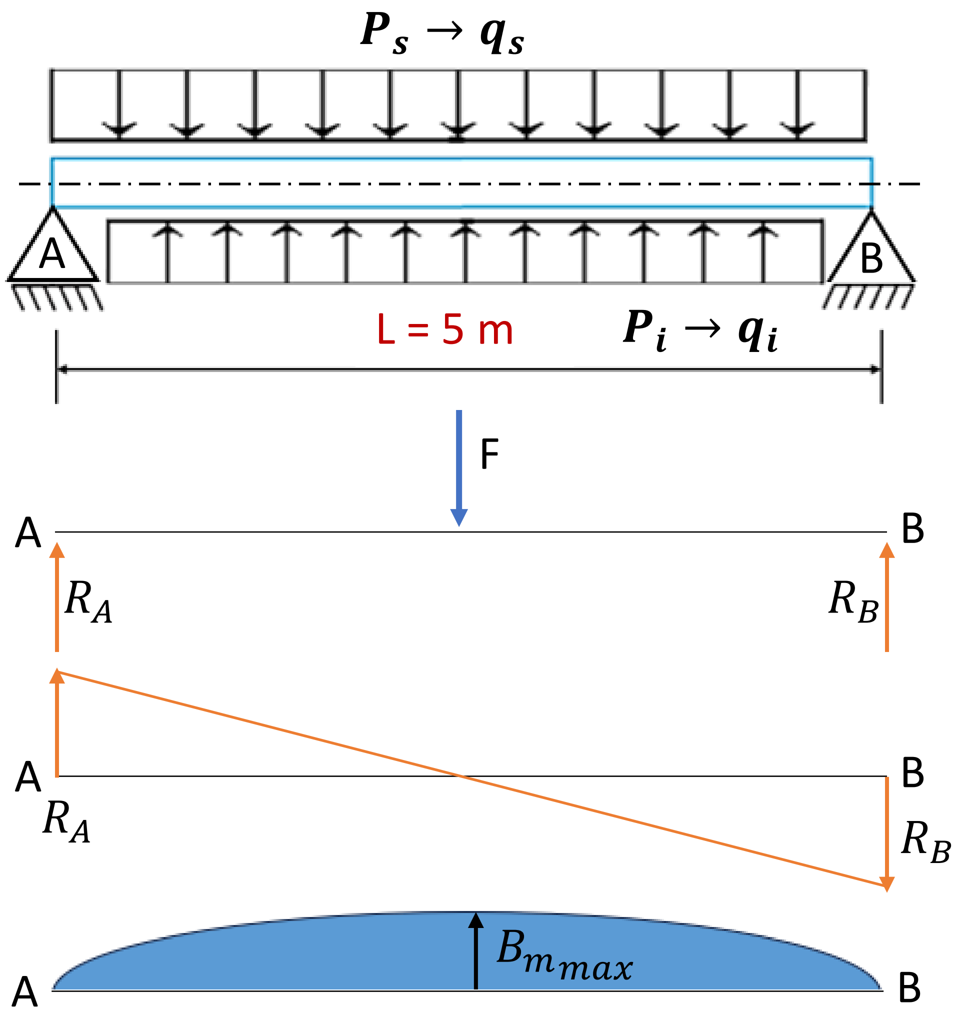
Real Model



Study Model



Study Model: Supported



- $P_s = P_0 + \rho g h$
- $P_i = P_0 + \rho g (h + D_n)$
- $dP = \rho g D_n$
- $F = dP \cdot A_L$
- $q = \frac{F}{L}$
- $A_L = \pi D_n L$

Free body diagram

Shear

$S(x) = -qx + T_0$

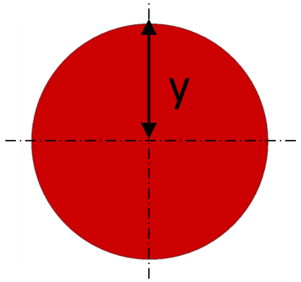
Bending moment

$B_m(x) = -\frac{qx^2}{2} + T_0 x + M_0$

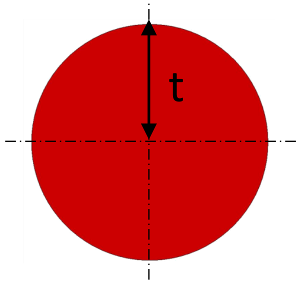
Von Mises' Stress (two-dimensional case)

$$\boldsymbol{\sigma_{VM}} = \sqrt{\boldsymbol{\sigma_x^2 + 3\tau_{xy}^2}}$$

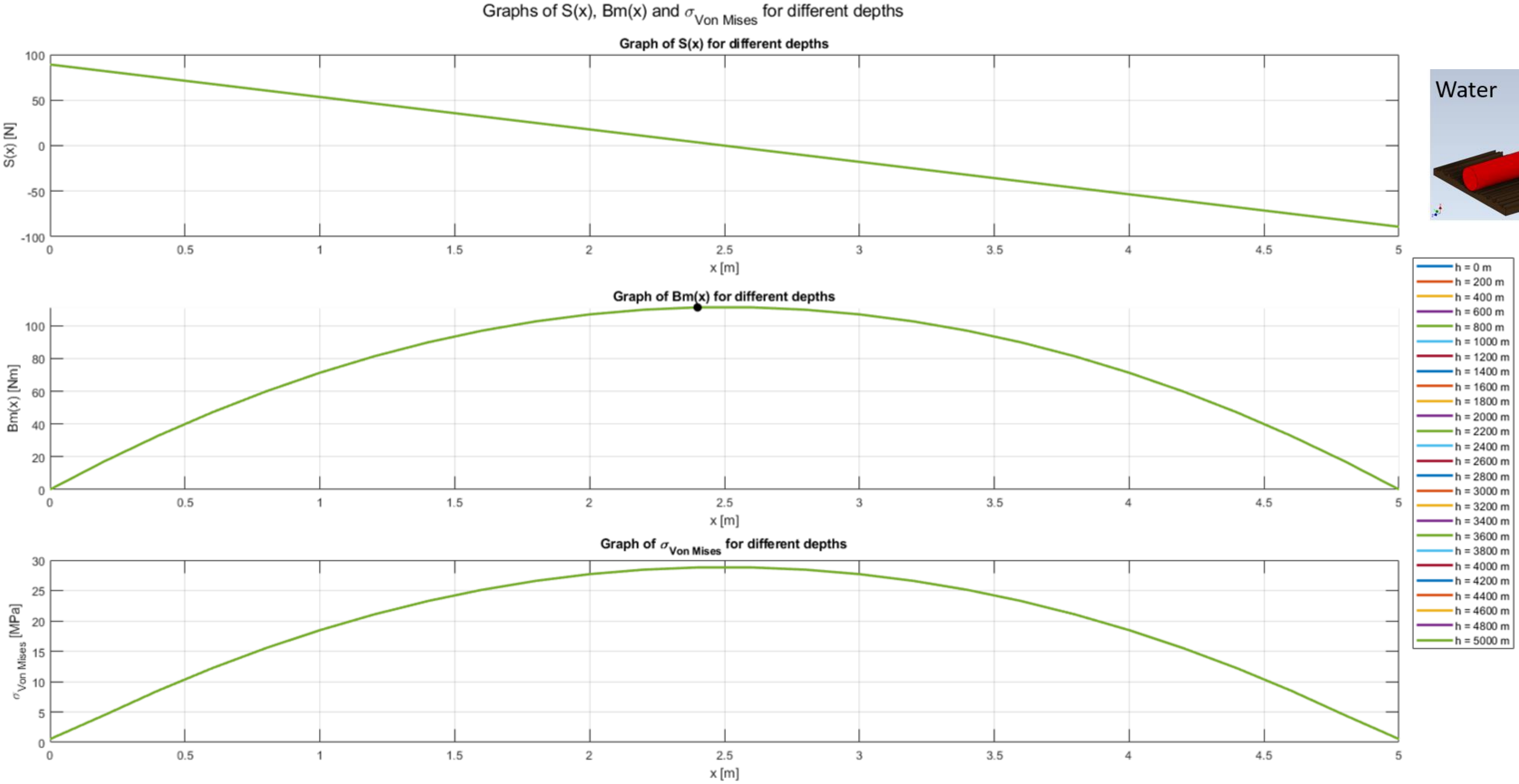
- $\sigma_x = \frac{B_m(x) \cdot y}{I}$

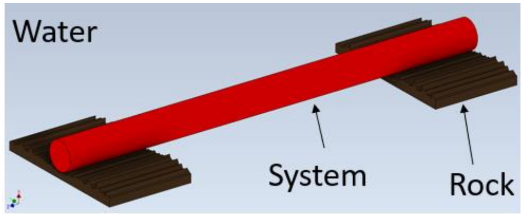


- $\tau_{xy} = \frac{S(x) \cdot Q}{I \cdot t}$ [Jouraski]

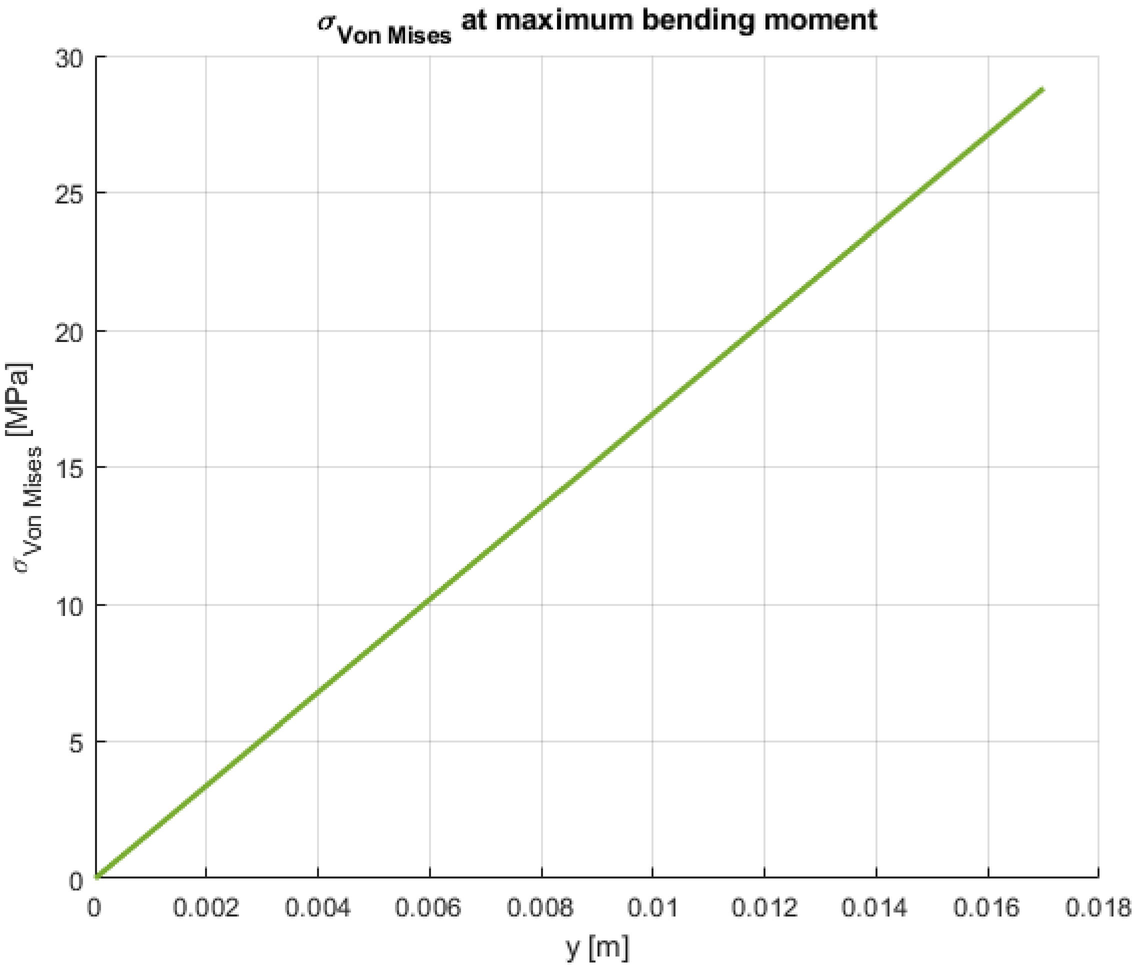


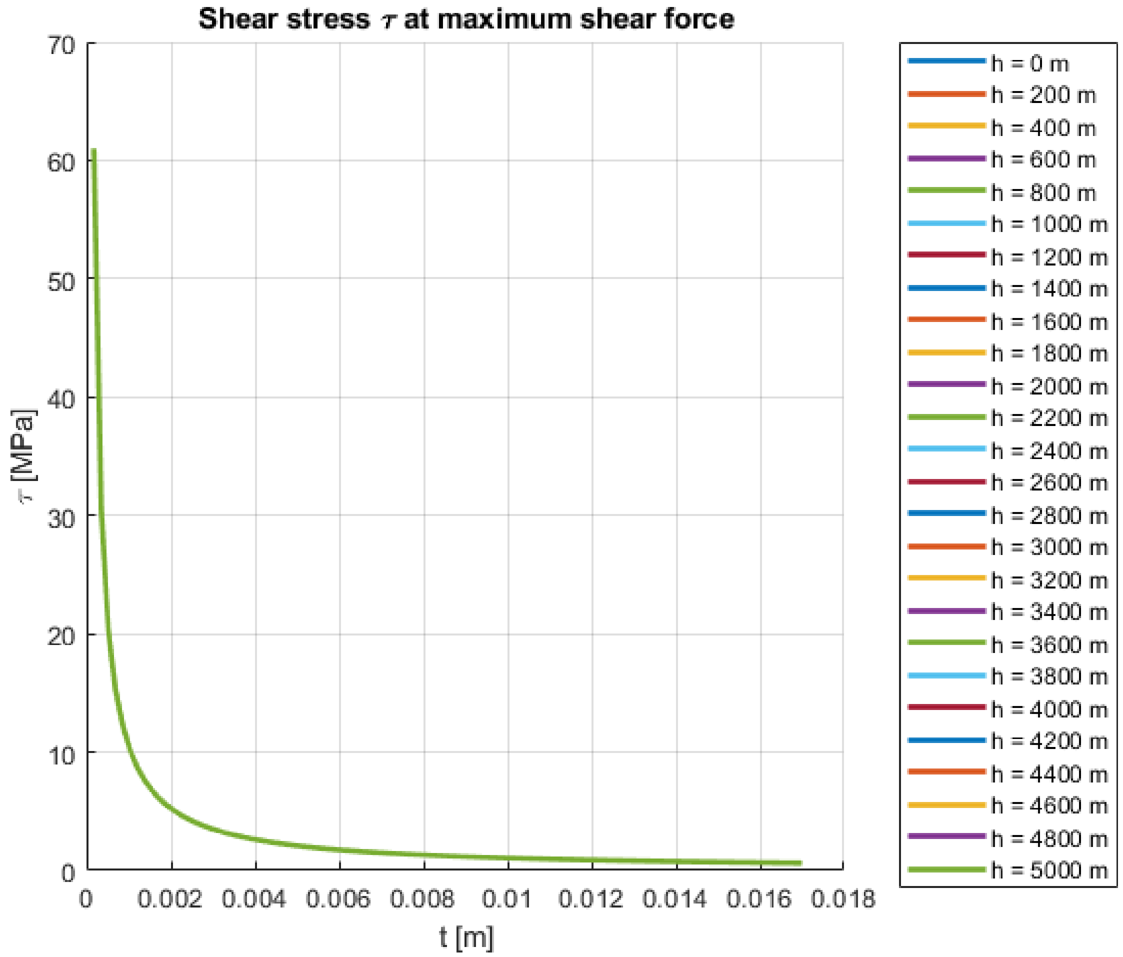
- $Q = \frac{\pi D_n^3}{64}$


Graphs of S(x), Bm(x) and $\sigma_{Von\ Mises}$ for different depths
Graph of S(x) for different depths
S(x) [N]
x [m]
Graph of Bm(x) for different depths
Bm(x) [Nm]
x [m]
Graph of $\sigma_{Von\ Mises}$ for different depths
$\sigma_{Von\ Mises}$ [MPa]
x [m]
h = 0 m
h = 200 m
h = 400 m
h = 600 m
h = 800 m
h = 1000 m
h = 1200 m
h = 1400 m
h = 1600 m
h = 1800 m
h = 2000 m
h = 2200 m
h = 2400 m
h = 2600 m
h = 2800 m
h = 3000 m
h = 3200 m
h = 3400 m
h = 3600 m
h = 3800 m
h = 4000 m
h = 4200 m
h = 4400 m
h = 4600 m
h = 4800 m
h = 5000 m

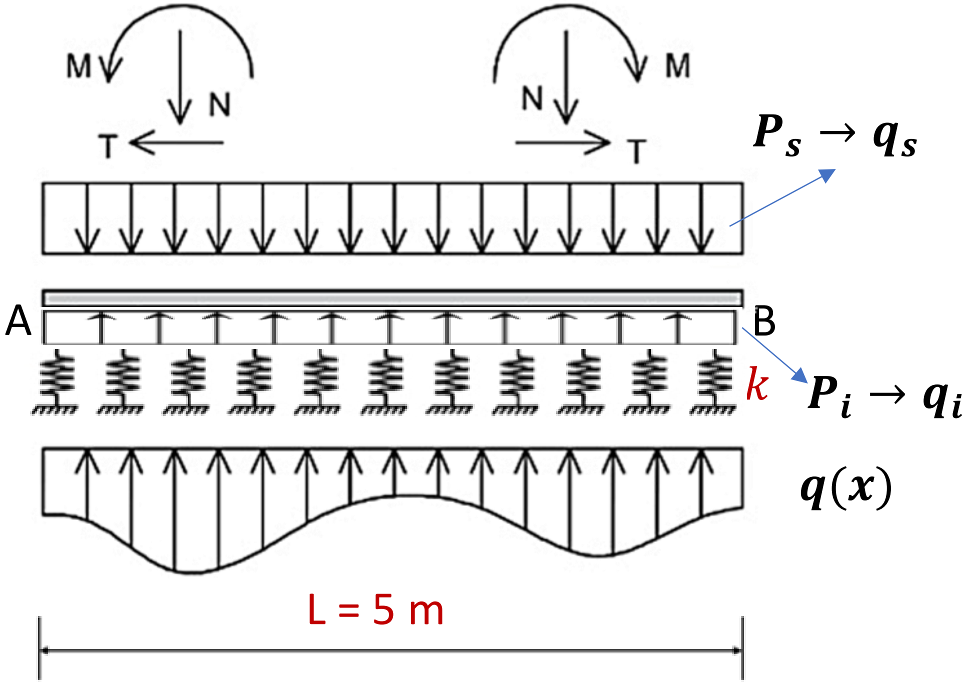

Water
System
Rock

Study Model: Supported





Study Model: Full Contact (sandy soil)



- $k = 10^6 N/m$
- $P_s = P_0 + \rho g h$
- $P_i = P_0 + \rho g(h + D_n)$
- $dP = \rho g D_n$
- $F = dP \cdot A_L$
- $q = \frac{F}{L}$
- $A_L = \pi D_n L$
- $\beta = \sqrt[4]{\frac{k}{EI}}$

$$EI\frac{d^4w(x)}{dx^4} + q_v(x) = q_{est}(x) \rightarrow Winkler$$

- $w(x) =$ *vertical displacement of the beam*
- $q_v(x) = w(x) \cdot k$
- $q_{est}(x) = q_0$

In our case, the solution is:

$$w(x) = A\cos(\beta x) + B\sin(\beta x) + Ce^{-\beta x} + D\,e^{\beta x}$$

- $B_m(x) = -EI\frac{d^2w(x)}{dx^2}$
- $S(x) = -EI\frac{d^3w(x)}{dx^3}$
- $\sigma_x = \frac{B_m(x) \cdot y}{I}$ and $\tau_{xy} = \frac{S(x) \cdot Q}{I \cdot t}$

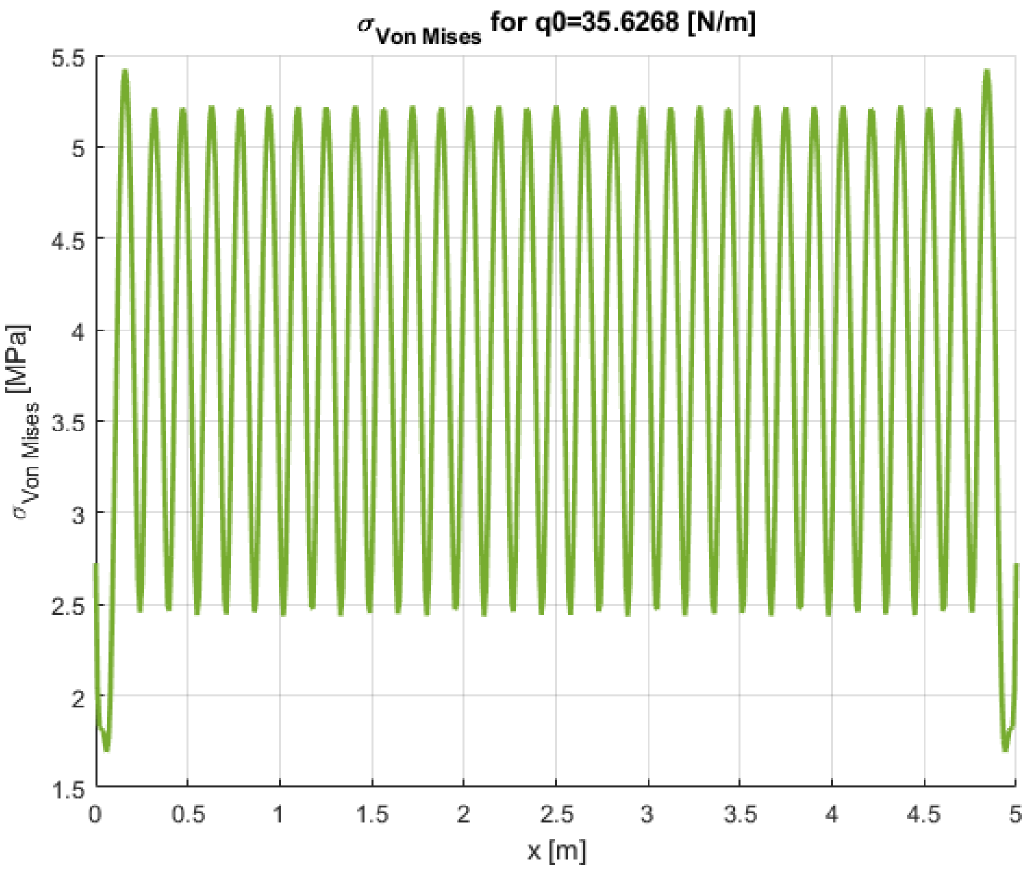
Boundary Conditions

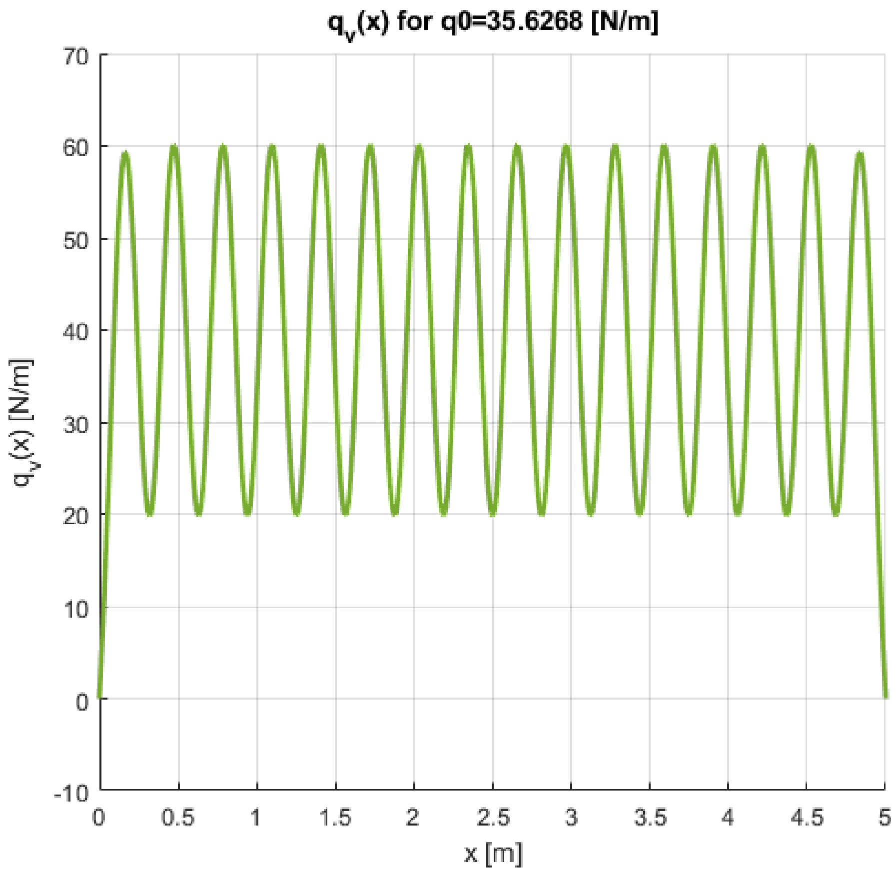
- $w(0) = 0$ and $w(L) = 0$
- $\left.\frac{d^2w(x)}{dx^2}\right|_{x=0} = 0$ and $\left.\frac{d^2w(x)}{dx^2}\right|_{x=L} = 0$

Von Mises' Stress (two-dimensional case)

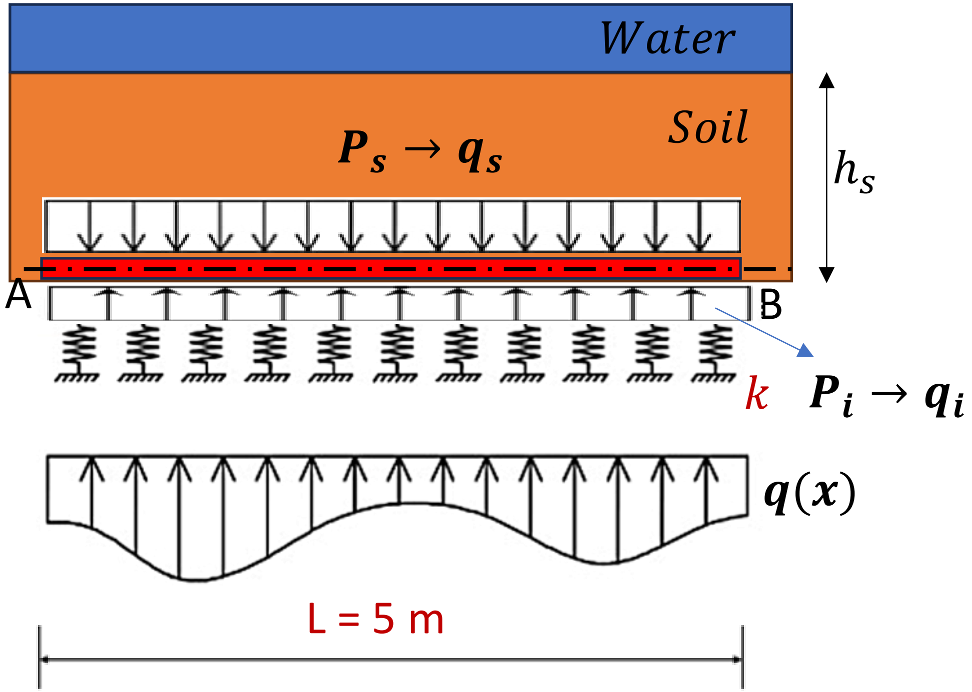
$$\sigma_{VM} = \sqrt{\sigma_x^2 + 3\tau_{xy}^2}$$

Study Model: Full Contact (sandy soil)





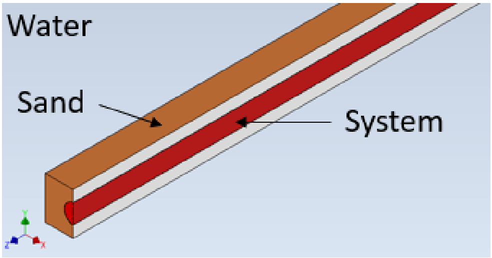
Study Model: Basement (sandy soil)



$$EI\frac{d^4w(x)}{dx^4} + q_v(x) = q_{est}(x) \rightarrow Winkler$$

- $w(x) =$ *vertical displacement of the beam*
- $q_v(x) = w(x) \cdot k$
- $q_{est}(x) = q_0$

- $\sigma' = (\gamma_s - \gamma_w)h_s$
- $u = \rho_w g h_s$
- $\sigma_v = \sigma' + u$
- $P_s = P_0 + \rho_w g h + \sigma_v h_s$
- $P_i = P_0 + \rho_w g h + \sigma_v(h_s + D)$
- $dP = (\rho_s - \rho_w) g D$
- $F = dP \cdot A_L$
- $q = \frac{F}{L}$
- $A_L = \pi D_n L$
- $k = 10^6 N/m$
- $\beta = \sqrt[4]{\frac{k}{EI}}$



In our case, the solution is:

$$w(x) = A\cos(\beta x) + B\sin(\beta x) + Ce^{-\beta x} + D\,e^{\beta x}$$

- $B_m(x) = -EI\frac{d^2w(x)}{dx^2}$
- $S(x) = -EI\frac{d^3w(x)}{dx^3}$
- $\sigma_x = \frac{B_m(x) \cdot y}{I}$ and $\tau_{xy} = \frac{S(x) \cdot Q}{I \cdot t}$

Boundary Conditions

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Von Mises' Stress (two-dimensional case)

$$\boldsymbol{\sigma_{VM} = \sqrt{\sigma_x^2 + 3\tau_{xy}^2}}$$

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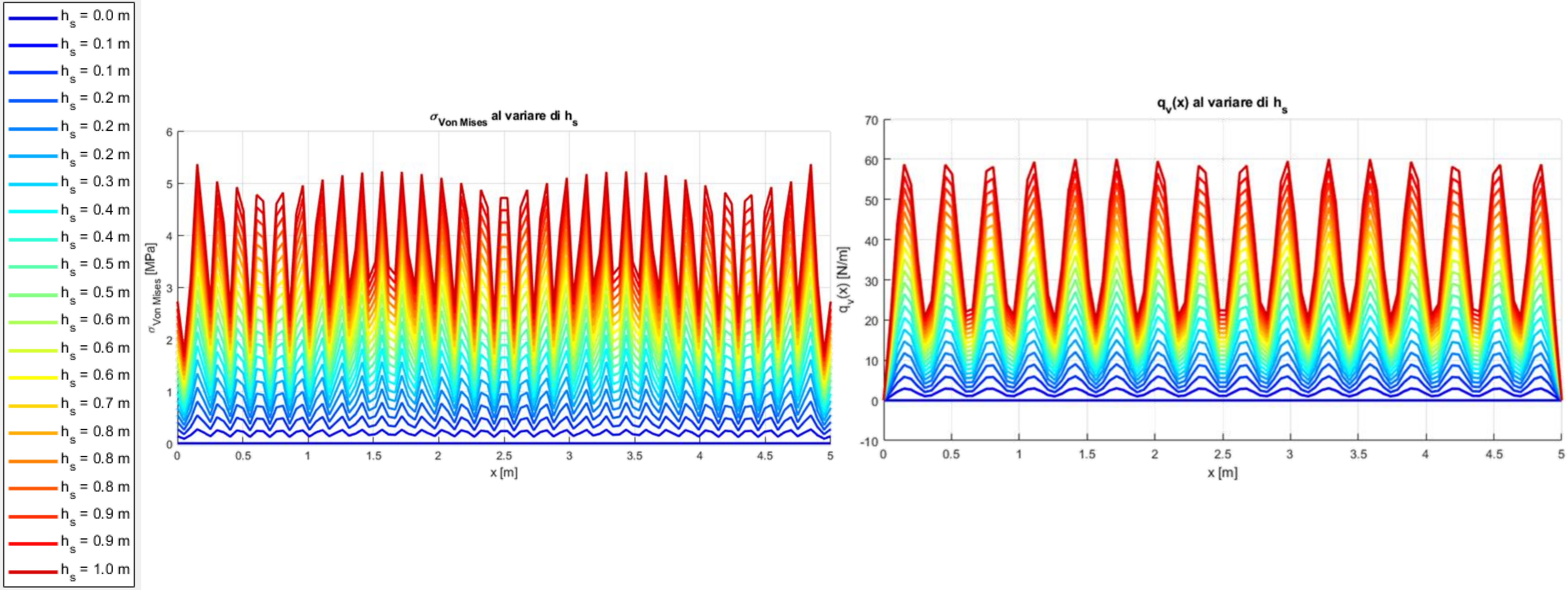
Study Model: Basement (sandy soil)



Thank you for your attention