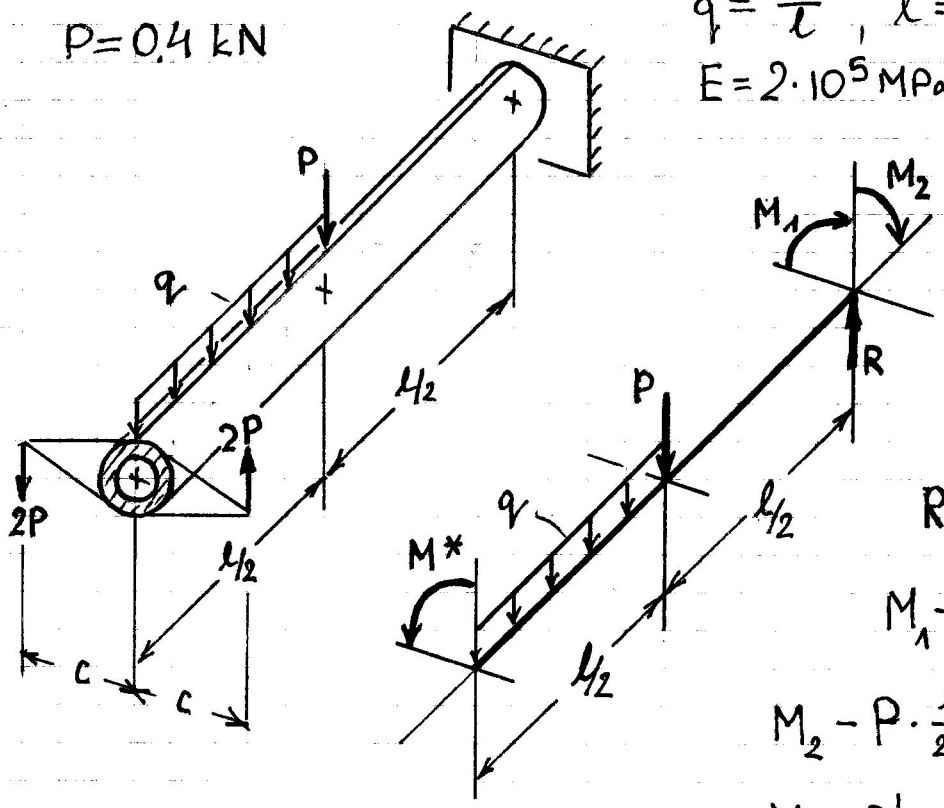
z1. Obciążenie złożone pręta

$P = 0.4\ kN$

$q = \frac{4P}{l}$, $l = 1\,m$, $c = 0.4\,m$, $D = 64$, $d = 60$

$E = 2 \cdot 10^5\ MPa$, $\nu = 0.3$,



$M^* \overset{ozn}{=} 2P \cdot 2c = 4Pc$

reakcje:

$R - P - q\frac{l}{2} = 0$

$R = P + q\frac{l}{2} = P + \frac{4P}{l}\frac{l}{2} = 3P$

$M_1 - M^* = 0 \rightarrow M_1 = M^* = 4Pc$

$M_2 - P \cdot \frac{l}{2} - q\frac{l}{2} \cdot \frac{3}{4}l = 0$

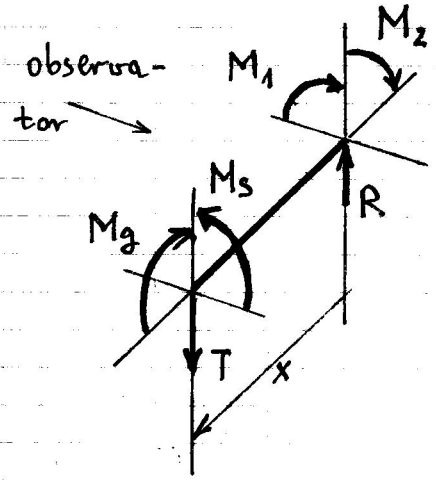
$M_2 = P\frac{l}{2} + \frac{3}{8}ql^2 = PL \cdot \frac{1}{2} + \frac{3}{8}\frac{4P}{l} \cdot l^2$

$M_2 = \frac{1}{2}Pl + \frac{3}{2}PL = 2PL = 2 \cdot 0.4\,kN \cdot 1\,m = 0.8\,kN\,m$

$R = 3P = 3 \cdot 0.4\,kN = 1.2\,kN$, $M_1 = M^* = 4Pc = 4\ 0.4\,kN \cdot 0.4\,m = 0.64\,kN\,m$

Siły przekrojowe:

$x \in (0, l/2)$:



$T - R = 0 \rightarrow T = R = 1.2\,kN$

$M_g - Rx + M_2 = 0 \rightarrow M_g = Rx - M_2$

$M_g = 3Px - 2PL$

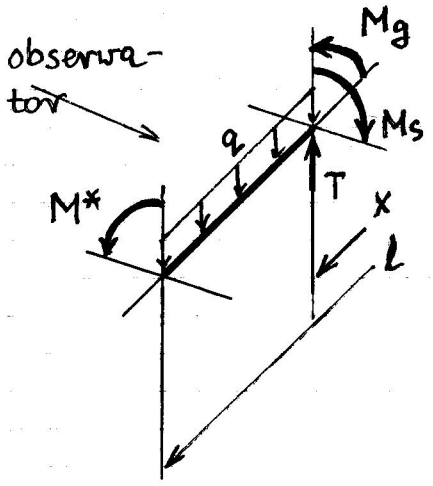
$M_g(0) = -2PL = -2 \cdot 0.4\,kN \cdot 1\,m = -0.8\,kN\,m$

$M_g(\frac{l}{2}) = 3P\frac{l}{2} - 2PL = -\frac{1}{2}PL = -\frac{1}{2} \cdot 0.4 \cdot 1 = -0.2\,kNm$

$M_s - M_1 = 0 \rightarrow M_s = M_1 = M^* = 4Pc = const.$

$M_s = 4 \cdot 0.4\,kN \cdot 0.4\,m = 0.64\,kNm$

$x \in (\frac{l}{2}, l)$: $\quad T - q(l-x) = 0 \rightarrow T = q(l-x)$



$$T = \frac{4P}{l}(l-x)$$

$$T(\tfrac{l}{2}) = \frac{4P}{l}(l-\tfrac{l}{2}) = 2P = 0.8\,kN$$

$$T(l) = \frac{4P}{l}(l-l) = 0$$

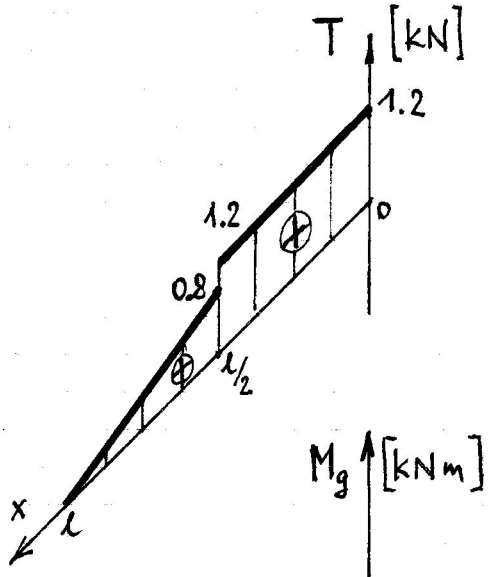
$$M_g + q\frac{(l-x)^2}{2} = 0 \rightarrow M_g = -q\frac{(l-x)^2}{2}$$

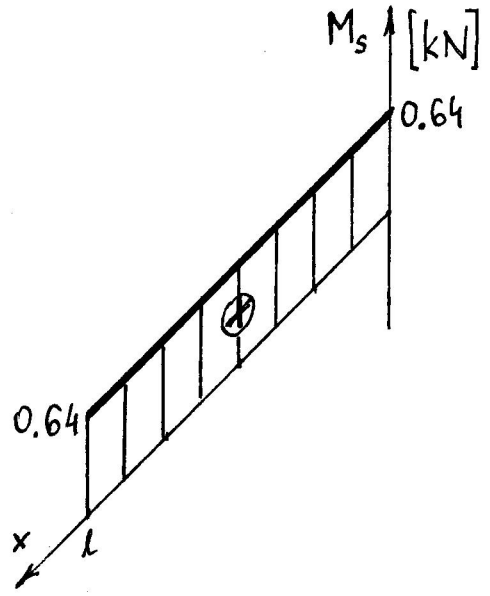
$$M_g = -\frac{1}{2}\cdot\frac{4P}{l}(l-x)^2 = -\frac{2P}{l}(l-x)^2$$

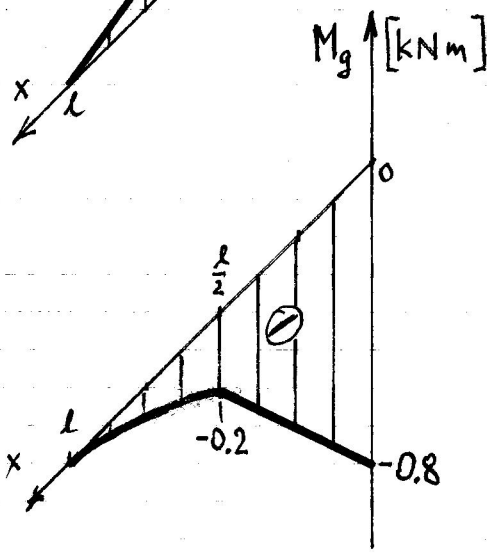
$$M_g(\tfrac{l}{2}) = -\frac{2P}{l}(\tfrac{1}{2})^2 = -\frac{1}{2}PL = -0.2\,kNm \quad , \quad M_g(l) = 0$$

$$M_g(\tfrac{3l}{4}) = -\frac{2P}{l}(l-\tfrac{3L}{4})^2 = -\frac{2P}{l}\cdot(\tfrac{l}{4})^2 = -\frac{1}{8}PL = -0.05\,kNm$$

$$M_s - M^* = 0 \rightarrow M_s = M^* = 4Pc = 0.64\,kNm$$







Najbardziej niebezpieczny przekrój

$x = 0$: $M_g = -0.8\,kNm$, $M_s = 0.64\,kNm$

Z1 c.d Obciążenie złożone

Stan naprężenia w górnym włóknie przekroju $x=0$

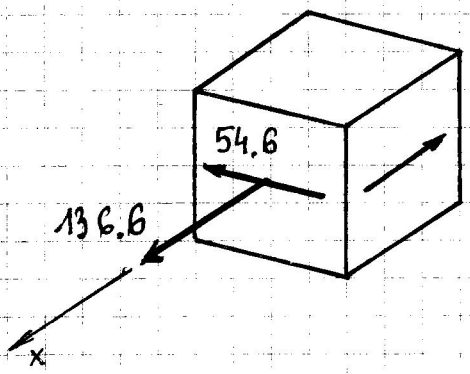
momenty bezwładności:

osiowy $J_y = \frac{\pi}{64} 64^4 \left(1-\left(\frac{60}{64}\right)^4\right) = 1.874 \cdot 10^5 \ mm^4$

biegunowy $J_o = 2 \cdot J_y = 3.748 \cdot 10^5 \ mm^4$

$$\sigma_g\left(z=\frac{D}{2}\right) = -\frac{-0.8 \cdot 10^6 \ Nmm \cdot 32 \ mm}{1.874 \cdot 10^5 \ mm^4} = 136.6 \ MPa$$

$$\tau_s\left(r=\frac{D}{2}\right) = \frac{0.64 \cdot 10^6 \ Nmm \cdot 32 \ mm}{3.748 \cdot 10^5 \ mm^4} = 54.6 \ MPa$$



$$\sigma_{red}^{T} = \sqrt{136.6^2 + 4 \cdot 54.6^2} = 174.9 \ MPa$$

$$\sigma_{red}^{H} = \sqrt{136.6^2 + 3 \cdot 54.6^2} = 166.1 \ MPa$$