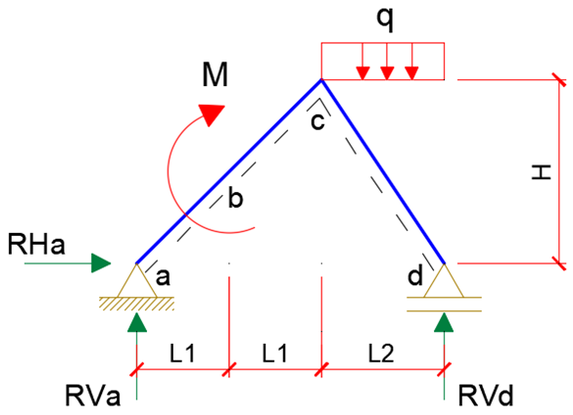
B2T4N0616A

- Considerando somente os efeitos de momentos fletores calcular o deslocamento vertical do ponto "c".



$L1 := 3,0$ m $\quad q := 20,0$ kN/m

$L2 := 4,0$ m $\quad M := 100$ kNm

$H := 5,0$ m

- Todas as barras tem seção transversal tubular com diâmetro externo "D" e espessura "t":

$D := 400$ mm

$t := 8$ mm

- Módulo de elasticidade de todas barras:

$E := 200$ GPa

Q01 - Qual o valor do momento fletor no ponto "c" do caso real de carregamento [em "kNm" e sinal conforme a convenção de diagramas] ?
Q02 - Qual o valor do momento fletor no ponto "c" do caso virtual de carregamento empregado para calcular o deslocamento solicitado [em "kNm" e em módulo] ?
Q03 - Qual o valor do deslocamento vertical do ponto "c" [em "mm" e com positivo para cima] ?

Transformação de unidades e propriedades geométricas e do material

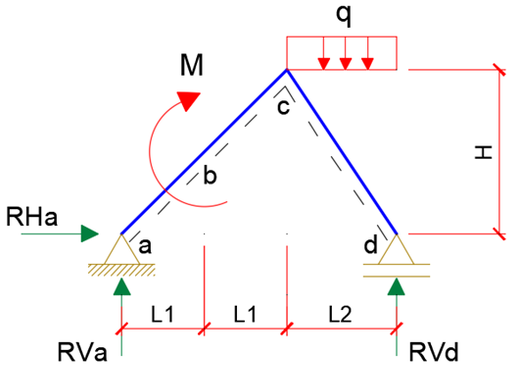
$E := E \cdot 10^{6} = 2 \cdot 10^{8}$ $\frac{kN}{m^2}$ $\quad D := \frac{D}{1000} = 0,4$ m $\quad t := \frac{t}{1000} = 0,008$ m

$d := D - 2 \cdot t = 0,3840$ m

$Iext := \frac{\pi \cdot D^4}{64} = 0,001257$ $\quad Iint := \frac{\pi \cdot d^4}{64} = 0,001067$

$I := Iext - Iint = 0,0001893$ m^4

Carregamento Real



Reações e Apoio:

ΣFh = 0 (+) para direita $\quad RHa := 0$

ΣMd = 0 (+) horário

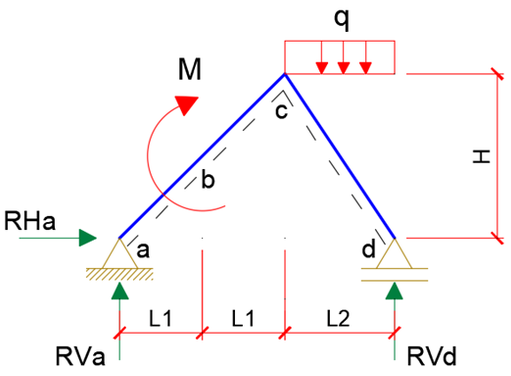
$RVa \cdot (2 \cdot L1 + L2) + M - \frac{q \cdot L2^2}{2} = 0$

$RVa := \frac{1}{2 \cdot L1 + L2} \cdot \left(-M + \frac{q \cdot L2^2}{2} \right) = 6$ kN

ΣFv = 0 (+) para cima

$RVd + RVa - q \cdot L2 = 0$

$RVd := -RVa + q \cdot L2 = 74$ kN



$Mb_e := RVa \cdot L1 = 18$ kN m

$Mb_d := RVa \cdot L1 + M = 118$ kN m

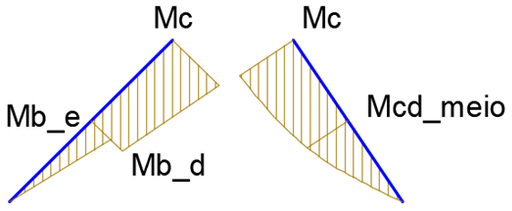
$Mc := RVa \cdot 2 \cdot L1 + M = 136$ kN m

$Mc := RVd \cdot L2 - \frac{q \cdot L2^{2}}{2} = 136$ kN m

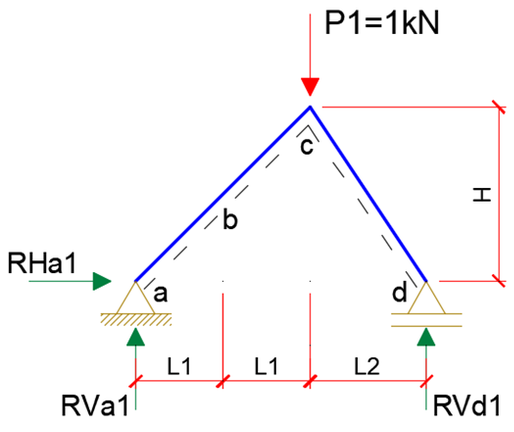
$Md := 0$

$Mcd_meio := \frac{(Mc + Md)}{2} + \frac{q \cdot L2^{2}}{8} = 108$ kN m

M Real



Carregamento Virtual



Reações de Apoio: $P1 := 1$ kN

ΣFh = 0 (+) para a direita

$RHa1 := 0$

ΣMa = 0 (+) antihorário

$RVd1 \cdot (2 \cdot L1 + L2) - P1 \cdot 2 \cdot L1 = 0$

$RVd1 := \frac{P1 \cdot 2 \cdot L1}{2 \cdot L1 + L2} = 0,6$ kN

ΣFv = 0 (+) para cima

$RVa1 - P1 + RVd1 = 0$

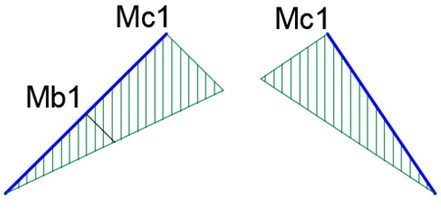
$RVa1 := P1 - RVd1 = 0,4$ kN

$Mb1 := RVa1 \cdot L1 - RHa1 \cdot \frac{H}{2} = 1,2$ kN m

$Mc1 := RVa1 \cdot 2 \cdot L1 = 2,4$ kN m

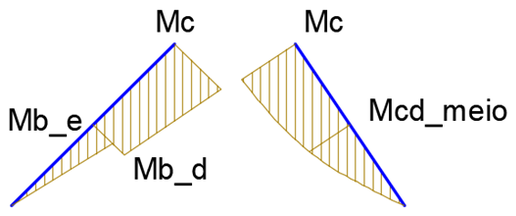
$Mc1 := RVd1 \cdot L2 = 2,4$ kN m

M Virtual

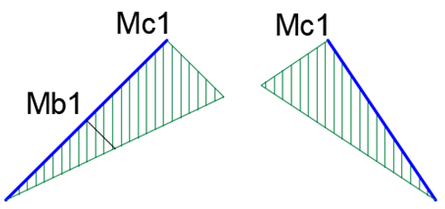


Cálculo do deslocamento vertical do ponto "c":

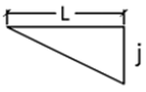
M Real

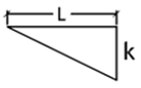


M Virtual



Barra "ab":





1/3 Ljk

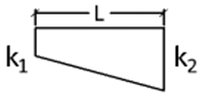
$Lab := \sqrt{L1^2 + \left(\frac{H}{2}\right)^2} = 3,9051$

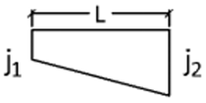
$k := Mb_e = 18,00$

$j := Mb1 = 1,200$

$\delta vc_ab := \frac{1}{3} \cdot Lab \cdot j \cdot k \cdot \frac{1}{E \cdot I} = 0,00074259$

Barra "bc":





1/6 L[$j_1(2k_1+k_2)$ + $j_2(k_1+2k_2)$]

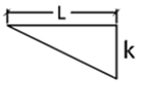
$Lbc := Lab = 3,9051$

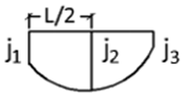
$k1 := Mb1 = 1,2$ $\quad k2 := Mc1 = 2,4$

$j1 := Mb_d = 118$ $\quad j2 := Mc = 136$

$\delta vc_bc := \frac{1}{6} \cdot Lbc \cdot \left(j1 \cdot (2 \cdot k1 + k2) + j2 \cdot (k1 + 2 \cdot k2)\right) \cdot \frac{1}{E \cdot I} = 0,023763$

Barra "cd":





1/6 Lk($2j_2$+j_3)

$Lcd := \sqrt{L2^2 + H^2} = 6,4031$

$k := Mc1 = 2,4$

$j2 := Mcd_meio = 108$

$j3 := Mc = 136$

$\delta vc_cd := \frac{1}{6} \cdot Lcd \cdot k \cdot (2 \cdot j2 + j3) \cdot \frac{1}{E \cdot I} = 0,023811$

$\delta vc := (\delta vc_ab + \delta vc_bc + \delta vc_cd) \cdot (-1000) = -48,3163$ mm

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$Q01 := Mc = 136$

$Q02 := |Mc1| = 2,4$

$Q03 := \delta vc = -48,3163$
