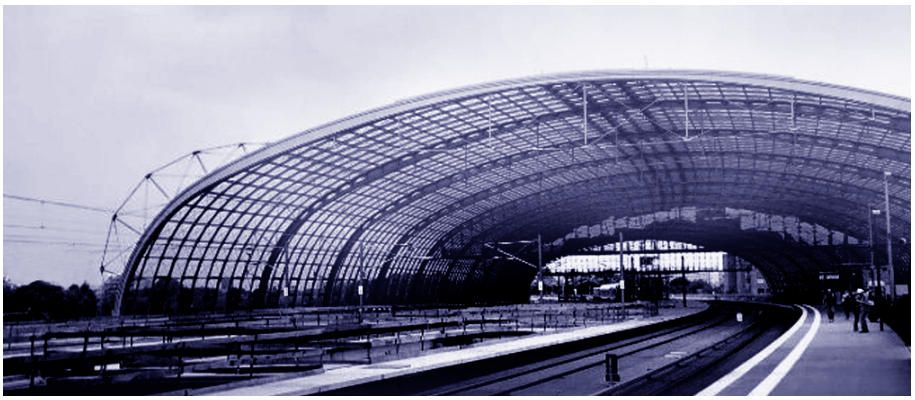
Materialmekanik VSMA10

Strukturmekanik VSMA20



# Formelblad, lastfall och tvärsnittsdata

# Formelblad för Materialmekanik och Strukturmekanik

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### Spännings-töjningssamband för linjärt elastiskt isotropt material

Enaxiell normalspänning:

$$\sigma_x = E\varepsilon_x$$

Fleraxiell normalspänning:

$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\nu\sigma_y}{E} - \frac{\nu\sigma_z}{E}$$

$$\varepsilon_y = -\frac{\nu\sigma_x}{E} + \frac{\sigma_y}{E} - \frac{\nu\sigma_z}{E}$$

$$\varepsilon_z = -\frac{\nu\sigma_x}{E} - \frac{\nu\sigma_y}{E} + \frac{\sigma_z}{E}$$

Skjuvspänning:

$$\tau = G\gamma \qquad G = \frac{E}{2(1+\nu)}$$

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### Temperaturtöjning

$$\varepsilon = \alpha(T - T_0)$$

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### Axiell belastning av stång

$$\sigma = \frac{N}{A} \qquad \varepsilon = \frac{\delta}{L} \qquad \delta = \frac{NL}{AE} \qquad \delta = \int_0^L \frac{N(x)}{A(x)E(x)}dx$$

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### Böjning av balk

Vid balkens ändar:

- Vid en fast inspänning är momentet i allmänhet skilt från noll.
- Vid ett fixlager eller rullager i balkens ände är momentet noll såvida inte ett punktmoment angriper vid stödet.

Balkdel utan last:

- Tvärkraften är konstant.
- Momentet varierar linjärt.

Balkdel med jämnt utbredd last:

- Tvärkraften varierar linjärt.
- Momentet varierar kvadratiskt.

Vid punktlast:

- Diskontinuitet i tvärkraftsdiagrammet.
- Knyck i momentdiagrammet.

Vid punktmoment:

- Tvärkraften opåverkad.
- Diskontinuitet i momentdiagrammet.

Allmänt:

- Där tvärkraften är noll har momentet ett extremvärde.
- Momentdiagrammet ligger på den dragna sidan, d.v.s. den konvexa sidan av balken om man skissar balkens utböjda form.

Normalspänning:

$$\sigma_x = -\frac{M_z}{I_z} y \qquad \sigma_x = \frac{M_y}{I_y} z$$

$$\sigma_{x,max} = \frac{M_z}{W_{el,z}} \qquad W_{el,z} = \frac{I_z}{|y_{max}|}$$

$$\sigma_x = \frac{N}{A} - \frac{M_z}{I_z} y + \frac{M_y}{I_y} z$$

Skjuvspänning:

$$\tau_{xy} = \frac{V_y A_V \bar{y}}{I_z b} \qquad A_V \bar{y} = \int_{A_V} y dA$$

$$v_{yx} = \frac{V_y A_V \bar{y}}{I_z}$$

Yttröghetsmoment:

$$I_z = \int_A y^2 \, dA \qquad I_y = \int_A z^2 \, dA$$

Rektangulärt tvärsnitt: $I_z = \frac{b\,h^3}{12}$ Cirkulärt tvärsnitt: $I_z = \frac{\pi R^4}{4}$

Parallellförflyttningssatsen: $I_{z'} = I_z + \bar{b}^2 A$

Samband mellan last - tvärkraft - böjmoment - vinkeländring - utböjning:

| | | | | | |
|---|---|---|---|---|---|
| utböjning | $v(x)$ | | | | |
| vinkeländring | $\theta(x) =$ | | $\dfrac{dv}{dx}$ | | |
| böjmoment | $M(x) = EI\dfrac{d\theta}{dx} =$ | | $EI\dfrac{d^2v}{dx^2}$ | | |
| tvärkraft | $V(x) = -\dfrac{dM}{dx} =$ | $-\dfrac{d}{dx}EI\dfrac{d^2v}{dx^2} =$ | $-EI\dfrac{d^3v}{dx^3}$ | (om $EI$ konstant) | |
| last | $q(x) = -\dfrac{dV}{dx} =$ | $\dfrac{d^2}{dx^2}EI\dfrac{d^2v}{dx^2} =$ | $EI\dfrac{d^4v}{dx^4}$ | (om $EI$ konstant) | |

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**Böjning av balk - elastiskt-idealplastiskt material**

$M_e = \sigma_s W_{el} \quad M_p = \sigma_s W_{pl}$

$\eta = \dfrac{W_{pl}}{W_{el}}$

Rektangulärt tvärsnitt: $W_{pl} = \dfrac{b\,h^2}{4}$ Sammansatt tvärsnitt: $W_{pl} = \Sigma A_i \bar{y}_i$

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**Vridning av cirkulär cylinder**

$\varphi = \dfrac{TL}{I_p\,G} \qquad \tau = \dfrac{Tr}{I_p}$

Polärt tröghetsmoment:
$I_p = \int_A r^2\,dA$

Solid cylinder: $I_p = \dfrac{\pi R^4}{2}$ Ihålig cylinder: $I_p = \dfrac{\pi(R_y^4 - R_i^4)}{2}$

Tunnväggig cylinder: $I_p \approx 2\pi R^3 b$

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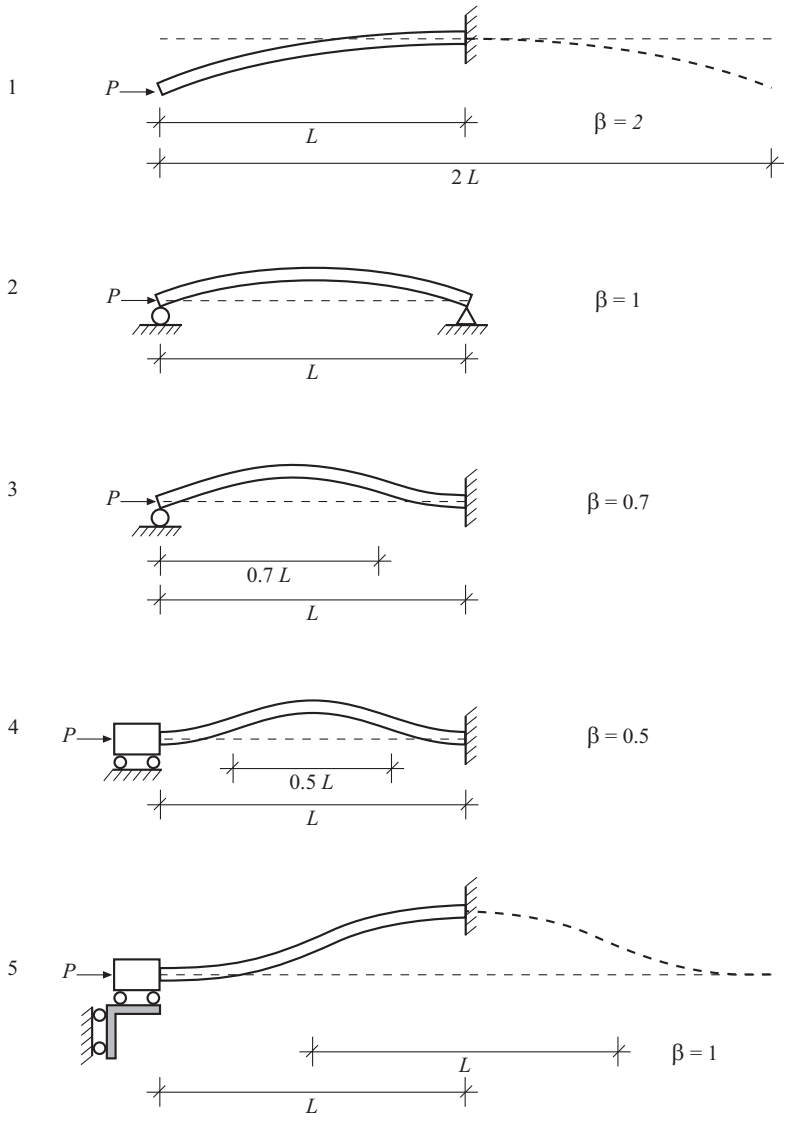
## Knäckningslast

$$P_c = \frac{\pi^2 EI}{(\beta L)^2}$$



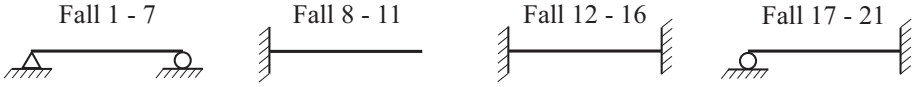

## Approximativ förstoringsfaktor för tryckt pelare

$$v_{II} = \frac{1}{1 - P/P_c}\, v_I$$

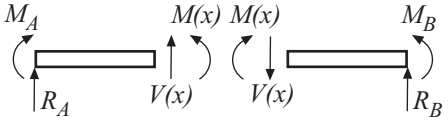
## Lastfall

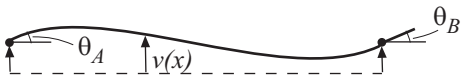
Enfacksbalkar med konstant böjstyvhet.

Randvillkor:




Beteckningar:
$L$ = längd
$E$ = elasticitetsmodul
$I$ = yttröghetsmoment
$R$ = upplagskraft
$V$ = tvärkraft
$M$ = böjmoment
$\theta$ = vinkeländring
$v$ = utböjning

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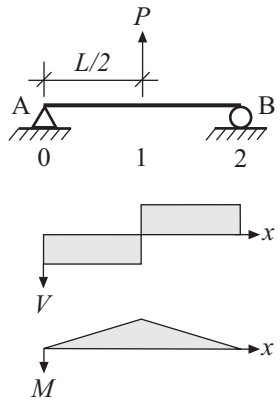
1




$$R_A = -\frac{P}{2} \qquad R_B = -\frac{P}{2}$$

$$V_{0-1} = \frac{P}{2} \qquad V_{1-2} = -\frac{P}{2}$$

$$M_{0-1} = -\frac{Px}{2} \qquad M_{1-2} = -\frac{P(L-x)}{2} \qquad M_{max} = -\frac{PL}{4}$$

$$\theta_A = \frac{PL^2}{16EI} \qquad \theta_B = -\frac{PL^2}{16EI}$$

$$v_{0-1} = \frac{PL^2}{16EI}\left(x - \frac{4x^3}{3L^2}\right) \qquad v_{max} = \frac{PL^3}{48EI}$$

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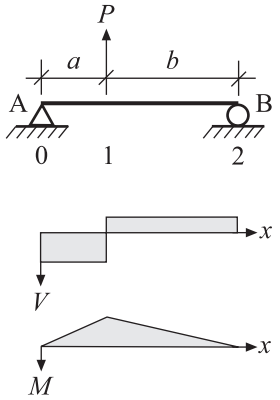
2




$$R_A = -\frac{Pb}{L} \qquad R_B = -\frac{Pa}{L}$$

$$V_{0-1} = \frac{Pb}{L} \qquad V_{1-2} = -\frac{Pa}{L}$$

$$M_{0-1} = -\frac{Pbx}{L} \qquad M_{1-2} = -\frac{Pa(L-x)}{L}$$

$$\theta_A = \frac{PbL}{6EI}\left(1 - \frac{b^2}{L^2}\right) \qquad \theta_B = -\frac{PaL}{6EI}\left(1 - \frac{a^2}{L^2}\right)$$

$$v_{0-1} = \frac{PLb}{6EI}\left(\left(1 - \frac{b^2}{L^2}\right)x - \frac{x^3}{L^2}\right) \qquad v_1 = \frac{Pa^2b^2}{3EIL}$$

$$v_{1-2} = \frac{Pa}{6EI}\left(-a^2 + \left(2L + \frac{a^2}{L}\right)x - 3x^2 + \frac{x^3}{L}\right)$$

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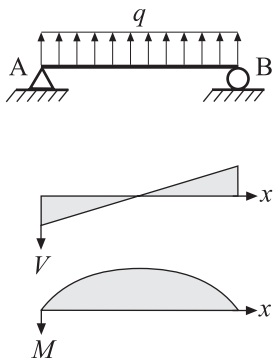
3




$$R_A = -\frac{qL}{2} \qquad R_B = -\frac{qL}{2}$$

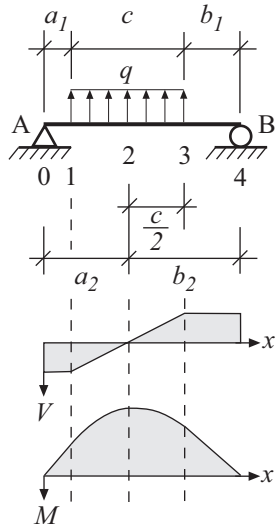
$$V = q\left(\frac{L}{2} - x\right)$$

$$M = \frac{q}{2}\left(-Lx + x^2\right) \qquad M_{max} = -\frac{qL^2}{8}$$

$$\theta_A = \frac{qL^3}{24EI} \qquad \theta_B = -\frac{qL^3}{24EI}$$

$$v = \frac{qL^3}{24EI}\left(x - 2\frac{x^3}{L^2} + \frac{x^4}{L^3}\right) \qquad v_{max} = v(0.5L) = \frac{5qL^4}{384EI}$$

4




$$R_A = -\frac{qcb_2}{L} \qquad R_B = -\frac{qca_2}{L}$$

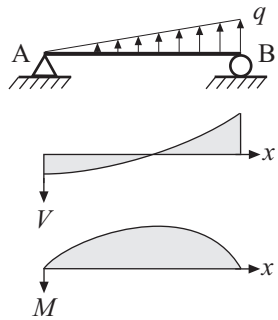
$$V_{1-3} = \frac{qcb_2}{L} - q(x - a_1)$$

$$M_{1-3} = q\left(\frac{a_1^2}{2} - \left(a_1 + \frac{cb_2}{L}\right)x + \frac{x^2}{2}\right) \qquad M_{max} = -\frac{qcb_2}{2L^2}(2a_1L + cb_2)$$

$$\theta_A = \frac{qcb_2L}{6EI}\left(1 - \frac{b_2^2}{L^2} - \frac{c^2}{4L^2}\right)$$

$$\theta_B = -\frac{qca_2L}{6EI}\left(1 - \frac{a_2^2}{L^2} - \frac{c^2}{4L^2}\right)$$

5




$$R_A = -\frac{qL}{6} \qquad R_B = -\frac{qL}{3}$$

$$V = \frac{q}{2}\left(\frac{L}{3} - \frac{x^2}{L}\right)$$

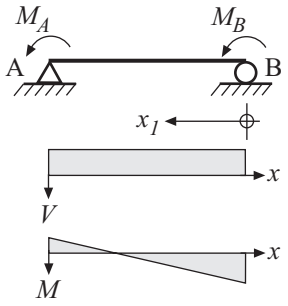
$$M = -\frac{qL}{6}\left(x - \frac{x^3}{L^2}\right) \qquad M_{max} = M(0.577L) = -0.064qL^2$$

$$\theta_A = \frac{7qL^3}{360EI} \qquad \theta_B = -\frac{8qL^3}{360EI}$$

$$v = \frac{qL^3}{360EI}\left(7x - \frac{10x^3}{L^2} + \frac{3x^5}{L^4}\right)$$

$$v_{max} = v(0.519L) = 0.00652\frac{qL^4}{EI}$$

6




$$R_A = \frac{M_A + M_B}{L} \qquad R_B = -\frac{M_A + M_B}{L}$$

$$V = -\frac{M_A + M_B}{L}$$

$$M = -M_A + (M_B + M_A)\frac{x}{L}$$

$$\theta_A = \frac{L}{6EI}(2M_A - M_B) \qquad \theta_B = \frac{L}{6EI}(2M_B - M_A)$$

$$v = \frac{L}{6EI}\left[M_A\left(x_1 - \frac{x_1^3}{L^2}\right) - M_B\left(x - \frac{x^3}{L^2}\right)\right]$$

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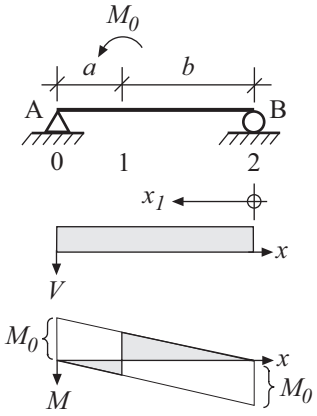
7




$$R_A = \frac{M_0}{L} \qquad R_B = -\frac{M_0}{L}$$

$$V = -\frac{M_0}{L}$$

$$M_{0-1} = M_0\frac{x}{L} \qquad M_{1-2} = -M_0\frac{L-x}{L}$$

$$\theta_A = -\frac{M_0 L}{6EI}\left(1 - \frac{3b^2}{L^2}\right) \qquad \theta_B = -\frac{M_0 L}{6EI}\left(1 - \frac{3a^2}{L^2}\right)$$

$$v_{0-1} = -\frac{M_0 L}{6EI}\left(\left(1 - \frac{3b^2}{L^2}\right)x - \frac{x^3}{L^2}\right)$$

$$v_{1-2} = \frac{M_0 L}{6EI}\left(\left(1 - \frac{3a^2}{L^2}\right)x_1 - \frac{x_1^3}{L^2}\right)$$

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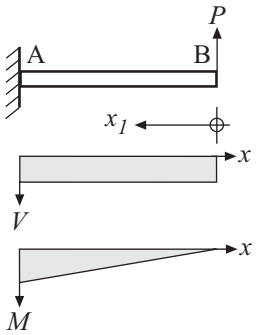
8




$$R_A = -P$$

$$V = P$$

$$M = Px_1$$

$$\theta_A = 0 \qquad \theta_B = \frac{PL^2}{2EI}$$

$$v = v_B - \frac{PL^2}{6EI}\left(3x_1 - \frac{x_1^3}{L^2}\right) \qquad v_B = \frac{PL^3}{3EI}$$

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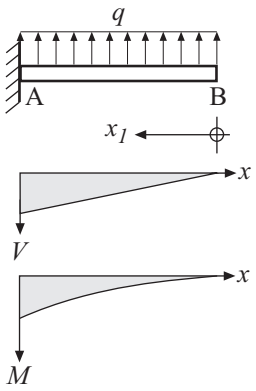
9




$$R_A = -qL$$

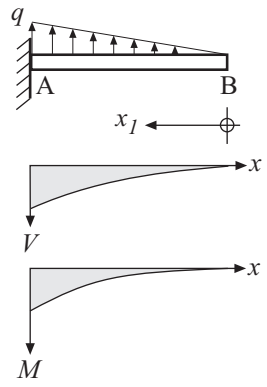
$$V = qx_1$$

$$M = \frac{qx_1^2}{2}$$

$$\theta_A = 0 \qquad \theta_B = \frac{qL^3}{6EI}$$

$$v = v_B - \frac{qL^3}{24EI}\left(4x_1 - \frac{x_1^4}{L^3}\right) \qquad v_B = \frac{qL^4}{8EI}$$

10




$$R_A = -\frac{qL}{2}$$

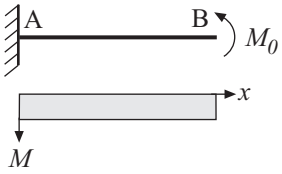
$$V = \frac{qx_1^2}{2L}$$

$$M = \frac{qx_1^3}{6L}$$

$$\theta_A = 0 \qquad \theta_B = \frac{qL^3}{24EI}$$

$$v = v_B - \frac{qL^3}{120EI}\left(5x_1 - \frac{x_1^5}{L^4}\right) \qquad v_B = \frac{qL^4}{30EI}$$

11




$$R_A = 0$$

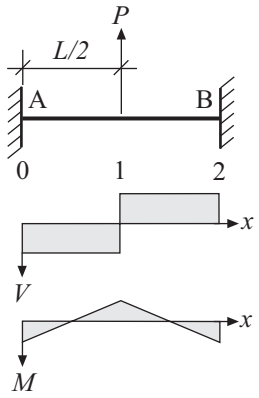
$$V = 0$$

$$M = M_0$$

$$\theta_A = 0 \qquad \theta_B = \frac{M_0 L}{EI}$$

$$v = \frac{M_0 x^2}{2EI} \qquad v_B = \frac{M_0 L^2}{2EI}$$

12




$$R_A = -\frac{P}{2} \qquad R_B = -\frac{P}{2}$$

$$V_{0-1} = \frac{P}{2} \qquad V_{1-2} = -\frac{P}{2}$$

$$M_A = \frac{PL}{8} \qquad M_1 = -\frac{PL}{8} \qquad M_B = \frac{PL}{8}$$

$$v_{0-1} = \frac{PL}{16EI}\left(x^2 - \frac{4x^3}{3L}\right) \qquad v_{max} = \frac{PL^3}{192EI}$$

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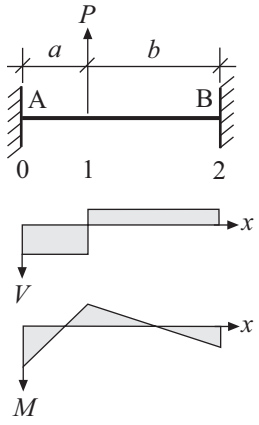
13




$$R_A = -\frac{Pb^2}{L^2}\left(1 + \frac{2a}{L}\right) \qquad R_B = -\frac{Pa^2}{L^2}\left(1 + \frac{2b}{L}\right)$$

$$V_{0-1} = \frac{Pb^2}{L^2}\left(1 + \frac{2a}{L}\right) \qquad V_{1-2} = -\frac{Pa^2}{L^2}\left(1 + \frac{2b}{L}\right)$$

$$M_A = \frac{Pab^2}{L^2} \qquad M_1 = -\frac{2Pa^2b^2}{L^3} \qquad M_B = \frac{Pba^2}{L^2}$$

$$v_{0-1} = \frac{Pa}{6EI}\left[\left(3 - 6\frac{a}{L} + 3\frac{a^2}{L^2}\right)x^2 - \left(1 - 3\frac{a^2}{L^2} + 2\frac{a^3}{L^3}\right)\frac{x^3}{a}\right]$$

$$v_1 = \frac{Pa^3b^3}{3EIL^3}$$

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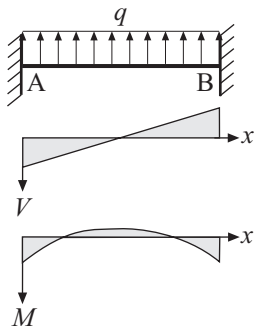
14




$$R_A = -\frac{qL}{2} \qquad R_B = -\frac{qL}{2}$$

$$V = q\left(\frac{L}{2} - x\right)$$

$$M = \frac{q}{2}\left(\frac{L^2}{6} - Lx + x^2\right)$$

$$M_A = M_B = \frac{qL^2}{12} \qquad M_{mitt} = -\frac{qL^2}{24}$$

$$v = \frac{qL^2}{24EI}\left(x^2 - \frac{2x^3}{L} + \frac{x^4}{L^2}\right) \qquad v_{max} = \frac{qL^4}{384EI}$$

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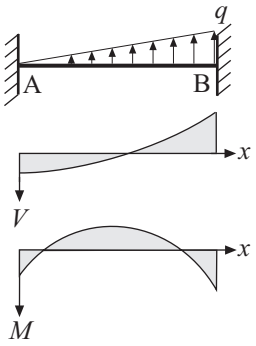
15




$$R_A = -\frac{3qL}{20} \qquad R_B = -\frac{7qL}{20}$$

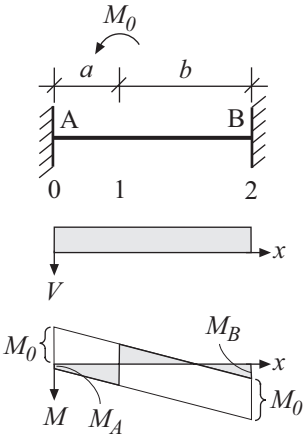
$$V = \frac{qL}{20}\left(3 - 10\frac{x^2}{L^2}\right)$$

$$M = \frac{qL^2}{60}\left(2 - 9\frac{x}{L} + 10\frac{x^3}{L^3}\right)$$

$$M_A = \frac{qL^2}{30} \qquad M_B = \frac{qL^2}{20}$$

$$M_{max} = M(0.548L) = -\frac{qL^2}{46.6}$$

16




$$R_A = -\frac{3M_0}{L}\left(\frac{a^2}{L^2} + \frac{b^2}{L^2} - 1\right) \qquad R_B = \frac{3M_0}{L}\left(\frac{a^2}{L^2} + \frac{b^2}{L^2} - 1\right)$$

$$V = \frac{3M_0}{L}\left(\frac{a^2}{L^2} + \frac{b^2}{L^2} - 1\right)$$

$$M_{0-1} = R_A x + M_A \qquad M_{1-2} = R_A x + M_A - M_0$$

$$M_A = M_0\left(\frac{a^2}{L^2} + \frac{2b^2}{L^2} - 1\right) \qquad M_B = -M_0\left(\frac{2a^2}{L^2} + \frac{b^2}{L^2} - 1\right)$$

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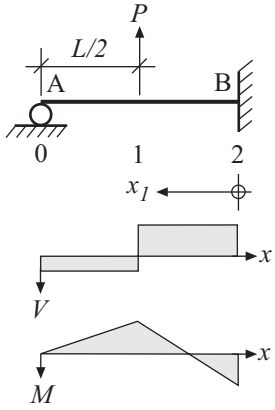


$$R_A = -\frac{5P}{16} \qquad R_B = -\frac{11P}{16}$$

$$V_{0-1} = \frac{5P}{16} \qquad V_{1-2} = -\frac{11P}{16}$$

$$M_1 = -\frac{5PL}{32} \qquad M_B = \frac{3PL}{16}$$

$$v_{0-1} = \frac{PL^2}{32EI}\left(x - \frac{5x^3}{3L^2}\right) \qquad v_{1-2} = \frac{PL}{32EI}\left(3x_1^2 - \frac{11x_1^3}{3L}\right)$$

$$v_1 = \frac{7PL^3}{768EI} \qquad v_{max} = v(0.447L) = \frac{PL^3}{107EI}$$

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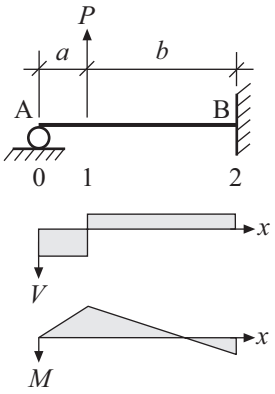


$$R_A = -\frac{Pb^2}{2L^2}\left(3-\frac{b}{L}\right) \qquad R_B = -\frac{Pa}{2L}\left(3-\frac{a^2}{L^2}\right)$$

$$V^{0-1} = \frac{Pb^2}{2L^2}\left(3-\frac{b}{L}\right) \qquad V^{1-2} = -\frac{Pa}{2L}\left(3-\frac{a^2}{L^2}\right)$$

$$M_B = \frac{Pa}{2}\left(1-\frac{a^2}{L^2}\right) \qquad M_1 = -\frac{Pb^2a}{2L^2}\left(2+\frac{a}{L}\right)$$

$$v_{0-1} = \frac{Pb^2}{12EI}\left[3\frac{ax}{L}-\left(2+\frac{a}{L}\right)\frac{x^3}{L^2}\right]$$

$$v_{1-2} = \frac{Pa}{12EI}\left[-2a^2+(3L+\frac{3a^2}{L})x-6x^2+\left(\frac{3}{L}-\frac{a^2}{L^3}\right)x^3\right]$$

$$v_1 = \frac{Pa^2b^3}{12EIL^2}\left(4-\frac{b}{L}\right)$$

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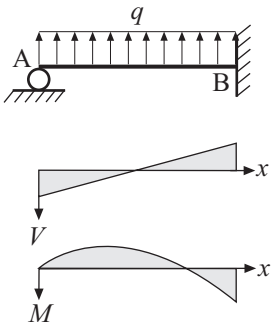
19




$$R_A = -\frac{3qL}{8} \qquad R_B = -\frac{5qL}{8}$$

$$V = q\left(\frac{3L}{8}-x\right)$$

$$M = -\frac{qL}{2}\left(\frac{3x}{4}-\frac{x^2}{L}\right)$$

$$M_B = \frac{qL^2}{8} \qquad M_{max,fält} = M(0.375L) = -\frac{9}{128}qL^2$$

$$v = \frac{qL^3}{48EI}\left(x-3\frac{x^3}{L^2}+2\frac{x^4}{L^3}\right)$$

$$v_{mitt} = \frac{qL^4}{192EI} \qquad v_{max} = v(0.42L) = \frac{qL^4}{185EI}$$

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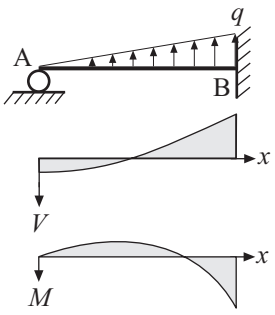
20




$$R_A = -\frac{qL}{10} \qquad R_B = -\frac{2qL}{5}$$

$$V = \frac{qL}{2}\left(\frac{1}{5}-\frac{x^2}{L^2}\right)$$

$$M = \frac{qL}{2}\left(-\frac{x}{5}+\frac{x^3}{3L^2}\right)$$

$$M_B = \frac{qL^2}{15} \qquad M_{max,fält} = M(0.447L) = 0.0298qL^2$$

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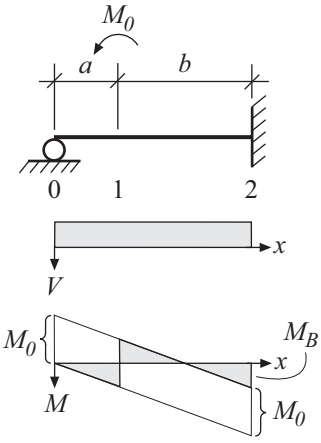
21




$$R_A = -\frac{M_0}{2L}\left(\frac{3a^2}{L^2} - 3\right) \qquad R_B = \frac{M_0}{2L}\left(\frac{3a^2}{L^2} - 3\right)$$

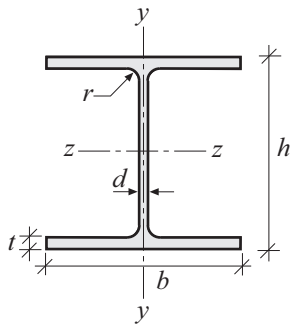
$$V = \frac{M_0}{2L}\left(\frac{3a^2}{L^2} - 3\right)$$

$$M_{0-1} = \frac{M_0 x}{2L}\left(3 - \frac{3a^2}{L^2}\right) \qquad M_{1-2} = \frac{M_0 x}{2L}\left(3 - \frac{3a^2}{L^2}\right) - M_0$$

$$M_B = \frac{M_0}{2}\left(1 - \frac{3a^2}{L^2}\right)$$

# Tvärsnittsdata HEA-profil

Beteckningar:




$A$ = Tvärsnittsarea
$A_w$ = Livarea
$F$ = Mantelarea per längdenhet
$g$ = Massa per längdenhet

| Profil | Tvärsnittsmått | | | | | Areor och massa | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $h$ | $b$ | $t$ | $d$ | $r$ | $A$ | $A_w$ | $F$ | $g$ |
| | mm | mm | mm | mm | mm | $mm^2$ | $mm^2$ | $m^2/m$ | kg/m |
| HEA 100 | 96 | 100 | 8.0 | 5.0 | 12 | 2124 | 400 | 0.561 | 16.7 |
| HEA 120 | 114 | 120 | 8.0 | 5.0 | 12 | 2534 | 490 | 0.677 | 19.9 |
| HEA 140 | 133 | 140 | 8.5 | 5.5 | 12 | 3142 | 638 | 0.794 | 24.7 |
| HEA 160 | 152 | 160 | 9.0 | 6.0 | 15 | 3877 | 804 | 0.906 | 30.4 |
| HEA 180 | 171 | 180 | 9.5 | 6.0 | 15 | 4525 | 912 | 1.02 | 35.5 |
| HEA 200 | 190 | 200 | 10.0 | 6.5 | 18 | 5383 | 1105 | 1.14 | 42.3 |
| HEA 220 | 210 | 220 | 11.0 | 7.0 | 18 | 6434 | 1316 | 1.26 | 50.5 |
| HEA 240 | 230 | 240 | 12.0 | 7.5 | 21 | 7684 | 1545 | 1.37 | 60.3 |
| HEA 260 | 250 | 260 | 12.5 | 7.5 | 24 | 8682 | 1688 | 1.48 | 68.2 |
| HEA 280 | 270 | 280 | 13.0 | 8.0 | 24 | 9726 | 1952 | 1.60 | 76.4 |
| HEA 300 | 290 | 300 | 14.0 | 8.5 | 27 | 11250 | 2227 | 1.72 | 88.3 |
| HEA 320 | 310 | 300 | 15.5 | 9.0 | 27 | 12440 | 2511 | 1.76 | 97.6 |
| HEA 340 | 330 | 300 | 16.5 | 9.5 | 27 | 13350 | 2822 | 1.79 | 105 |
| HEA 360 | 350 | 300 | 17.5 | 10.0 | 27 | 14280 | 3150 | 1.83 | 112 |
| HEA 400 | 390 | 300 | 19.0 | 11.0 | 27 | 15900 | 3872 | 1.91 | 125 |
| HEA 450 | 440 | 300 | 21.0 | 11.5 | 27 | 17800 | 4577 | 2.01 | 140 |
| HEA 500 | 490 | 300 | 23.0 | 12.0 | 27 | 19750 | 5328 | 2.11 | 155 |
| HEA 550 | 540 | 300 | 24.0 | 12.5 | 27 | 21180 | 6150 | 2.21 | 166 |
| HEA 600 | 590 | 300 | 25.0 | 13.0 | 27 | 22650 | 7020 | 2.31 | 178 |
| HEA 650 | 640 | 300 | 26.0 | 13.5 | 27 | 24160 | 7938 | 2.41 | 190 |
| HEA 700 | 690 | 300 | 27.0 | 14.5 | 27 | 26050 | 9222 | 2.50 | 204 |
| HEA 800 | 790 | 300 | 28.0 | 15.0 | 30 | 28580 | 11010 | 2.70 | 224 |
| HEA 900 | 890 | 300 | 30.0 | 16.0 | 30 | 32050 | 13280 | 2.90 | 252 |
| HEA 1000 | 990 | 300 | 31.0 | 16.5 | 30 | 34680 | 15310 | 3.10 | 272 |

$I_z$, $I_y$ = Yttröghetsmoment
$W_{el,z}$, $W_{el,y}$ = Elastiskt böjmotstånd
$W_{pl,z}$, $W_{pl,y}$ = Plastiskt böjmotstånd
$i_z$, $i_y$ = Tröghetsradie

| Profil | Böjning kring $z$-axeln | | | | Böjning kring $y$-axeln | | | |
|---|---|---|---|---|---|---|---|---|
| | $I_z$ | $W_{el,z}$ | $W_{pl,z}$ | $i_z$ | $I_y$ | $W_{el,y}$ | $W_{pl,y}$ | $i_y$ |
| | $\cdot 10^6$ mm$^4$ | $\cdot 10^3$ mm$^3$ | $\cdot 10^3$ mm$^3$ | mm | $\cdot 10^6$ mm$^4$ | $\cdot 10^3$ mm$^3$ | $\cdot 10^3$ mm$^3$ | mm |
| HEA 100 | 3.492 | 72.8 | 83.0 | 40.6 | 1.338 | 26.8 | 41.1 | 25.1 |
| HEA 120 | 6.062 | 106 | 119 | 48.9 | 2.309 | 38.5 | 58.9 | 30.2 |
| HEA 140 | 10.33 | 155 | 173 | 57.3 | 3.893 | 55.6 | 84.8 | 35.2 |
| HEA 160 | 16.73 | 220 | 245 | 65.7 | 6.156 | 76.9 | 118 | 39.8 |
| HEA 180 | 25.10 | 294 | 325 | 74.5 | 9.246 | 103 | 156 | 45.2 |
| HEA 200 | 36.92 | 389 | 429 | 82.8 | 13.36 | 134 | 204 | 49.8 |
| HEA 220 | 54.10 | 515 | 568 | 91.7 | 19.55 | 178 | 271 | 55.1 |
| HEA 240 | 77.63 | 675 | 745 | 101 | 27.69 | 231 | 352 | 60.0 |
| HEA 260 | 104.5 | 836 | 920 | 110 | 36.68 | 282 | 430 | 65.0 |
| HEA 280 | 136.7 | 1010 | 1110 | 119 | 47.63 | 340 | 518 | 70.0 |
| HEA 300 | 182.6 | 1260 | 1380 | 127 | 63.10 | 421 | 641 | 74.9 |
| HEA 320 | 229.3 | 1480 | 1630 | 136 | 69.85 | 466 | 710 | 74.9 |
| HEA 340 | 276.9 | 1680 | 1850 | 144 | 74.36 | 496 | 756 | 74.6 |
| HEA 360 | 330.9 | 1890 | 2090 | 152 | 78.87 | 526 | 802 | 74.3 |
| HEA 400 | 450.7 | 2310 | 2560 | 168 | 85.64 | 571 | 873 | 73.4 |
| HEA 450 | 637.0 | 2900 | 3220 | 189 | 94.65 | 631 | 966 | 72.9 |
| HEA 500 | 869.6 | 3550 | 3950 | 210 | 103.7 | 691 | 1060 | 72.4 |
| HEA 550 | 1119 | 4150 | 4620 | 230 | 108.2 | 721 | 1110 | 71.5 |
| HEA 600 | 1412 | 4790 | 5350 | 250 | 112.7 | 751 | 1160 | 70.5 |
| HEA 650 | 1752 | 5470 | 6140 | 269 | 117.2 | 782 | 1200 | 69.7 |
| HEA 700 | 2153 | 6240 | 7030 | 288 | 121.8 | 812 | 1260 | 68.4 |
| HEA 800 | 3034 | 7680 | 8700 | 326 | 126.4 | 843 | 1310 | 66.5 |
| HEA 900 | 4221 | 9480 | 10800 | 363 | 135.5 | 903 | 1410 | 65.0 |
| HEA 1000 | 5538 | 11200 | 12800 | 400 | 140.0 | 934 | 1470 | 63.5 |