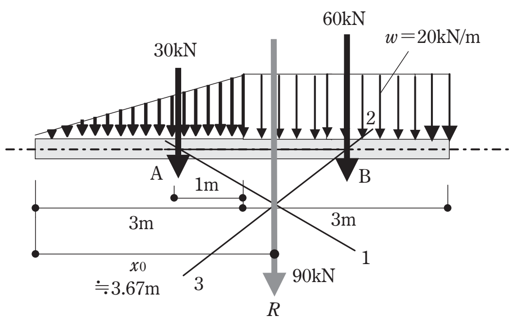
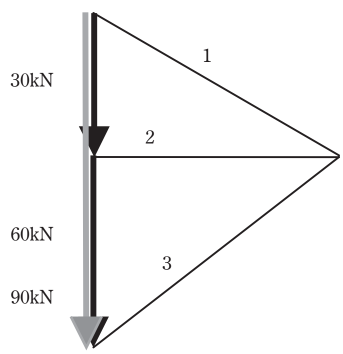
付録

わかる建築学4　建築構造力学
15章 演習問題 解答

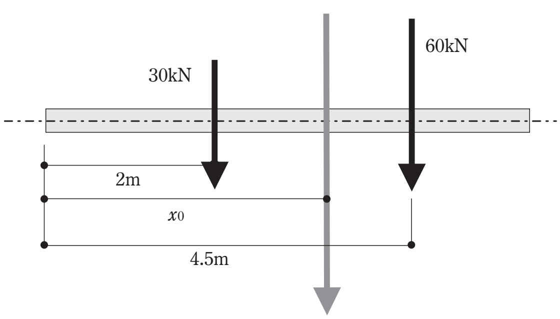
演習問題 1.1

<連力図>





<バリニオンの定理>

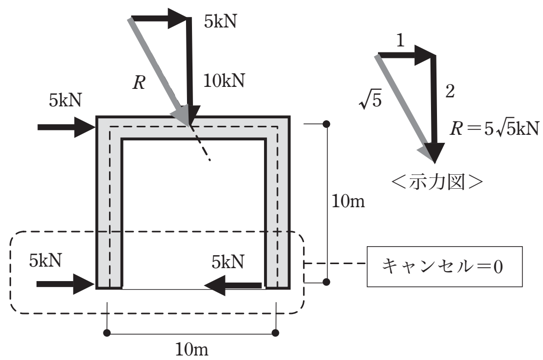


$30 \times 2 + 60 \times 4.5 = R \times x_0$

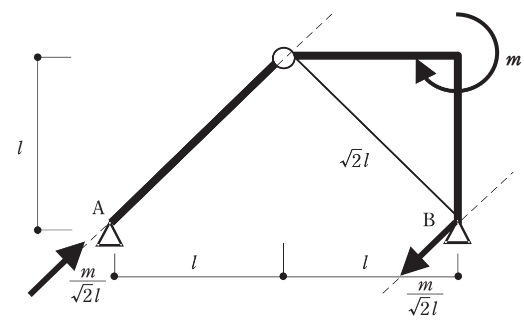
$R = 90\text{kN}$

$$\therefore x_0 = \frac{(60+270)}{90} = \frac{33}{9} \fallingdotseq 3.67\text{m}$$

演習問題 1.2



演習問題 1.3

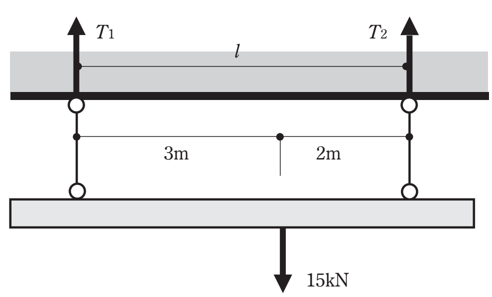


A・B点に作用する力$=\dfrac{m}{\sqrt{2}\,l}$

作用方向：図の通り

演習問題 1.4

(a)



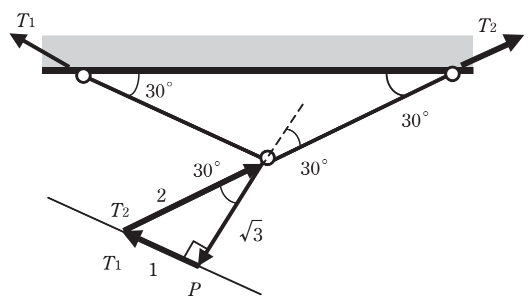
<バリニオンの定理>

$$\frac{T_1}{T_2}=\frac{2}{3},\quad T_2=P-T_1$$

$$T_1=\frac{2}{3}\cdot(P-T_1)\quad \therefore T_1=\frac{2}{5}P=6\text{kN}$$

$$T_2=15-T_1=9\text{kN}$$

(b)

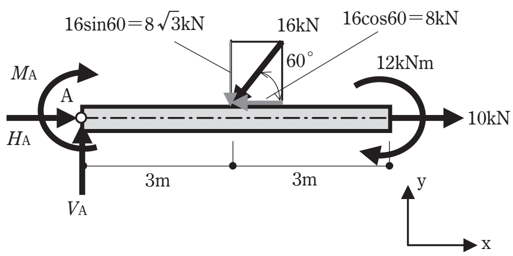


図の示力図より，

$$T_1=\frac{P}{\sqrt{3}}$$

$$T_2=\frac{2P}{\sqrt{3}}$$

演習問題 1.5



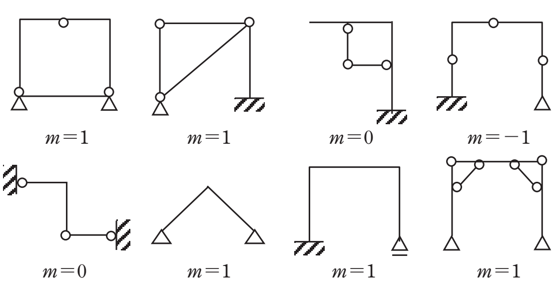
$$\Sigma\ X=0\ ;H_A+10-8=0\quad \therefore H_A=-\ 2\text{kN}$$

$$\Sigma\ Y=0\ ;V_A-8\sqrt{3}=0\quad \therefore V_A=8\sqrt{3}\,\text{kN}$$

$$\Sigma_A M=0\ ;\ M_A+12+3\times 8\sqrt{3}=0$$

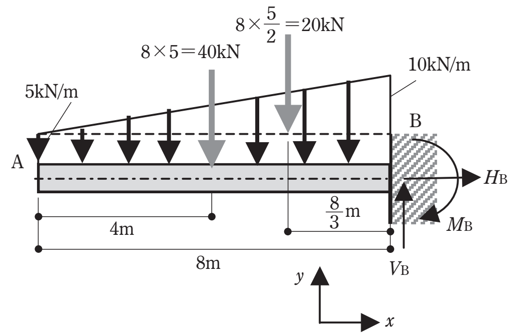
$$\therefore M_A=-(12+24\sqrt{3})\text{kN}$$

演習問題 2.1



演習問題 2.2

(a)



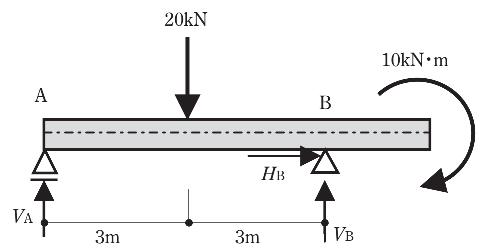
$$\Sigma\ X=0\ ;H_B=0\quad \therefore H_B=0$$

$$\Sigma\ Y=0\ ;V_B-40-20=0\quad \therefore V_B=60\text{kN}$$

$$\Sigma_B M=0\ ;M_B-40\times 4-20\times\frac{8}{3}=0$$

$$\therefore M_B=\frac{640}{3}\text{kN}$$

(b)



$$\Sigma\ X=0\ ;H_B=0\quad \therefore H_B=0$$

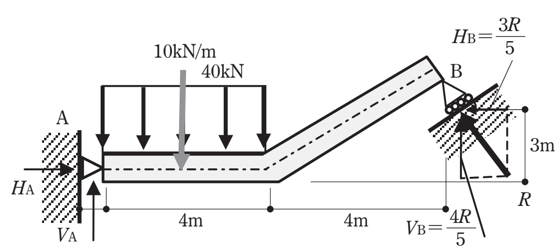
$$\Sigma\ Y=0\ ;V_A+V_B-20=0\quad \therefore V_A+V_B=20\text{kN}$$

$$\Sigma_B M=0\ ;V_A\times 6-20\times 3+10=0$$

$$\therefore V_A=\frac{50}{6}=\frac{25}{3}\text{kN}$$

$$V_B=20-\frac{25}{3}=\frac{35}{3}\text{kN}$$

(c)



$$\Sigma\ X=0\ ;H_A+H_B=H_A-\frac{3R}{5}=0,\quad H_A=\frac{3R}{5}$$

$$\Sigma\ Y=0\ ;\ V_A+V_B-40=0,\ \ V_A=40\text{kN}-\frac{4R}{5}$$

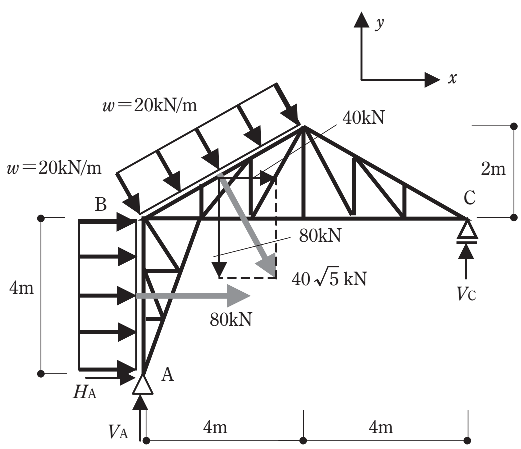
$$\Sigma_A M=0\ ;\ -3\times\frac{3R}{5}-8\times\frac{4R}{5}+40\times2=0$$

$$R=\frac{400}{41}\text{kN}$$

$$\therefore H_A=\frac{3R}{5}=\frac{240}{41}\text{kN}$$

$$V_A=40-\frac{4R}{5}=40-\frac{320}{41}\text{kN}=\frac{1320}{41}\text{kN}$$

演習問題 2.3



$\Sigma\ X=0\ ;\ H_A+80+40=0\quad \therefore H_A-120\text{kN}$

$\Sigma\ Y=0\ ;\ V_A+V_C-80=0,\ \ V_A+V_C=80\text{kN}$

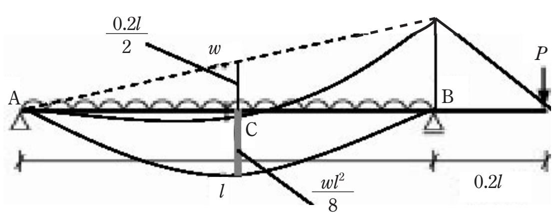
$\Sigma_A M=0\ ;\ -V_C\times8+80\times2+80\times2+40\times5$

$=0$

$\therefore V_C=65\text{kN}$

$V_A=15\text{kN}$

演習問題 4.1

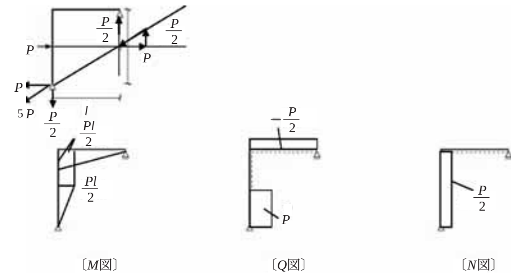


$0.1P=wl/8$

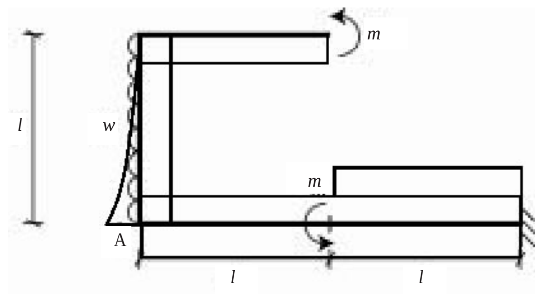
$\therefore 0.8P=wl$

$P:wl=1:0.8$

演習問題 5.1



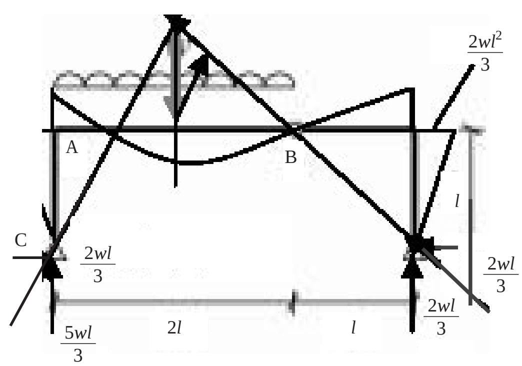
演習問題 5.2



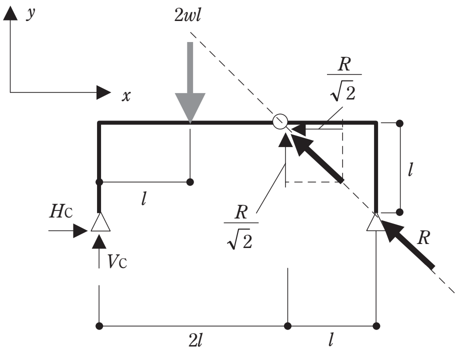
$$-\frac{wl^2}{2}+m=0$$

$$\therefore m=\frac{wl^2}{2}$$

演習問題 5.3



＜反力＞



$$\Sigma X=0\;;\;H_c-\frac{R}{\sqrt{2}}=0\quad \therefore H_c=\frac{R}{\sqrt{2}}$$

$$\Sigma Y=0\;;\;V_c-2wl+\frac{R}{\sqrt{2}}=0,\ \ V_c=2wl-\frac{R}{\sqrt{2}}$$

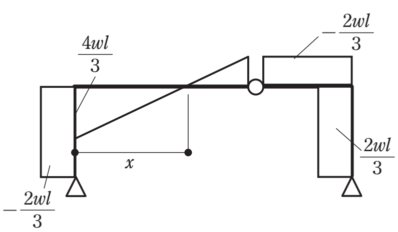
$$\Sigma_C M=0\;;\;2wl\times l-2l\times\frac{R}{\sqrt{2}}-l\times\frac{R}{\sqrt{2}}=0$$

$$R=\frac{2wl\sqrt{2}}{3}$$

$$\therefore H_c=\frac{2wl}{3}$$

$$V_c=\frac{4wl}{3}$$

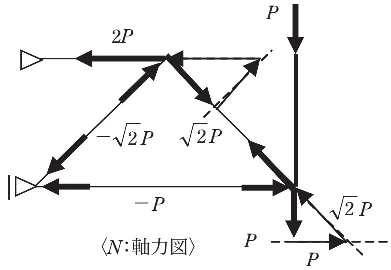
＜せん断力がゼロとなる位置 x ＞



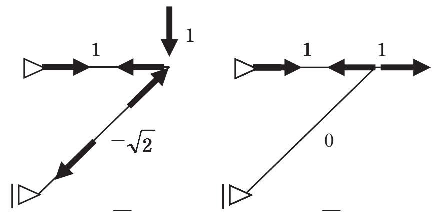
$$2l:x=\frac{6wl}{3}:\frac{2wl}{3}$$

$$\therefore x=\frac{2l}{3}$$

演習問題 6.1



〈N：軸力図〉



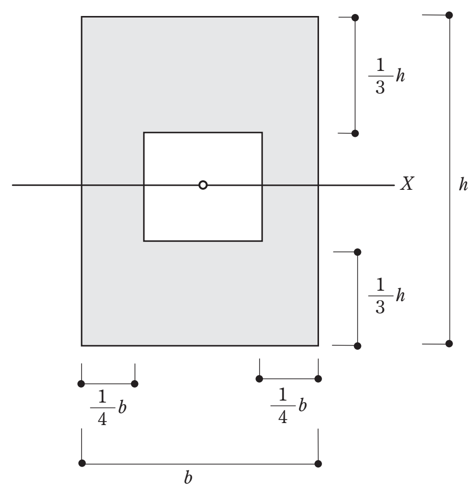
〈$\overline{N}_1$〉 〈$\overline{N}_2$〉

	長さ	剛性	N	$\overline{N}_1$	$\overline{N}_2$	$\int\frac{N_1N}{EA}dx$	$\int\frac{N_2N}{EA}dx$
AC	a	EA	2P	1	1	$\frac{2Pa}{EA}$	$\frac{2Pa}{EA}$
AB	$\sqrt{2}a$	EA	$-\sqrt{2}P$	$-\sqrt{2}$	0	$\sqrt{2}\frac{Pa}{EA}$	0
					δ	$(2+\sqrt{2})\frac{Pa}{EA}$	$\frac{2Pa}{EA}$

鉛直変位：$\delta_v=(2+\sqrt{2})\dfrac{Pa}{EA}$

水平変位：$\delta_H=\dfrac{2Pa}{EA}$

演習問題 7.1

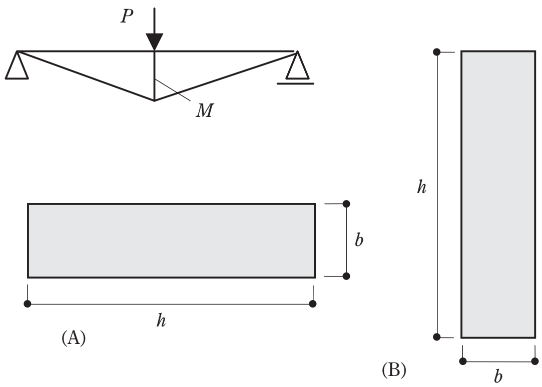


$$I_1=\frac{bh^3}{12}$$

$$I_2=\frac{b}{2}\cdot\left(\frac{h}{3}\right)^3=\frac{2}{9}\cdot\frac{bh^3}{12}$$

$$I=I_1-I_2=\left(1-\frac{2}{9}\right)\cdot\frac{bh^3}{12}=\frac{7}{9}\cdot\frac{bh^3}{12}$$

演習問題 7.2



$$I_A=\frac{hb^3}{12},\quad Z_A=\frac{hb^2}{6}$$

$$I_B=\frac{bh^3}{12},\quad Z_B=\frac{bh^2}{6}$$

$$\sigma_b=\frac{M}{Z}$$

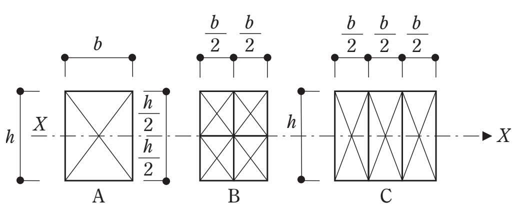
$$M_A=\frac{Pl}{4},\quad M_B=\frac{15Pl}{4}$$

$$\sigma_b=\frac{Pl}{\frac{hb^2}{6}}=\frac{15Pl}{\frac{bh^2}{6}}$$

$$\frac{1}{hb^2}=\frac{15}{bh^2}$$

$\therefore h：b ＝ 15：1$

演習問題 7.3



曲げ剛性：曲げ強さは$\sigma=\dfrac{M}{Z}$で求められるので，断面係数$Z=\dfrac{bh^2}{6}$が小さいほど曲げに対し強いことを意味する．したがって，Zが大きいほど曲げ剛性が大となる．

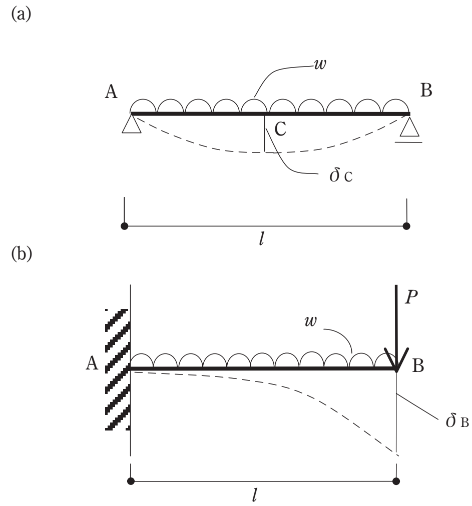
$$Z=\frac{bh^2}{6}$$

$$Z_B=4\times\frac{\frac{b}{2}\cdot\left(\frac{h}{2}\right)^2}{6}=0.5\times\frac{bh^2}{6}$$

$$Z_C=3\times\frac{\frac{b}{2}\cdot h^2}{6}=1.5\times\frac{bh^2}{6}$$

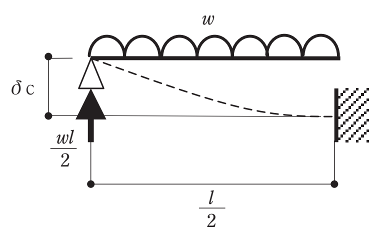
$\therefore$ A：B：C ＝ 1：0.5：1.5

演習問題 8.1



$$\delta_B(P)=\frac{Pl^3}{3EI}\qquad \delta_B(w)=\frac{wl^4}{8EI}$$

$$\delta_B=\delta_B(P)+\delta_B(w)=\frac{Pl^3}{3EI}+\frac{wl^4}{8EI}=\frac{l^3(8P+3w)}{24EI}$$



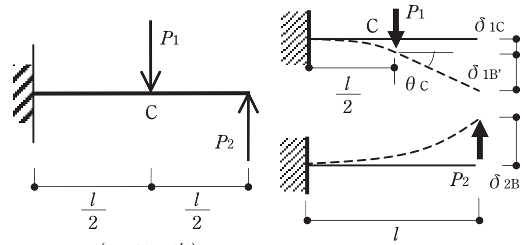
$$\delta_C(w)=\frac{1}{16}\cdot\frac{wl^4}{8EI}=\frac{wl^4}{128EI}$$

$$\delta_C\left(P=\frac{wl}{2}\right)=\frac{wl}{2}\cdot\frac{1}{8}\cdot\frac{l^3}{3EI}=\frac{wl^4}{48EI}$$

$$\delta_C=\delta_C\left(P=\frac{wl}{2}\right)-\delta_C(w)=\frac{wl^4}{48EI}-\frac{wl^4}{128EI}=\frac{5wl^4}{384EI}$$

$$\frac{\delta_C}{\delta_B}=\frac{\frac{5wl^4}{384EI}}{\frac{l^3(8P+3w)}{24EI}}=\frac{\frac{5}{16}wl}{8P+3w}$$

演習問題 8.2



$(E, I$は一定$)$

$$\delta_{2B} = \frac{P_2 l^3}{3EI}$$

$$\theta_C = \frac{P_1 \cdot \frac{1}{4} \cdot l^2}{2EI}$$

$$\delta_{1B'} = \theta_C \times \frac{l}{2} = \frac{P_1 \cdot \frac{1}{8} l^3}{2EI}$$

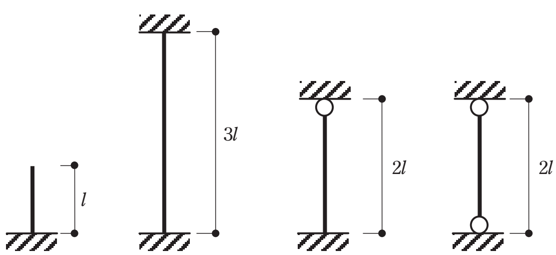
$$\delta_{1C} = \frac{P_1 \cdot \frac{1}{8} l^3}{3EI}$$

$$\delta_{1B} = \delta_{1C} + \delta_{1B'} = \frac{P_1 \cdot \frac{1}{8} l^3}{3EI} + \frac{P_1 \cdot \frac{1}{8} l^2}{2EI} = \frac{5P_1 l^3}{48EI}$$

$$\frac{\delta_{2B}}{\delta_{1B}} = \frac{\frac{P_2 l^3}{3EI}}{\frac{5P_1 l^3}{48EI}} = \frac{16P_2}{5P_1} = 1$$

$P_1 : P_2 = 16 : 5$

演習問題 8.3



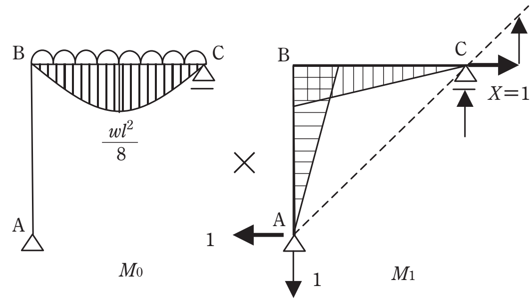
A	B	C	D
$l_k = 2l$	$l_k = 0.5 \times 3l = 1.5l$	$l_k = 0.7 \times 2l = 1.4l$	$l_k = 1 \times 2l = 2l$

$\therefore$ A = D > B > C

演習問題 9.1

1）左向き

2）理由



$\delta_{10} + \delta_{11} X = 0$　・(C 点の水平変位が右側に生じると仮定して X を作用させた)

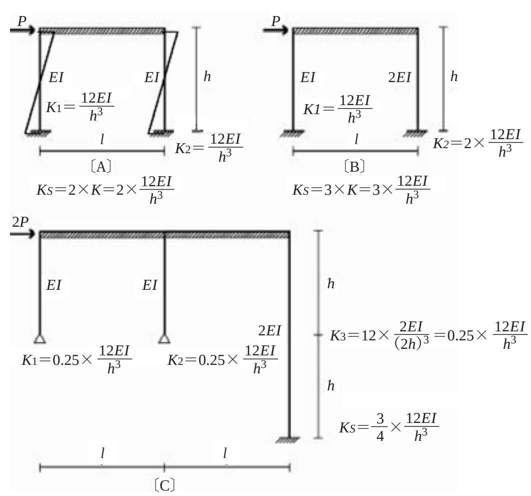
$$X = -\frac{\delta_{10}}{\delta_{11}}$$

(1)　$\delta_{10} = \int M_1 M_0 \beta(\mathrm{B-C}) =$ 正

(2)　$\delta_{11} = \int M_1 M_1 \beta(\mathrm{B-C}) =$ 正

$\therefore X =$ 負となるので，$X = 1$ と仮定した方向と逆に反力が生じる．

演習問題 10.1



$P = K_S \cdot \delta$ より

$$\delta_A = \frac{P}{K_S} = \frac{P}{2} \times \frac{12EI}{h^3} = \frac{P}{2} \times \frac{1}{\frac{12EI}{h^3}}$$

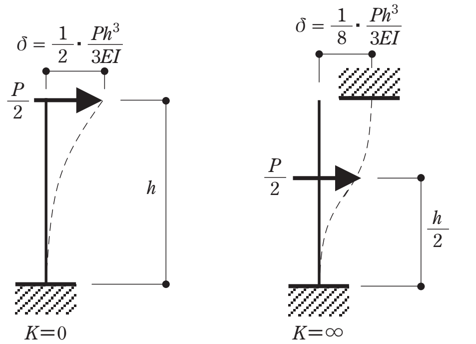
$$\delta_B = \frac{P}{3} \times \frac{12EI}{h^3} = \frac{P}{3} \times \frac{1}{\frac{12EI}{h^3}}$$

$$\delta_C = \frac{2P}{\frac{3}{4}} \times \frac{12EI}{h^3} = \frac{8P}{3} \times \frac{1}{\frac{12EI}{h^3}}$$

$$\therefore \delta_A : \delta_B : \delta_C = \frac{1}{2} : \frac{1}{3} : \frac{8}{3} = 1 : \frac{2}{3} : \frac{16}{3}$$

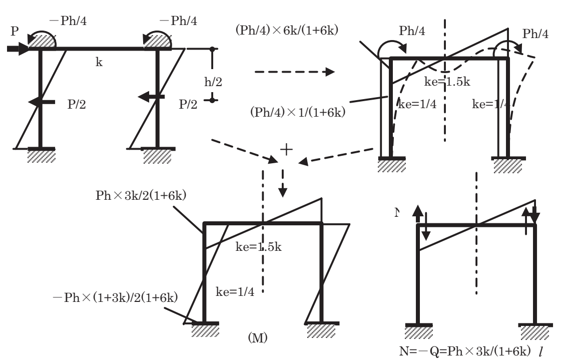
演習問題 11.1

(1) 柱頭の変位：小さくなる



(2) 柱頭部の曲げモーメント：大きくなる；

$$\frac{Ph \cdot 3k}{l(1+6k)} = \frac{Ph \cdot 3}{2\left(\dfrac{1}{k}+6\right)}$$

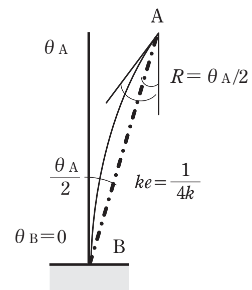


(3) 柱の軸力：大きくなる：$N = -Q = Ph \times \dfrac{3k}{(1+6k)l}$

柱の有効剛比（k →大，N →小）

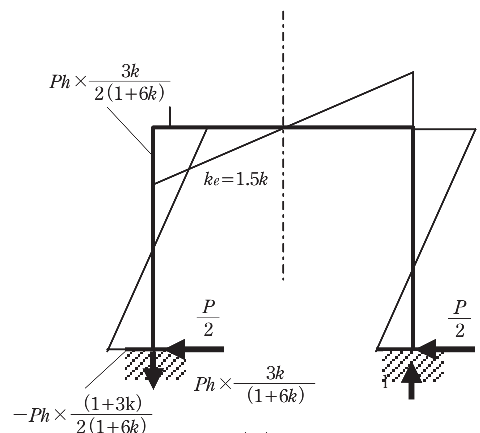
〈補足〉水平移動する柱の剛比 k_e

$$k_e = k \cdot \frac{2\theta_A + \theta_B - 3R}{2\theta_A} = \frac{1}{4} \cdot k$$

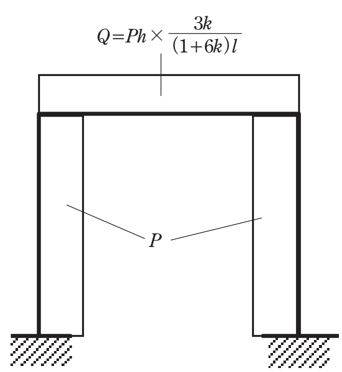


せん断力が生じない場合

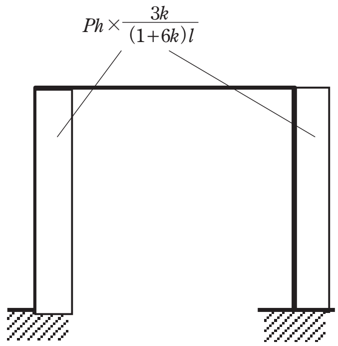
演習問題 11.2



(M)



(Q)

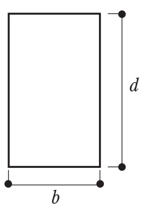


(N)

演習問題 12.1

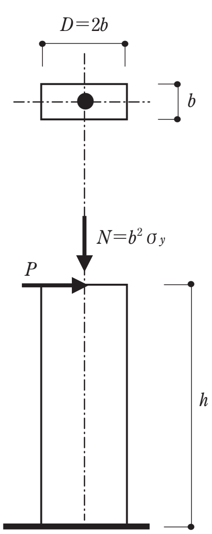
1. 2.4 kN
2. 800 N
3. 245mm 以上であれば条件を満足する．

演習問題 13.1



$M_p=0.25\cdot b\cdot d^2\cdot\sigma_y$

演習問題 13.2



$P_u=\dfrac{0.75b^3}{h}\cdot\sigma_y$

演習問題 13.3

$P_C=12\text{kN}$

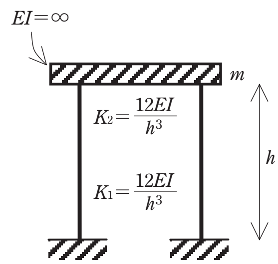
演習問題 13.4

$P_u=100\text{kN}$

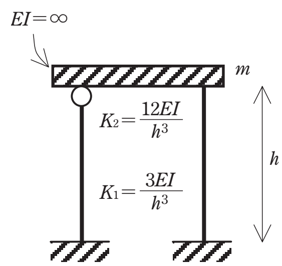
演習問題 13.5

$Q_{u1}=600\text{kN}$

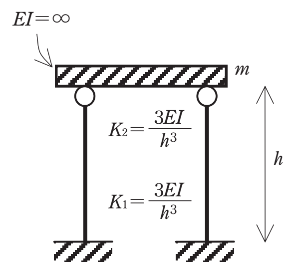
演習問題 14.1



A



B



C

$K=K_1+K_2$

$$K_{SA}=\frac{12EI}{h^3}+\frac{12EI}{h^3}=\frac{24EI}{h^3}$$

$$K_{SB}=\frac{3EI}{h^3}+\frac{12EI}{h^3}=\frac{15EI}{h^3}$$

$$K_{SC}=\frac{3EI}{h^3}+\frac{3EI}{h^3}=\frac{6EI}{h^3}$$

$$T_A=2\pi\sqrt{\frac{m}{K_{SA}}}=2\pi\sqrt{\frac{mh^3}{24EI}}$$

$$T_B=2\pi\sqrt{\frac{m}{K_{SB}}}=2\pi\sqrt{\frac{mh^3}{15EI}}$$

$$T_C=2\pi\sqrt{\frac{m}{K_{SC}}}=2\pi\sqrt{\frac{mh^3}{6EI}}$$

$\therefore T_C>T_B>T_A$