Example F10: Effect of lateral bracing.

For the following beam, compute the maximum factored load, P_f, for the following three cases.

- Case a): compression flange fully braced laterally.
- Case b): compression flange braced only at the supports.
- Case c): compression flange braced at the supports and at the point of application of the load.

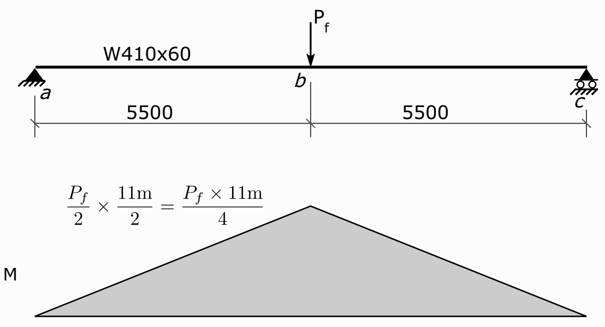
Use ASTM A992 steel.

In [1]:

```
from Designer import SST, figure, show
from math import sqrt
```

In [2]:

```
figure("eg-F10.svg")
```



In [3]:

```
phi = 0.9
Fy = 345.
Dsg,d,b,t,w,Ix,Zx,Iy,J,Cw = SST.section('W410x60','Dsg,D,B,T,W,Ix,Zx,Iy,J,Cw')
h = d - 2*t
show('Dsg,d,b,t,w,h,*10**6,Ix,Iy,*10**3,Zx,J,*10**9,Cw,*,Fy')
```

```
Dsg = W410x60
d   = 407
b   = 178
t   = 12.8
w   = 7.7
h   = 381.4
Ix  = 216 * 10**6
Iy  = 12 * 10**6
Zx  = 1190 * 10**3
J   = 328 * 10**3
Cw  = 468 * 10**9
Fy  = 345
```

Check Local Buckling

In [4]:

```
show('bel/t = b/(2*t), 170/sqrt(Fy)')  # check flange against class 2 limits
```

```
bel/t        = 6.953
170/sqrt(Fy) = 9.152
```

In [5]:

```
show('h/w, 1700/sqrt(Fy)')  # check web against class 2 limits
```

```
h/w           = 49.53
1700/sqrt(Fy) = 91.52
```

Therefore section is class 2 (or perhaps class 1 - that doesn't matter)

Case a) fully braced

From § 13.5: $M_r = \phi M_p = \phi F_y Z_x$

In [6]:

```
Mr = phi*Fy*Zx * 1E-6   # * 1E-6 converts from N-mm to kN-m
Pf = Mr * 4. / 11.
show('Mr,Pf')
```

```
Mr = 369.5
Pf = 134.4
```

For case a), maximum $P_f = 134$ kN.

Case b) lateral bracing at supports only

The last paragraph of § 13.6 a) says the following:

> _For unbraced beam segments loaded above the shear centre between brace points, where the method of load delivery to the member provides neither lateral nor rotational restraint to the member, the associated destabilizing effect shall be taken into account using a rational method. For loads applied at the level of the top flange, in lieu of a more accurate analysis, M_u may be determined using $\omega_2 = 1.0$ and using an effective length, for pin-ended beams, of $1.2L$ and for all other cases, $1.4L$._

It seems reasonable that the above should apply to this case, so use an unbraced length of compression flange equal to 1.2 times the distance between supports.

S16-16 § 13.6 a) ii) gives the following for calculating M_u:

$$M_u = \frac{\omega_2 \pi}{L}\sqrt{EI_yGJ + \left(\frac{\pi E}{L}\right)^2 I_y C_w}$$

Often, we re-write that to make it a little simpler to apply manually:

$$A = EI_yGJ$$

$$B = \left(\frac{\pi E}{L}\right)^2 I_y C_w$$

$$M_u = \frac{\omega_2 \pi}{L}\sqrt{A+B}$$

In [7]:

```
pi = 3.14159
E = 200000.
G = 77000.
```

In [8]:

```
omega2 = 1.0
L = 1.2*11000
A = E*Iy*G*J
B = Iy*Cw*(pi*E/L)**2
Mu = (omega2*pi/L)*sqrt(A+B) * 1E-6   # for result in kN-m

Mp = Fy*Zx * 1E-6

show('omega2,L,A,B,Mu,Mp,0.67*Mp')
```

```
omega2  = 1
L       = 13200
A       = 6.061e+22
B       = 1.272e+22
Mu      = 64.45
Mp      = 410.6
0.67*Mp = 275.1
```

As $M_u \leq 0.67M_p$, $M_r = \phi M_u$:

In [9]:

```
Mr = phi*Mu
Pf = Mr * 4. / 11.
show('Mr,Pf')
```

```
Mr = 58.01
Pf = 21.09
```

For case b), maximum $P_f = 21.1$ kN.

Case c) Lateral bracing at ends and at centre

From Figure 2-17 in the commentary, $\omega_2 = 1.75$.

Or, the long way from § 13.6 a) ii):

$\kappa = 0$

(because in the beam segments between the brace points, *ab* and *bc*, the smallest end moment is 0, and $0/anything$ is zero, as long as $anything \neq 0$).

And then:

$\omega_2 = 1.75 + 1.05\kappa + 0.3\kappa^2 = 1.75$

In [10]:

```
omega2 = 1.75
L = 5500.
A = E*Iy*G*J
B = Iy*Cw*(pi*E/L)**2
Mu = (omega2*pi/L)*sqrt(A+B) * 1E-6   # for result in kN-m

Mp = Fy*Zx * 1E-6

show('omega2,L,A,B,Mu,Mp,0.67*Mp')
```

```
omega2  = 1.75
L       = 5500
A       = 6.061e+22
B       = 7.329e+22
Mu      = 365.8
Mp      = 410.6
0.67*Mp = 275.1
```

In this case, $M_u > 0.67M_p$ and thus M_r is given by § 13.6 a) i):

In [11]:

```
Mr = min( 1.15*phi*Mp*(1 - 0.28*Mp/Mu), phi*Mp )
Pf = Mr * 4. / 11.
show('Mr,Pf')
```

```
Mr = 291.4
Pf = 106
```

For case c) maximum $P_f = 106$ kN.

Summary

Case	P_f max.
a) fully braced	134 kN
b) braced at ends only	21.1 kN
c) braced at ends and center	106 kN

In [ ]:

```
```