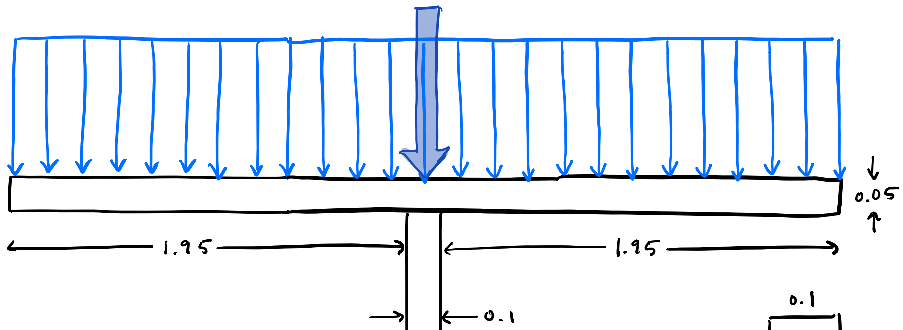
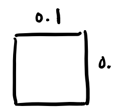
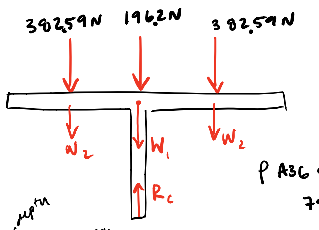
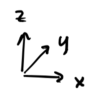








ρ A36 steel = 7800 kg/m³

depth, thickness

$(0.1m)(2m)(1000\ kg/m^3) = 200\ kg/m$

distributed over column $= \frac{200\ kg}{m}(9.81\ \frac{m}{s^2})$

$= 1962.0\ N/m$

$\rightarrow 1962.0\ N/m\ (0.1m) = 196.2\ N$

distributed over rest of gate:

$= 1962.0\ \frac{N}{m}(1.95m) = 3825.9\ N$

depth, thickness

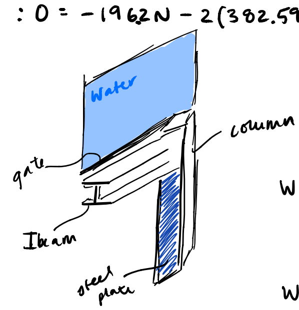
W_{gate} over column: $(0.1m)(0.05m)(7800\ \frac{kg}{m^3})(9.81\ \frac{m}{s^2})$

$= 382.59\ N/m$

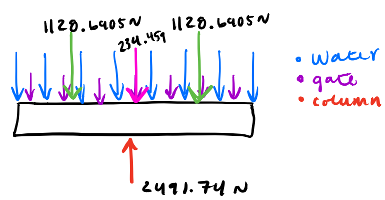
$\Rightarrow 382.59\ N/m\ (0.1m) = 38.259\ N$

W_{gate} rest: $382.59\ N/m(1.95m) = 746.0505\ N$

$\uparrow^{+} \Sigma F_z : 0 = -196.2N - 2(382.59N) - 38.259N + R_c - (2)(746.0505N) \Rightarrow R_c = 2491.74$



Each I beam:



W_{gate} over I beam:

$(382.59\ N/m)(1.95m)$

$= 746.0505$

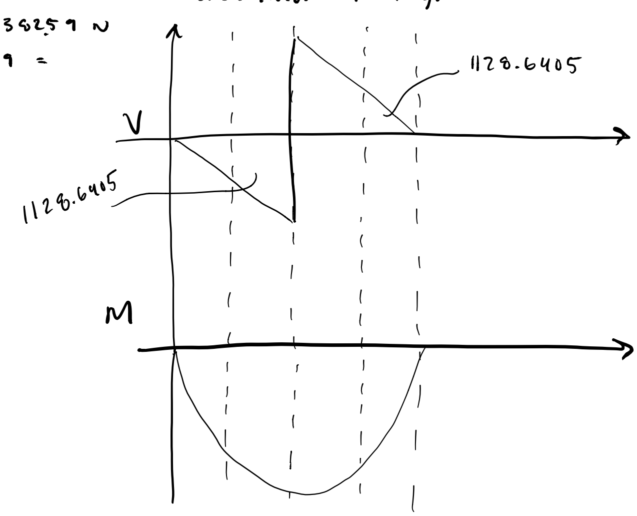
W_{H_2O} over I beam:

$(1962\ N/m)(1.95m) = 3825.9\ N$

$746.0505 + 382.59 =$

$1128.6405\ N$

• shear/moment diagram



$V = 2257.281$ = worst shear

$M_{max} =$

Euler's Buckling Eq: $P_{cr} = \dfrac{\pi^2 EI}{(KL)^2}$

fixed-fixed, $K = 0.5$
pinned-fixed, $K = 0.7$

$E = 200$ GPa
$\sigma_y = 250$ MPa

$$I_{yy} = \frac{1}{12}(0.1m)(0.1m)^3 = 8.333(10^{-6})m^4$$

Q: fixed-fixed or pin-fixed?

$$P_{cr} = \frac{\pi^2 (200(10^9)\frac{N}{m^2})(8.333(10^{-6})m^4)}{(0.5(3m))^2} = \underline{7310.5 \text{ kN}}$$

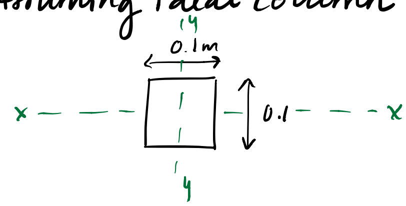
Q: safety-factor?

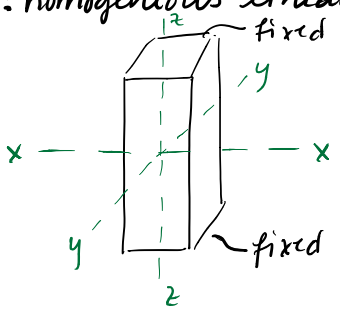
$$\sigma_{cr} = \frac{\pi^2 E}{(KL/r)^2} = \frac{\pi^2 (200 \times 10^9 \frac{N}{m^2})}{(0.5)^2 (3m)^2 (1/8.333(10^{-4})m^2)} = \frac{\pi^2 (200)(10^5)\frac{N}{m^2}(8.333)}{(0.5)^2 (3)^2} = \underline{731053 \text{ kPa}}$$

$$r = \sqrt{I/A} = \sqrt{8.333(10^{-6})m^4 / 0.01m^2} = \sqrt{8.333(10^{-4})m^2}$$

$\therefore \sigma_{cr} < \sigma_y$ (buckling before yielding)

→ Assuming ideal column: homogeneous linear elastic, perfectly straight





(I-beam along x-x axis)

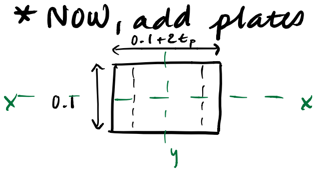
since square, will buckle about x-x or y-y

→ P_{cr} = critical load, max load allowed before buckling, load $P < P_{cr}$
- I must be least moment of inertia

→ σ_{cr} = critical stress, ave normal stress just before buckling, $\sigma_{cr} < \sigma_y$

→ Safety factor ⇒ $P_{allow} = \dfrac{P_{cr}}{F.S.}$

* Now, add plates of thickness t_p (thickness of plate)



→ will buckle about y-y axis

$$I_{xx} = \frac{(0.1+t_p)(0.1)^3}{12} \qquad I_{yy} = \frac{(0.1)(0.1+t_p)^3}{12}$$

↳ use I_{xx} for P_{cr} and σ_{cr} bc $< I_{yy}$

* New critical load:

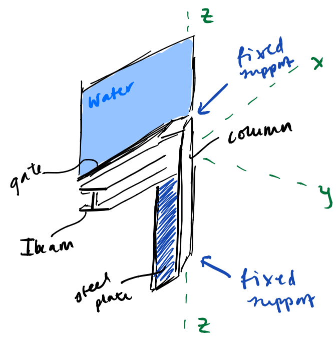
$$P_{CR} = \frac{\pi^2 EI}{(KL)^2} = \frac{\pi^2 (200(10^9)\frac{N}{m^2})[(0.1+t_p)(0.1m)^3]}{(0.5)^2 (3m)^2 \, 12} = \underline{73108 \frac{kN}{m}(0.1m + t_p)}$$

* New critical stress:

$$\sigma_{CR} = \frac{\pi^2 E}{(KL/r)^2} = \frac{\pi^2 (200(10^9)\frac{N}{m^2})(8.333(10^{-4})m^2)}{(0.5)^2 (3m)^2} = \underline{731081 \text{ kPa}}$$

(same as before)

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{(0.1+t_p)(0.1)^3}{12(0.1+t_p)(0.1)}} = \sqrt{\frac{(0.1)^2}{12}} = \sqrt{8.333(10^{-4})}$$



Wt of Water initially over entire gate & columns:

$\rho = 1000\ kg/m^3$ gate dimensions: $4m \times 5m \times 0.05m$

$\rho_{st} = 7800\ kg/m^3$

$$Wt_{H_2O,i} = (1000\ kg/m^3)(4m)(5m)(2m)(9.81\ m/s^2) = \underline{392.4\ kN}$$

$$Wt \text{ of } H_2O \text{ w/ reinforcement} = \underline{784.8\ kN}$$

$$Wt \text{ of gate} = (7800\ kg/m^3)(4m)(5m)(0.05m)(9.81\ m/s^2) = \underline{76.518\ kN}$$

*measurements @ 25°C [Range ∈ (5°C, 40°C)]

coefficient of thermal exp (linear)

Thermal Stress: function of temperature: $\delta_T = \alpha \Delta T L$

$\alpha_{A36} = 11.7(10^{-6})\ 1/°C$

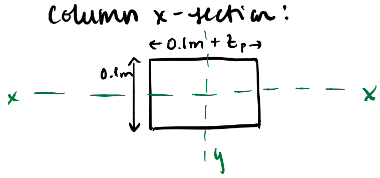
$$\delta = (11.7(10^{-6})\ 1/°C)(5-25)(4m) = -0.936\ mm$$
$$(40-25) = 0.702\ mm$$

{ Width of gate Range: 4m $+.702\ mm$, $-0.936\ mm$ }

$$\delta = (11.7(10^{-6})\ 1/°C)(5°-25°)(3m) = -0.702\ mm$$
$$(40°-25°) = 0.5265\ mm$$

{ length of column range: 3m $+0.5265\ mm$, $-0.702\ mm$ }

Column x-section:



{ column x-section range
0.1m $+0.01755\ mm$, $-0.0234\ mm$
$0.1m + t_p$ $+0.1755(0.1+t_p)\ mm$, $-0.234(0.1+t_p)\ mm$ }

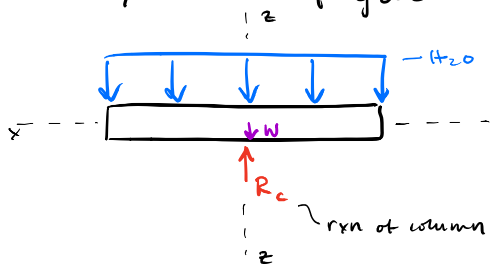
t_p = thickness of steel plate

→ thermal expansion will affect I, therefore also P_{cr}

→ as I gets smaller, critical load decreases

*thermal expansion will affect I-beam dimensions so need to consider when choosing I beam

* Shear / Moment of gate



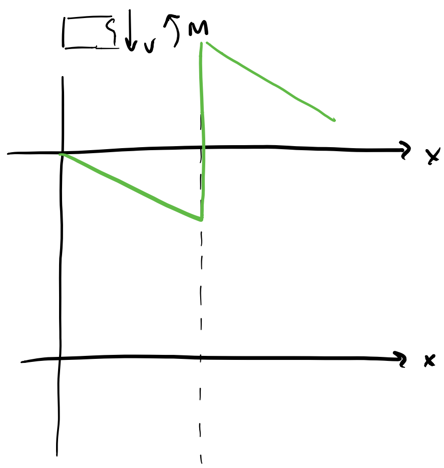
→ take section of gate that's 0.1m back in y-y direction

$(4m)(0.1m)(0.05m)(7800\ kg/m^3)(9.81\ m/s^2) =$
$W_{gate} = 1.53036\ kN$

$(4m)(0.1m)(2m)(1000\ kg/m^3)(9.81\ m/s^2) =$
$W_{H_2O} = 7.848\ kN$
$R_c = 9.37836\ kN$

$\uparrow + \ \Sigma F_z: -1.53036\ kN - 7.848\ kN + R_c = 0$

W_{H_2O} distributed $= -1.962\ kN/m$



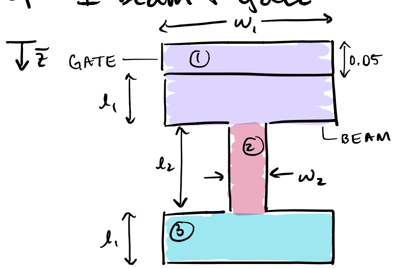
σ_{max} = maximum normal stress = 250 MPa

$$\sigma_{max} = \frac{Mc}{I}$$

c = ⊥ dist from NA to furthest pt.

M = resultant internal moment

I of I-beam + gate



NA location:

$$\left[\underbrace{(w_1)(l_1+0.05)}_{A_1}\overbrace{\left(\frac{l_1+0.05}{2}\right)}^{z_1} + \underbrace{(w_2)(l_2)}_{A_2}\underbrace{\left(0.05+l_1+\frac{l_2}{2}\right)}_{z_2} + \underbrace{(w_1)(l_1)}_{A_3}\underbrace{\left(0.05+l_1+l_2+\frac{l_1}{2}\right)}_{z_3}\right]\left(\frac{1}{A_1+A_2+A_3}\right)$$

$$= \bar{z}$$

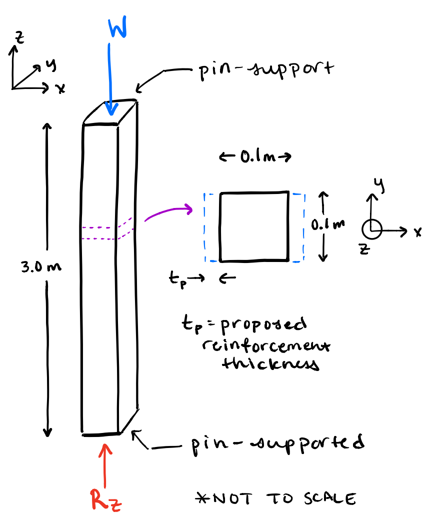
$$I_{total} = I_1 + I_2 + I_3$$

$$I_1 = \left(\tfrac{1}{12}\right)(w_1)(l_1+0.05)^3 + (w_1)(l_1+0.05)\left(\bar{z} - \frac{0.05+l_1}{2}\right)^2$$

$$I_2 = \left(\tfrac{1}{12}\right)(w_2)(l_2)^3 + (w_2)(l_2)\left(0.5+l_1+\frac{l_2}{2} - \bar{z}\right)^2$$

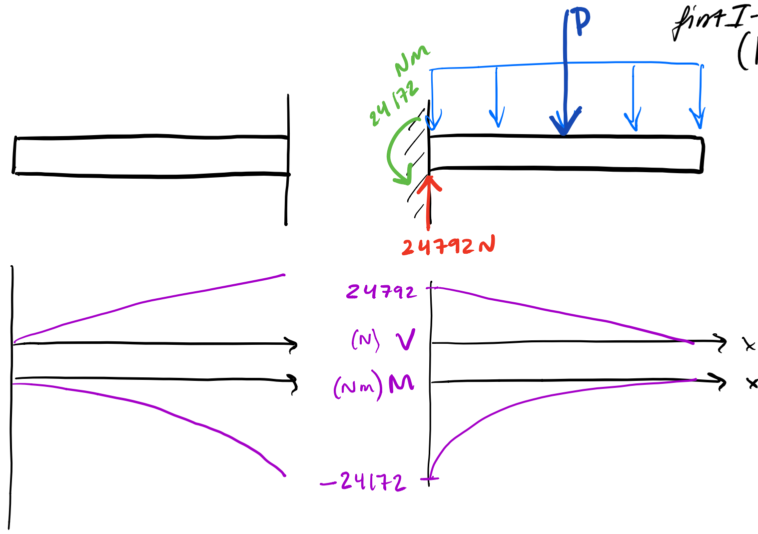
$$I_3 = \frac{1}{12}(w_1)(l_1)^3 + (w_1)(l_1)\left(0.05+l_2+\frac{3}{2}l_1 - \bar{z}\right)^2$$

use this image for how calculated I of Ibeam



use this image for buckling analysis

Bending analysis



first I-beam

$(1000\ kg/m^3)(.324m)(4m)(9.81\frac{m}{s^2})$

ht   bar wt

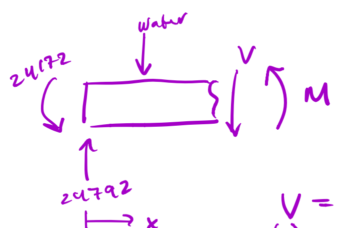
$12713.76\ N/m = \omega(x)$

$\times 1.95m = 24791.832\ N$

$V = 24792 - 12713.76x$

$\Sigma F_y = 0: 24792 - 12713.76x - V = 0$

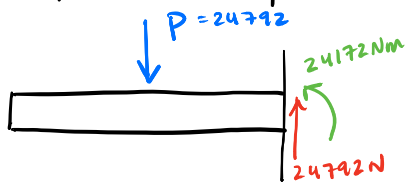
$\Sigma M = 0: M + 24172 + 12713.76x\left(\frac{x}{2}\right) - 24792x = 0$



$\underset{(N)}{V} = 24792 - 12713.76x$

$\underset{(Nm)}{M} = -\frac{12713.76}{2}x^2 + 24792x - 24172$

Deflection Analysis



$$EI\frac{d^2v}{dx^2} = M(x)$$

$$M(x) = 0 \qquad EI\frac{d^2v}{dx^2} = 0$$

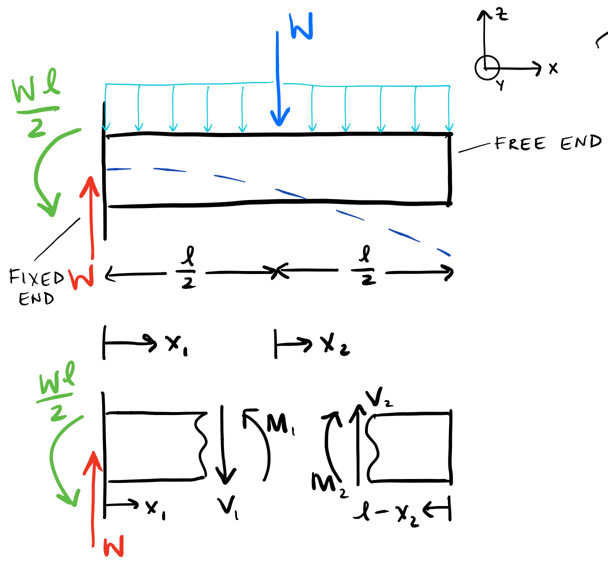
$$EI\frac{dv}{dx} = C_1$$

$$EIv_1 = C_1x + C_2$$

$$v_1 = \frac{P}{6EI}\left[3(L-a)^2x_1 - 3a(L-a)^2 - 2(L-a)^3\right]$$

$$v_2 = \frac{P}{6EI}\left[x_2^3 - 3(L-a)x_2^2\right]$$

inputs:
P
E
I
L
a
x



use this image for deflection analysis and bending analysis

* mention symmetry and why only analyzed one side

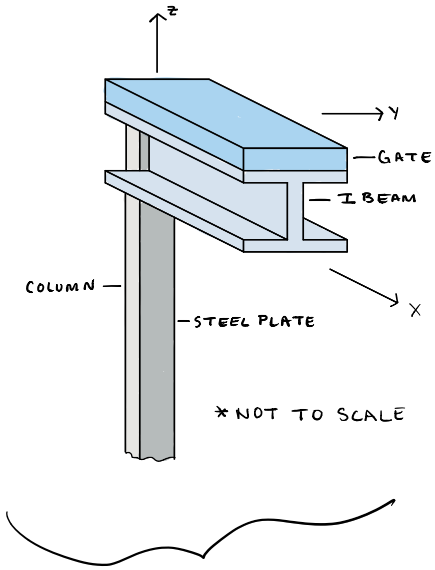
$$v_1 = \frac{P}{12EI}(2x_1^3 - 3x_1^2)$$

$$v_2 = \frac{PL^2}{48EI}(-6x_2 + L)$$

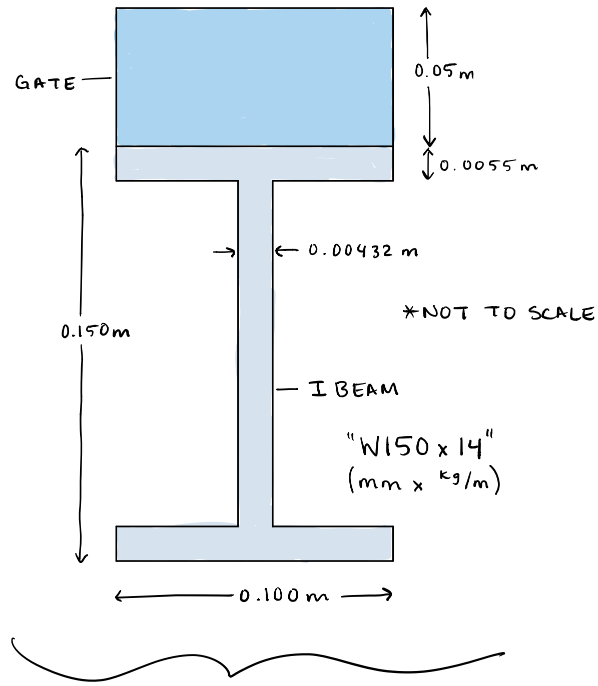
deflection w/out beam:

$$P = (4m)(0.1m)(1000\ kg/m^3)(9.81\ m/s^2)(1.95m)$$
$$= 7651.8$$

$$I = \tfrac{1}{12}(0.1m)(0.05m)^3$$
$$= 1.041667(10^{-6})\ m^4$$



use this for general schematic of set-up



use this for final I Beam Designation