ASSIGNMENT 5
SOLUTION

1. a) In plate girders, the depth h is usually large. Therefore, the requirement is given in order to prevent the occurrence of buckling in the web of plate girders under the vertical component of the compressive force in the flange resulting from the curvature of the compression flange.

b) Assumptions are

1. k = 1.0
2. $\varepsilon_f = \dfrac{\sigma_y + \sigma_r}{E}$
3. $\sigma_f = \sigma_y$
4. $\sigma_r = \dfrac{\sigma_y}{3}$
5. E = 200 x 10^3 MPa , μ = 0.3

c) We know that $k = \left(\dfrac{1}{K}\right)^2$, and K varies based on the type of the boundary conditions of the column:

1. Pinned-Pinned K= 1.0
2. Fixed-Pinned K= 0.7
3. Fixed-Fixed K = 0.5

Therefore, K = 1.0 is an upper bound. A lower bound for K is 0.5, and the corresponding $k = \left(\dfrac{1}{0.5}\right)^2 = 4$

d) $\sigma_{cr} = k\dfrac{\pi^2 E}{\left(\dfrac{L}{r}\right)^2}$ is the buckling stress in a column but $\sigma_{cr} = k\dfrac{\pi^2 E}{\left(1-\mu^2\right)\left(\dfrac{L}{r}\right)^2}$ is the buckling stress in a plate with a large value of "h" compared to its width. It is clear that the second equation is more accurate because it includes Poisson's ratio and it means that we consider buckling in two-way direction.

e) $$\frac{h}{w} = \sqrt{\frac{\pi^2 E}{12\left(1-\mu^2\right)}\frac{A_w}{A_f}\frac{1}{2\sigma_f \varepsilon_f}}$$

$$\frac{h}{w} = \sqrt{\frac{\pi^2 E}{12\left(1-0.4^2\right)} \times \frac{0.5}{2\dfrac{\sigma_y}{E}\left(\sigma_y + \dfrac{\sigma_y}{3}\right)}} = \frac{\pi E}{\sigma_y}\sqrt{\frac{0.5}{12\left(1-0.4^2\right)\times 2\left(1+\frac{1}{3}\right)}}$$

$$\frac{h}{w} = \frac{85,693}{F_y}$$

$$\varepsilon_f = \frac{\sigma_y + \sigma_r}{E} = \frac{\sigma_y + 0.5\sigma_y}{E} = \frac{1.5\sigma_y}{E}$$

$$\frac{h}{w}=\sqrt{\frac{\pi^2 E}{12\left(1-0.3^2\right)}\times 0.5\frac{1}{2\sigma_y\times 1.5\frac{\sigma_y}{E}}}$$

$$\frac{h}{w}=\sqrt{\frac{\pi^2 E^2\times 0.5}{12\left(1-0.3^2\right)\times 3}}\frac{1}{\sigma_y}$$

$$\frac{h}{w}=\frac{77,623}{\sigma_y}=\frac{77,623}{F_y}$$

2. Given:

$F_y = 300$ MPa
h = 1500 mm
a = 1620 mm
w_1= 6 mm
w_2 = 20 mm

a) Spacing:

- $\frac{h}{w_1}=\frac{1500}{6}=250>150 \triangleright \frac{a}{h}\leq\frac{67500}{\left(h/w_1\right)^2}\leq\frac{67500}{\left(250\right)^2}\triangleright a\leq 1620mm$
  (a chosen = 1620 mm) OK
- $\frac{h}{w_2}=\frac{1500}{20}=75<150 \triangleright \frac{a}{h}\leq 3 \triangleright a\leq 4500mm$
  (a chosen = 1620 mm) OK

<u>Therefore, spacing fall within the limits of S16</u>

b) Maximum Permissible Web Slenderness:

$$\frac{h}{w}\leq\frac{83000}{F_y}$$

$$\frac{83,000}{F_y}=\frac{83,000}{300}$$

$\frac{h}{w_1}=250\leq 277$ OK

$\frac{h}{w_2}=75\leq 277$ OK

<u>Therefore, S16.1 conditions on maximum slenderness is met</u>

c) $\frac{a}{h} = \frac{1620}{1500} = 1.08 > 1.0$

$$k_v = 5.34 + \frac{4}{(a/h)^2} = 5.34 + \frac{4}{(1.08)^2} = 8.77$$

$$\sqrt{\frac{k_v}{F_y}} = \sqrt{\frac{8.77}{300}} = 0.171$$

$$439\sqrt{\frac{k_v}{F_y}} = 75.1$$

$$621\sqrt{\frac{k_v}{F_y}} = 106.2$$

- $\frac{h}{w_1} > 621\sqrt{\frac{k_v}{F_y}} = 106.2$

$$F_{cre} = \frac{180000 k_v}{\left(h/w_1\right)^2} = \frac{180000(8.77)}{(250)^2} = 25.3MPa$$

$$F_t = \left(0.5F_y - 0.866F_{cre}\right)\left[\frac{1}{\sqrt{1+(a/h)^2}}\right]$$

$$F_t = \left(0.5*300 - 0.866*25.3\right)\left[\frac{1}{\sqrt{1+(1.08)^2}}\right] = 87MPa$$

$F_s = F_{cre} + F_t = 25.3 + 87 = 112.3$ MPa

$$V_{r1} = \phi A_w F_s = 0.9 \times 1500 \times 6 \times 112.3 \times 10^{-3} = 910kN$$

- $\frac{h}{w_2} \leq 439\sqrt{\frac{k_v}{F_y}}$

$$F_s = 0.66F_y = \left(0.66 \times 300\right) = 198MPa$$

$$V_{r2} = \phi A_w F_s = 0.9 \times 1500 \times 20 \times 198 \times 10^{-3} = 5,346kN$$

d) The presence of stiffener is justified for the case (w_1=6mm) since it considerably increases the shear capacity. However, for the case (w_2=20mm), they do not contribute to the shear capacity and they can be removed for economical design.

The shear capacity for the case (w_2=20mm) is significantly higher than the case (w_1=6mm) due to:

1. A higher value of F_s
2. A higher value of A_w