3 (cont'd).

<u>Constitutive Laws.</u> Effective length of 1 & 2 is 250 mm

Bolt. tensile force F_1 & extension δ_1

$\therefore \quad F_1 = k_1 \delta_1 \; ; \; k_1 = \frac{\pi}{4} \times 18^2 \times 207 / 250 = 211$ kN/mm

Sleeve compressive F_2 & contraction δ_2

$\therefore \quad F_2 = k_2 \delta_2 \; ; \; k_2 = \frac{\pi}{4}(35^2 - 20^2) \times 50/250 = 130$ kN/mm

<u>Solution</u> – 4 equations, 4 unknowns.

Eliminate deflexions to get

$$\left.\begin{aligned} F_1 &= k_e(\Delta + P/k_2) = F_i + P k_e/k_2 \\ F_2 &= k_e(\Delta - P/k_1) = F_i - P k_e/k_1 \end{aligned}\right\} \frac{1}{k_e} = \frac{1}{k_1} + \frac{1}{k_2}$$

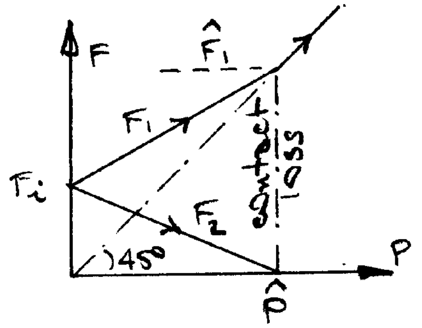
where F_i is the initial load (i.e. $P = 0$) due to tightening by Δ.

$$k_e = 1/(1/211 + 1/130) = 80 \text{ kN/mm}$$

So the force relations are:

$F_1 = F_i + 0.619\,P$

$F_2 = F_i - 0.381\,P$



These plot as shown. As P increases, the load in the bolt increases also, but that in the sleeve drops from initial F_i until eventually contact is lost and F_1 takes all P.

To increase the load $\hat{P}$, when contact is lost, we therefore strive to increase F_i. But this tends to increase both F_1 and F_2. The maximum forces sustainable are

$\hat{F}_1 = \frac{\pi}{4} \times 18^2 \times 550 = 140$ kN

$\hat{F}_2 = \frac{\pi}{4}(35^2 - 20^2) \times 80 = 52$ kN.

From above therefore

if F_1 is limiting, max $\hat{P} = 140$ kN.

if F_2 is limiting, max $F_i = 52$ kN

which latter corresponds to $\hat{P} = 52/0.381 = 136$ kN

So the sleeve limits the load to 136 kN, which necessitates an initial force of 52 kN.

4. If the bars share the load, their required cross-sectional areas are each

$A = 5E3(N) \times 2.5/250(N/mm^2) = 50\ mm^2$

and so stiffness is $k = 50 \times 207/500 = 20.7$ kN/mm

Indeterminate, let "c" subscript refer to centre bar, "o" subscript refer to each of outer bars.

<u>Compatibility</u> – Assume centre bar is long by amount Δ.