ARCH 324 - Structures 2, Winter 2009

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\[ \text{Find: } A_5 \]

\[ UDL = 1.4 \times 500 = 700 \text{kip} \]
\[ ULC = 1.7 \times 1250 = 2125 \text{kip} \]
\[ ULC = \frac{2125}{2825} = 0.753 \text{kip} \]
\[ M_n = \frac{wL^2}{8} = \frac{2825 \times (40)^2}{8} = 565 \text{kip-ft} \]
\[ M_w = \frac{M_n}{0.9} = \frac{565}{0.9} = 627.8 \text{kip-ft} \]

Determine if compression block falls entirely within top slab:
\[ z_s = 2'' + 20'' + 1'' = 23'' \]
\[ A_w = 2'' \times 30'' = 60 \text{in}^2 \]
\[ M_w = 0.85 f'_c A_w z_s = 0.85 \times (4.5 \text{ksi})(60 \text{in}^2)(23'') = 5278.5 \text{kip-in} \times \frac{1}{12} = 440 \text{kip-ft} \]

This is not sufficient to cover required moment capacity (627.8 kip-ft). Therefore, the stress block extends into the webs.

The moment capacity required by the webs is:
\[ M_{ow} = M_n - M_w = 627.8 - 440 = 187.8 \text{kip-ft} \]
\[ z_w = 2'' + (20'' - \frac{9}{2}''') = 22'' - \frac{9}{2}'' \]
\[ A_{ow} = (3'' + 4'' + 3'') = 10 \text{in}^2 \]
\[ M_{kw} = 0.85 f'_c A_{ow} z_w = 187.8 \text{kip-ft} \]
\[ 0.85 \times (4.5 \text{ksi})(10 \text{in}^2)(22'' - \frac{9}{2}''') = 187.8 \text{kip-ft} \times 12'' \]
\[ 22a - \frac{a^2}{2} = \frac{1878 \times 12}{0.85 \times 4.5 \times 10} = 58.92 \text{in}^2 \]
\[ a^2 - 14a + 117.8 = 0 \text{in}^2 \]
Solving the quadratic:

\[ a = \frac{44 \pm \sqrt{44^2 - 4(117.8)}}{2} \]

\[ a = 2.865'' \quad \text{not possible} \]

\[ 2w = 22'' - \frac{a}{2} = 22'' - \frac{2.865''}{2} = 20.57'' \]

\[ A_{cw} = 10a (\text{in}^2) = 10 \times 2.865 (\text{in}) = 28.65 \text{ in}^2 \]

\[ M_{nw} = 0.85 f'c A_{c2} = 0.85 \left( 45 \text{ ksi} \right) \left( 28.65 \text{ in}^2 \right) \left( 20.57'' \right) \]

\[ = 2254 \text{ k-in} = 182.8 \text{ k-ft} \]

Find the area of steel required for each section:

\[ A_{st} = \frac{M_{nt}}{f_y Z_t} = \frac{52.78.5 \text{ k-in}}{50 \text{ ksi} \times 23''} = 4.59 \text{ in}^2 \]

\[ A_{sw} = \frac{M_{nw}}{f_y Z_w} = \frac{2254 \text{ k-in}}{50 \text{ ksi} \times 20.57''} = 2.19 \text{ in}^2 \]

\[ A_s = A_{st} + A_{sw} = 4.59 \text{ in}^2 + 2.19 \text{ in}^2 = 6.78 \text{ in}^2 \] QED