Dimensions of beam and stirrups

\[ bw := 12 \text{ in} \quad d := 16 \text{ in} \]

\[ Av := (2 \cdot 0.11) \text{ in}^2 = 0.22 \text{ in}^2 \]

Factored demands

\[ L := 24 \text{ ft} \quad w_d := 1.60 \frac{\text{kip}}{\text{ft}} \quad w_i := 2.0 \frac{\text{kip}}{\text{ft}} \]

\[ w_u := 1.2 \cdot w_d + 1.6 \cdot w_i = 5.12 \frac{\text{kip}}{\text{ft}} \]

\[ V_u := w_u \cdot \frac{L}{2} = 61.44 \text{ kip} \]

\[ V_{\text{umax}} := V_u - w_u \cdot d = 54.613 \text{ kip} \quad \text{at d away from support} \]

\[ V_{u_{CL}} := -1.6 \cdot w_i \cdot \frac{3 \cdot L}{8} + 1.6 \cdot w_i \cdot \left( \frac{L}{2} \right) = 9.6 \text{ kip} \quad \text{at midspan.} \]

Material Properties

\[ f_c := 4000 \text{ psi} \quad f_y := 60 \text{ ksi} \quad \phi := 0.75 \]

Concrete Contribution to Shear Strength

\[ V_c := 2 \cdot \sqrt{\frac{f_c}{\text{psi}}} \cdot bw \cdot d = 24.3 \text{ kip} \]

Can Concrete Carry Demands without stirrups?

\[ V_{\text{calone}} := \frac{\phi \cdot V_c}{2} = 9.1 \text{ kip} \]

Even where \( V_u \) is smallest, it is still larger than this value, thus need at least min. stirrups throughout.
What is Minimum stirrups (smax)?

\[
\begin{align*}
\text{smax1} &= \frac{d}{2} = 8 \text{ in} && \text{Smallest controls} \\
\text{smax2} &= 24 \text{ in} \\
\text{smax31} &= \frac{Av \cdot fy}{50 \text{ psi} \cdot bw} = 22 \text{ in} \\
\text{smax32} &= \frac{Av \cdot fy}{0.75 \left( \sqrt{\frac{fc}{\text{psi}}} \cdot bw \right)} = 23.19 \text{ in} \\
\text{smax} &= 8 \text{ in}
\end{align*}
\]

Design Strength for Smax

\[
\begin{align*}
\text{Vssmax} &= Av \cdot fy \cdot \frac{d}{smax} = 26.4 \text{ kip} \\
\phi Vn &= \phi \left( Vc + Vssmax \right) = 38 \text{ kip}
\end{align*}
\]

Vu=54.6 kips at 16 in from support

Find Stirrups for Maximum Vu, d from support

\[
\text{sreq} = \frac{Av \cdot fy \cdot d}{Vumax \phi - Vc} = 4.4 \text{ in} \quad \text{Say 4 in.}
\]

Design Shear Strength with s=4 in.

\[
\phi Vn = \phi \left( Vc + Av \cdot fy \cdot \frac{d}{4 \text{ in}} \right) = 57.8 \text{ kip}
\]

Find a space in between smax and s= 4in. Choose s=6 in.

\[
\phi Vn = \phi \left( Vc + Av \cdot fy \cdot \frac{d}{6 \text{ in}} \right) = 44.6 \text{ kip}
\]

Vu=44.6 kips at 3.7 ft from support
Check if $V_s$ is larger than $4(f'c^{0.5})bw*d$ and $8(f'c^{0.5})bw*d$

\[
fourV_c := 2 \cdot (V_c) = 48.6 \text{ kip}
\]

\[
eightV_c := 2 \cdot (fourV_c) = 97.1 \text{ kip}
\]

At location of maximum $V_u$, the demand in $V_s$ is largest

\[
V_{smax} := \frac{V_{umax}}{\phi} - V_c = 48.5 \text{ kip}
\]

This is less than $8*(f'c^{0.5})bw*d$ so $bw$ and $d$ are ok. and is also just less than $4**(f'c^{0.5})bw*d$ so no need to

reduce $s_{max}$ to $s_{max} := \frac{d}{4} = 4 \text{ in}$

or 12 in. here.

Check the design curves below

Design strength > factored demands everywhere
1.5 in clear cover all around

Elevation View with Stirrup Spacing

Section View with Stirrup Detail