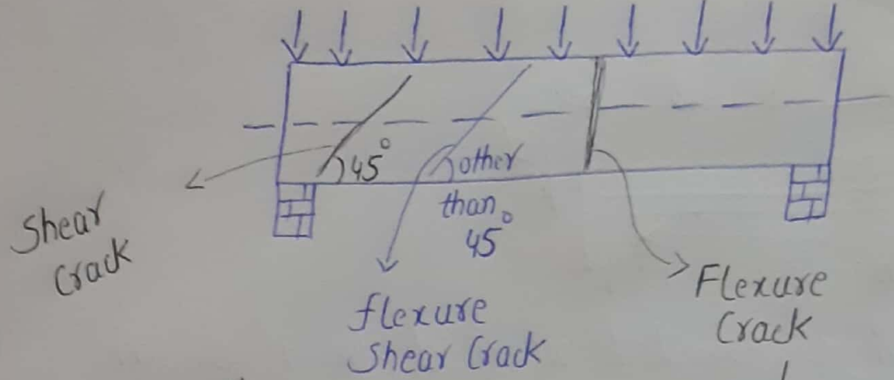
07/05/2020 Page-01 ; Lecture-01 (After Mid Term)

Shear Design of Rectangular Beams:

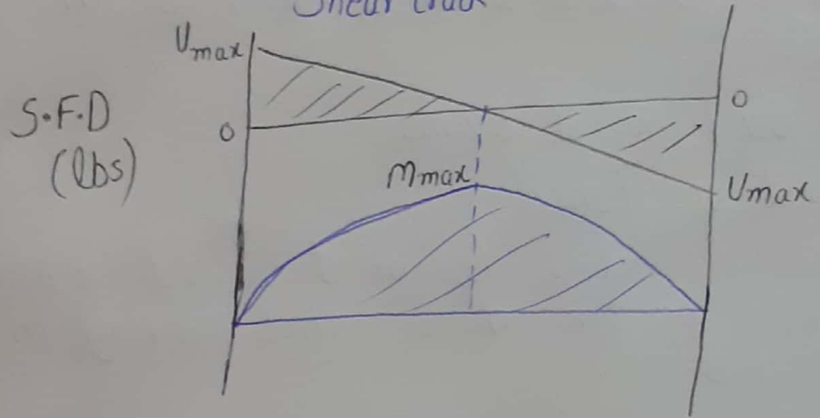
-> Starting Point of Shear Cracks
- -> Material Weak
- -> Maximum Shear.



Max. Bending Stress = $\frac{M*y}{I}$

↓

It will be max. at mid Section at the outer most fibre.



* To resist the moment due to externally applied loads, longitudinal or, main reinforcement is provided.
* To resist the shear, stirrups or, web reinforcement is provided.

* Types of Web Reinforcement:

-> For stirrup, generally #3 or, #4 bar can be used because Larger bar cannot bent easily.

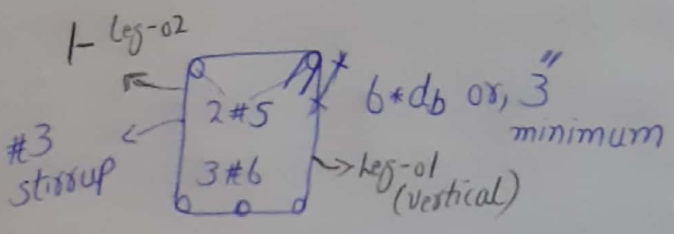


Figure-01: Two leg U-Shape stirrup.

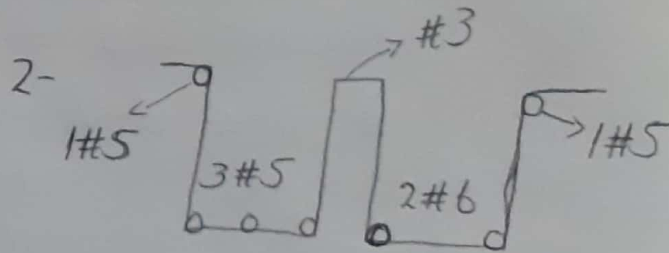
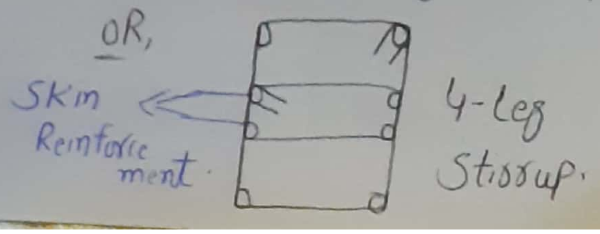


Figure: 02 : 4-leg Stirrup

OR,



A_v = Area of stirrup

$= 2 * \frac{\pi}{4} * d_b^2$ (d_b -> diameter of bar/stirrup)

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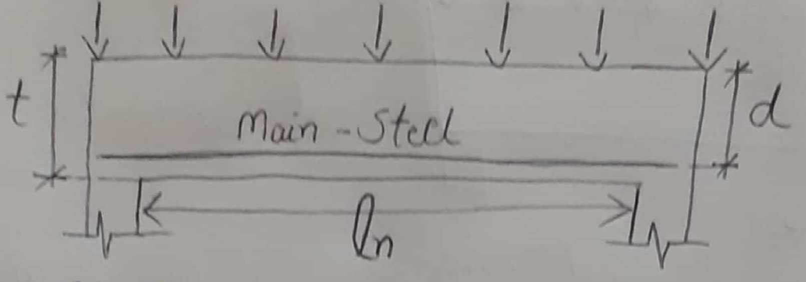
-> Deep Beam: If the ratio of clear span to the overall depth/thickness is less than or, equal to 4.

$$l_n/t \leq 4$$



-> Skin Reinforcement: It is provided when depth of beam exceeding 30" OR, 36".

* To prevent lateral buckling of beams.
* To enhance torsional resistance.

-> Skin reinforcement are additional reinforcement should be placed near the vertical faces in the tension to control cracking in the web.

ACI code Provisions for Shear Design:

-> Critical section is at a distance 'd' from the face of support.

a- Shear strength capacity of concrete $= V_c = 2 * \sqrt{f'_c} * b_w * d$

* V_u = Total factored shear force applied at a given section.

b- Minimum Web Reinforcement:

If $V_u \leq \phi * V_c$ -> Theoretically no web reinforcement is required. However, ACI code require provision of alleast a minimum area of web reinforcement equal to:

-> $Av_{min} = \dfrac{0.75 * \sqrt{f'_c} * b_w * S}{f_y}$ OR, -> $Av_{min} = \dfrac{50 * b_w * S}{f_y}$

Also, from these two formulas, you can find Max. spacing.

$S_{max} = \dfrac{Av * f_y}{0.75 * \sqrt{f'_c} * b_w}$ OR, $S_{max} = \dfrac{A_v * f_y}{50 * b_w}$

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* If $V_u < \frac{1}{2} * \phi * V_c$ → Then No Web Reinforcement is needed

where; S = longitudinal Spacing of web Reinf = inches
f_y = Yield Strength of Steel (web)
A_v = Total Cross-section area of web steel with in distance 'S'

* First stirrup is provided at a distance $S/2$.
* Shear at critical section is represented by 'V_u'.
* Between critical section 'V_u' and 'ϕV_c', Spacing b/w web reinforcement can be find by the following formula;

$$S = \frac{\phi * A_v * f_y * d}{V_u - \phi V_c}$$

* Preferably $S \not< 4''$, because of Proper compaction, vibration and Pouring of concrete etc.

→ V_s = Shear force carried by web reinf./stirrups.
According to ACI code;
If $V_s \le 4 * \sqrt{f'_c} * b_w * d$, Then Max. spacing of stirrups will be smallest of the following four conditions.

1- 24″ 2- $d/2$ 3- $S_{max} = \frac{A_v * f_y}{0.75 * \sqrt{f'_c} * b_w}$ 4- $S_{max} = \frac{A_v * f_y}{50 * b_w}$

And, if $V_s > 4 * \sqrt{f'_c} * b_w * d$ → Then Maximum spacing will be halved.

And if $V_s > 8 * \sqrt{f'_c} * b_w * d$
Then either increase cross-sectional dimensions.
OR, Increase f'_c.

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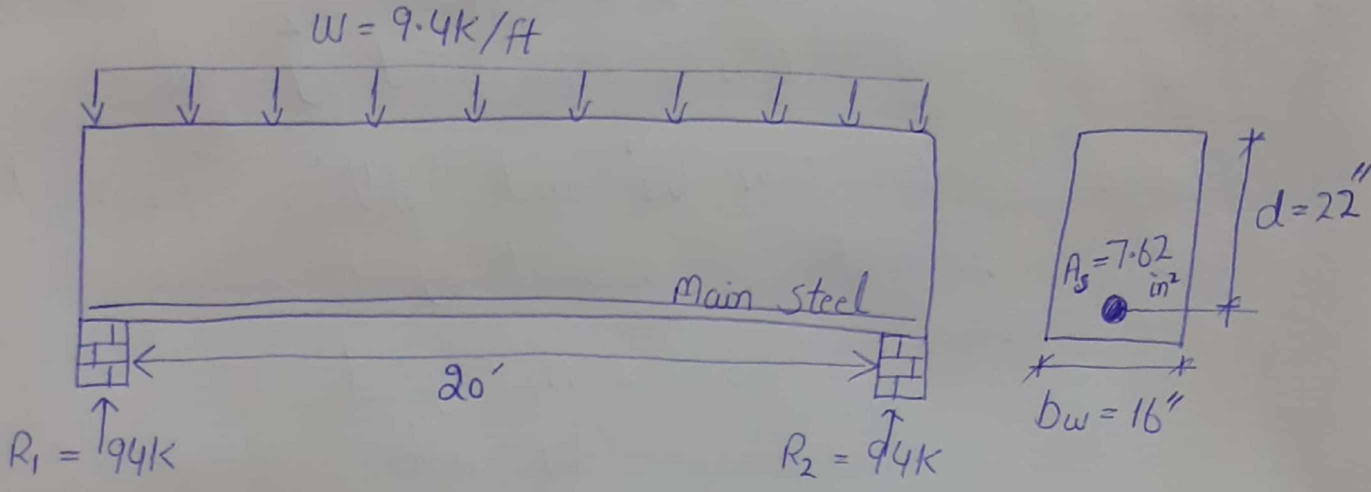
Design Problem-01: A simply supported rectangular beam 16" wide having an effective depth of 22" carries a total factored load of 9.4K/ft on a 20 ft. clear span. It is reinforced with 7.62 in² of tensile steel which continues un-interrupted into the supports. If $f'_c = 4000$ Psi and $f_y = 60000$ Psi. Using vertical U-stirrup. Design the web/shear reinforcement.

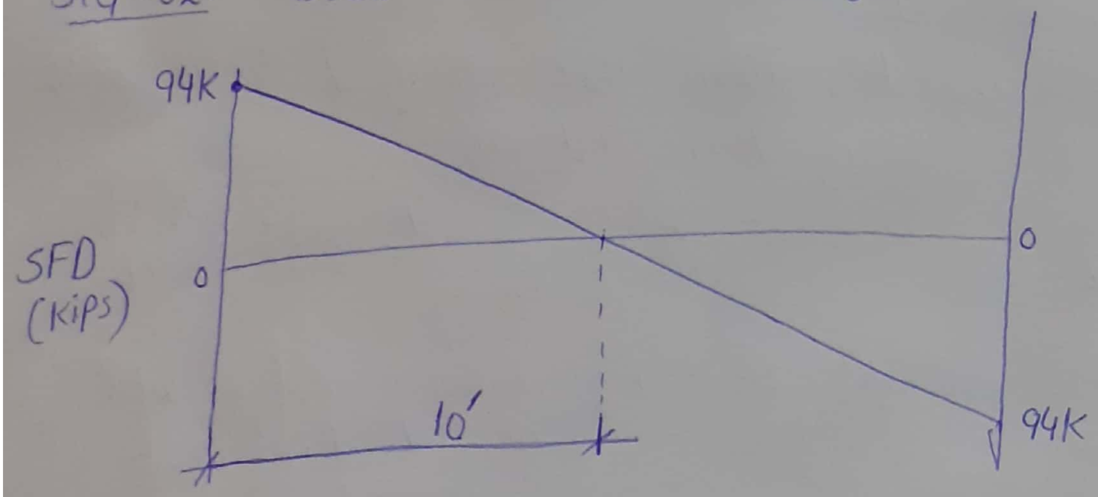
Sol:



Step-01: Find values of 'R_1' and 'R_2'.

Total Load = $9.4 \times 20 = 188/2 = 94K$.

Step-02: Draw its Shear force diagram.



Step-03: Find value of critical shear 'V_u' and its location.

As, we know that critical section is located at distance 'd' from face of support = d = 22" = 1.83'.

Value of Critical Shear at distance 'd' by similarity of Triangles.

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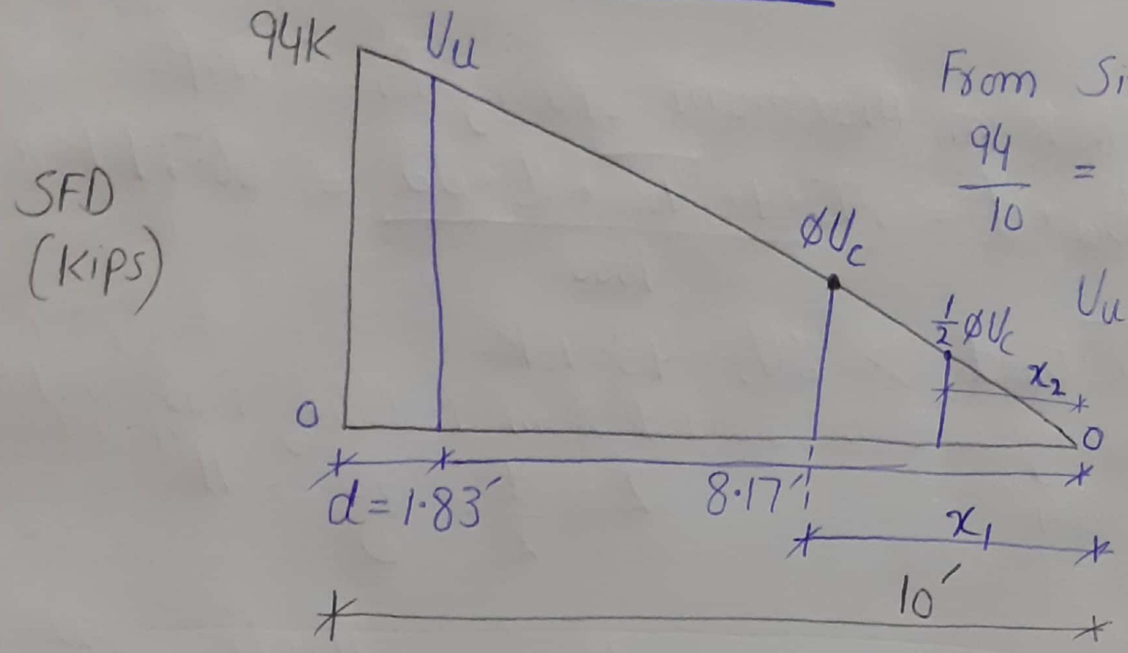

From Similar Δ's.

$$\frac{94}{10} = \frac{V_u}{8.17}$$

$V_u = 76.80$ kips

Step-04: Find Value of 'ϕV_c' and '$\frac{1}{2}\phi V_c$' and also its distances from zero shear to right side.

$$\phi V_c = \phi * 2 * \sqrt{f'_c} * b_w * d = \frac{0.75 * 2 * \sqrt{4000} * 16 * 22}{1000} = 33.40K$$

Location of ϕV_c by Similarity of Δ's.

$$\frac{94}{10} = \frac{33.40}{x_1} \Rightarrow x_1 = 3.55'.$$

Now;

$$\frac{1}{2}\phi V_c = \frac{33.40}{2} = 16.70\text{ K}$$

Location of $\frac{1}{2}\phi V_c \Rightarrow \frac{94}{10} = \frac{16.70}{x_2} \Rightarrow x_2 = 1.78'$

Step-05: Value of ϕV_s. $(V_u = \phi V_s + \phi V_c)$

So, $\phi V_s = V_u - \phi V_c = 76.80 - 33.40 = 43.40K$.

Step-06: Check on section adequacy.

$$\phi * 8 * \sqrt{f'_c} * b_w * d = \frac{0.75 * 8 * \sqrt{4000} * 16 * 22}{1000} = 133.57K$$

As, $\phi V_s < \phi 8\sqrt{f'_c}\, b_w d \Rightarrow$ It means section is adequate.

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Step-07: Check on Maximum spacing for Stirrups.

$\phi * 4 * \sqrt{f'_c} * b_w * d = \frac{0.75 * 4 * \sqrt{4000} * 16 * 22}{1000} = 66.79$ Kip

As, $\phi 4 \sqrt{f'_c}\, b_w d > \phi V_s = 43.40K$.

So, Max. Spacing will be selected from following four conditions.

1- $S_{max} = 24''$

2- $\frac{d}{2} = \frac{22}{2} = 11''$

3- $S_{max} = \frac{A_v * f_y}{0.75 * \sqrt{f'_c} * b_w}$

$= \frac{0.22 * 60000}{0.75 * \sqrt{4000} * 16} = 17.40''$

4- $S_{max} = \frac{A_v * f_y}{50 * b_w} = \frac{0.22 * 60000}{50 * 16}$

$= 16.50''$

From above four conditions, Least value of spacing for #3, 2 legged Stirrup will be selected.

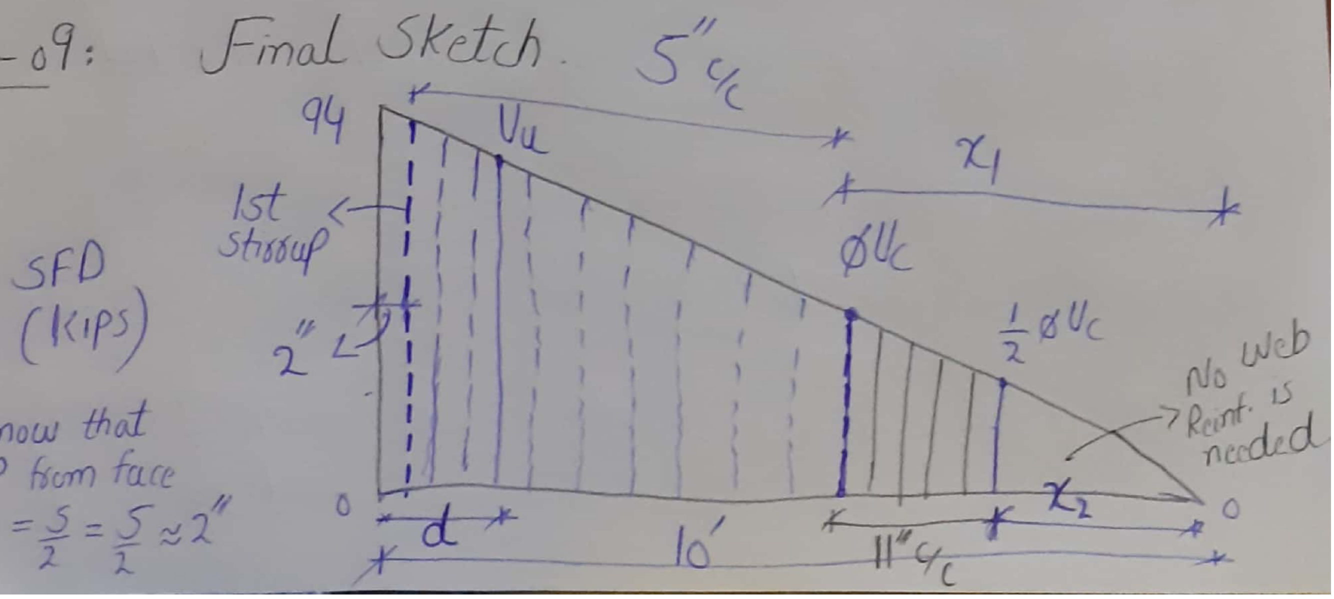
So, $S_{max} = 11''$ c/c

Step-08: Spacing of Stirrup from/at Critical section.

$S = \frac{\phi * A_v * f_y * d}{V_u - \phi V_c} = \frac{0.75 * 0.22 * 60 * 22}{76.80 - 33.44}$

$S = 5''$ c/c.

Step-09: Final Sketch.

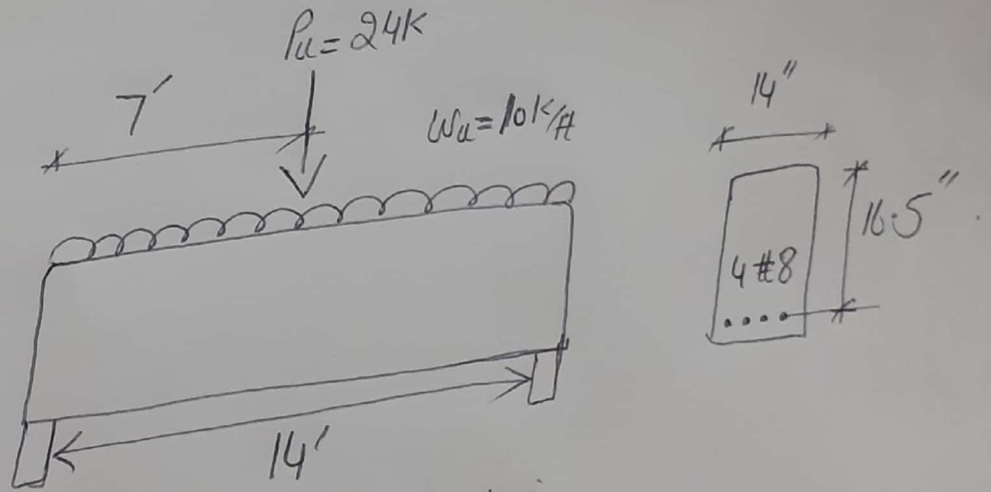


* As we know that first stirrup from face of support $= \frac{S}{2} = \frac{5}{2} \approx 2''$

Home Work;

Pb-01: A rectangular beam having $b = 12''$ and $d = 22''$ spans 20 ft. face to face of simple supports. It is reinforced for flexure with three No. 11 bars that continue uninterrupted to the ends of the span. It is to carry service D.L of 1.63 kips/ft (including Self wt.) and service L.L of 3.26 kips/ft, both uniformly distributed along the span. Design the shear reinforcement using No. 3 vertical U-Stirrups. Material Strengths are $f'_c = 4000$ psi and $f_y = 60000$ Psi.

Pb-02:



$f'_c = 4ksi$, $f_y = 60 ksi$

Design for Shear at;

i)- distance 'd' from face of support.

ii)- at distance 4'-0" from face of support.

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