REINFORCED CONCRETE

Written By :

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A Hand-note On

REINFORCED CONCRETE

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Topics

Theory

Doubly reinforced beam

T-beam

Lintel

Slab

Stir-up

Stair

Theory

মো: আহসান হাবীব

04,10,09

1. What are the difference between WSD and USD method?

WSD method	USD method
i) It is the old method and used for particular cases.	i) It is the modern method and universally used.
ii) It counts the stress upon proportional limit.	ii) It counts the stress upon yield point.
iii) Stress is increased by multiplying factor of safety.	iii) Stress is decreased by multiplying factor of safety.
iv) Design load is computed as ω = Dead Load + Live load	iv) Design load is computed as $\omega = (1.2 \times \text{Dead load}) + (1.6 \times \text{Live load})$
v) Modular ratio is used for determining moment capacity.	v) Steel ratio is used for determining moment capacity
Working Stress Design	Ultimate Strength Design

00,03

2. Write down the advantages and disadvantages of WSD and USD method.

Advantage of WSD:

i) The critical deflection is normally under service load for which WSD method is appropriate.

ii) With high stress steel reinforcing, crack width at working load can be a consideration.

Advantages of USD:

i) USD method ensures proper factor of safety.

ii) USD method is necessary for pre-stressed concrete.

3. What is a T-beam? 01, 03, 04, 06, 11, 10

T-beam:

A T-beam is a beam which consists of a rectangular flange cast integrally with the beam subjected to tension and a rectangular web below the flange.

4. What are the advantages of T-beam over rectangular beam?

01, 06, 07

Advantages of T-beam over rectangular beam:

i) In T-beam flange can resist more compressive stress than rectangular beam.

ii) In T-beam web thickness is less and so that material use is less than a rectangular beam.

iii) T-beam is economical compared to a rectangular beam.

00,03,04,06,07,08

5. State the fundamental assumptions made in the analysis of reinforced concrete structures.

The following assumptions are made for the analysis of reinforced concrete:

i) At any section, internal forces and external load at that section are in equilibrium.

ii) The strain in an embeded reinforcing bar and that in the surrounding bar are the same.

iii) Cross-sections which were plain before loading remains plain after loading.

iv) Concrete is not capable of resisting any tensile stress.

v) The modulus of elasticity of steel and concrete are constant.

vi) All tensile stresses are taken by steel only and the tensile resistance of concrete is nill.

vii) The theory is based on actual stress-strain relationship.

98,00

6. What do you mean by under-reinforcement and over-reinforcement and balanced design. Which one is more rational?

Under-reinforced design:

If the amount of reinforcement used is less than the required amount for balanced design it is called under reinforced design. Under reinforcement failure occurs in this case.

Over-reinforced design:

If the amount of reinforcement used is more than the required amount for balanced design, it is called over reinforced design. This design is expensive and failure occurs in concrete without any warning.

Balanced design:

If the amount of reinforcement is provided just according to the required amount, the design is called balanced design. In this case steel failure is caused with warning but concrete fails without warning.

Among the three, in case of under reinforced design steel is provided less than required amount so it is economical. Also, failure occurs in concrete by giving warning. So under reinforced design is more rational.

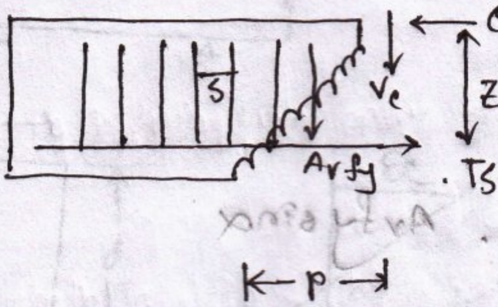
06

7. Distinguish between singly and doubly reinforced beam.

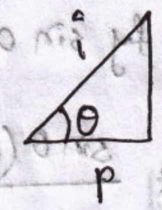
Singly reinforced beam	Doubly reinforced beam
i) No steel is provided in compression zone.	i) Steel is provided in compression zone as well as tension zone.
ii) Suitable for unrestricted dimension of beam.	ii) Suitable for limited dimension of beam.
iii) All the compressive stress is carried by concrete.	iii) Compressive stress is carried by concrete as well as steel.

00, 01, 02, 03, 04, 07, 11, 10

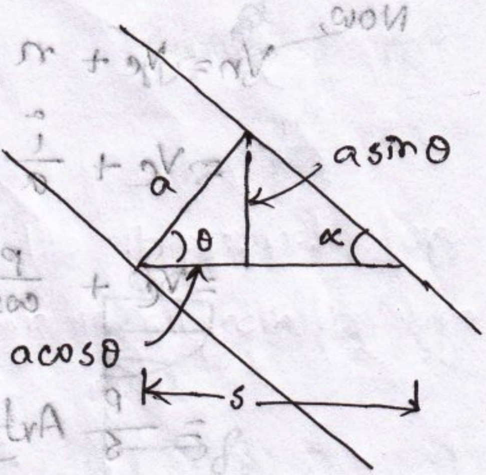
Derive an expression for spacing of $\boxed{\text{inclined}}$ / vertical stirrup.



(a)



(b)



(c)

Let us consider the diagonal crack as shown in the figure, Let,

p = Horizontal projection of crack

i = Inclined length of crack

a = " spacing of bar

s = Horizontal spacing of bar

θ = Inclination of crack

α = " of bar

for the total crack from figure (b)

$$\frac{p}{i} = \cos\theta \quad \Rightarrow i = \frac{p}{\cos\theta}$$

for the crack in between two bar from figure (c)

$$s = a\cos\theta + \frac{a\sin\theta}{\tan\alpha}$$

$$\Rightarrow a = \frac{s}{\cos\theta + \frac{\sin\theta}{\tan\alpha}} = \frac{s}{\sin\theta(\cot\theta + \cot\alpha)}$$

00,05,07, 11

10. Why shrinkage reinforcement is provided? ~~Sol.~~ State its ACI specification.

In one-way slabs distribution reinforcement is provided at perpendicular direction of main reinforcement which is also known as shrinkage reinforcement. It is provided inorder to reduce shrinkage and to distribute cracks and temperature contractions.

ACI specification for shrinkage reinforcement / distribution reinforcement / temperature reinforcement:

	Reinforcement / total concrete area
Grade 40-50	0.002
Grade 60	0.0018
Grade more than 60	$\frac{0.0018 \times 60000}{f_y}$

11. What are the ACI codes for minimum clear distance between adjacent bars?

The ACI codes specifies that, the minimum clear distance between adjacent bars shall not be less than the nominal diameter of the bars, or $1\frac{1}{3}$ times the maximum coarse aggregate size or 1 inch. Where reinforcement is placed in two or more layers, the clear distance between the layers must not be less than 1" and the bars in the upper layer should be placed directly above those in the bottom layer.

00, 01, 02, 03, 04, 05, 07, 08

12. What is diagonal tension? Discuss the formation of diagonal crack in RC beam.

Diagonal tension:

In an uniformly distributed loaded beam, the shear stress is produced maximum at neutral axis and zero at the outer fibers. And tensile and compressive flexure stresses develops maximum at the outer fibers. If the beam is reinforced with longitudinal steels only, cracks may form diagonally. The stresses producing these cracks are known as diagonal stress.

Formation of diagonal crack:

In short spans, when shear becomes large enough the diagonal tension near the neutral axis leads to the formation of a crack at approximately 45°. This crack is called diagonal crack.

There crack extends untill stopped by load or reaction

In longer spans, the diagonal crack develops as a growth or extension of a vertical moment crack which turns into an inclined crack.

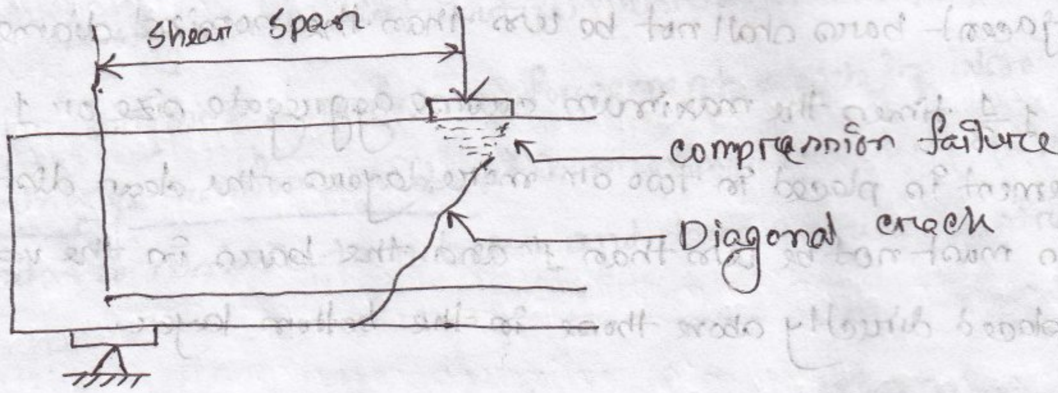


Fig: Formation of diagonal crack

11, 10, 08

13. Explain the bond, developed bond or anchorage bond.

Bond:
Bond is defined as the cohesion or adhesion between the steel and concrete over entire length of the steel bar.

Developed bond:
The developed or anchorage bond is the average bond stress over the entire length of the bar, within which the bar tension is being changed from T to Zero (anchorage length) or zero to T (development length).

14. Give the ACI specification for T-beams?

ACI code specification for T-beams:

i) It should not exceed $\frac{1}{4}$ th of span.

ii) The overhanging width on either side of the beam web should not exceed 8 times the thickness of the slab nor $\frac{1}{2}$ of the clear distance to next beam.

iii) Steel ratio should not exist the following limit,

$$(\rho_w)_{max} = 0.75(\rho_b + \rho_f)$$

where, ρ_b = Balance steel ratio for rectangular portion

ρ_f = ,, ,, ,, for flange

iv) Tensile steel ratio must not be less than,

$$\rho_{min} = \frac{3}{f_y}\sqrt{f_c'} \text{ and } \geq \frac{200}{f_y}$$

15. Explain how bond failure occurs?

When heavy loads are applied on the beam, the beam bends but the steel bars try to maintain their original length. As a results, the bar may slip logitudinally with respect to the adjacent concrete. Such a beam will collapse as the bar is pulled through the concrete. This type of failure is bond failure. This is the process by which a beam fails in bond.

08

16. Explain why mild steel is used as reinforcement in RCC structure?

or,

State the points in favour of mild steel to be used as good reinforcement in RC structures.

The following are the required characteristics of material, which can be used as good reinforcement;

i) It should be able to develop perfect bond with concrete.

ii) The co-efficient of thermal expansion should be nearly same as that of concrete.

Con - 6.5×10^{-6}
steel - 5.5×10^{-6}

iii) It should be easily available.

iv) It should have high tensile strength.

v) It should be easily cut and bend.

vi) It should not produce any harmful effect combining with concrete.

It is found that all these requirements are fulfilled by mild steel. That is why mild steel is used as reinforcement in RCC structures.

01, 05

17. What is ϕ? Why strength reduction factor ϕ is lower for shear than flexure?

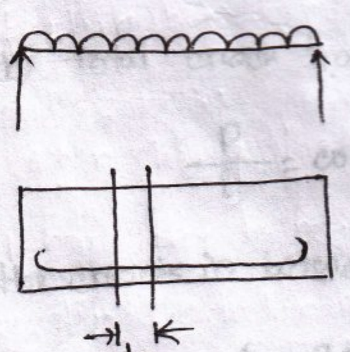
Strength reduction factor ϕ:

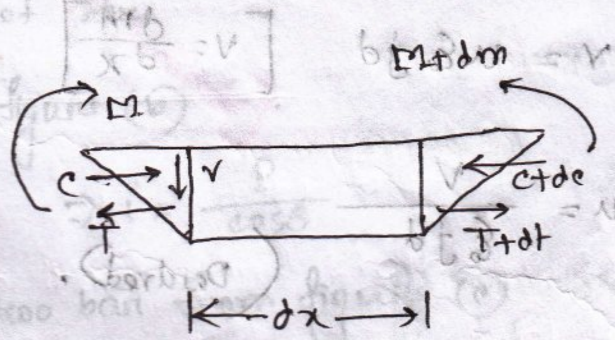
To provide safety, the theoretical ultimate strength is reduced by a co-efficient which is known as strength reduction factor and it is denoted by ϕ.

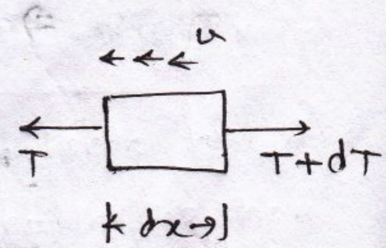
The flexure failure of beam depends on the quality of steel which can be controlled more precisely than shear failure as shear failure depends on the quality of concrete which varies from time to time. That is why more safety is required for shear strength. Due to this reason, ϕ for shear (0.75) is less than ϕ (0.9) for flexure.

02, 08, 11

18. Derive an expression for bending / flexural bond stress.







Let us consider a beam as shown above. Let us consider an elementary portion of the beam of length dx.

Now, for equilibrium,

$$M = A_s f_y jd = Tjd$$

Similarly, $M + dM = (T + dT) jd$

Change in moment,

$$M + dM - M = (T + dT) jd - Tjd$$

$$\Rightarrow dM = dT\, jd$$

$$\Rightarrow dT = \frac{dM}{jd} \quad \cdots\cdots \text{(i)}$$

for flexural bond stress, u

$$dT = u(\Sigma_0\, dx) \quad \cdots\cdots \text{(ii)}$$

where, Σ_0 = perimeter

from (i) and (ii),

$$\frac{dM}{jd} = u(\Sigma_0\, dx)$$

$$\Rightarrow \frac{dM}{dx} = u \Sigma_0 jd$$

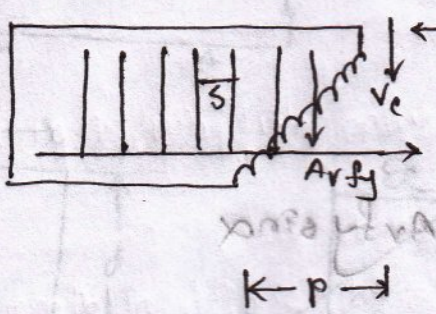
$$\Rightarrow V = u \Sigma_0 jd \quad \left[V = \frac{dM}{dx}\right]$$

$$\therefore u = \frac{V}{\Sigma_0 jd}$$

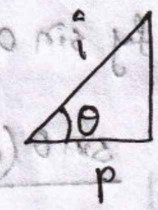
(Derived).

00, 01, 02, 03, 04, 07, 11, 10

Q. Derive an expression for spacing of $\boxed{\text{inclined}}$ / vertical stirrup.



(a)



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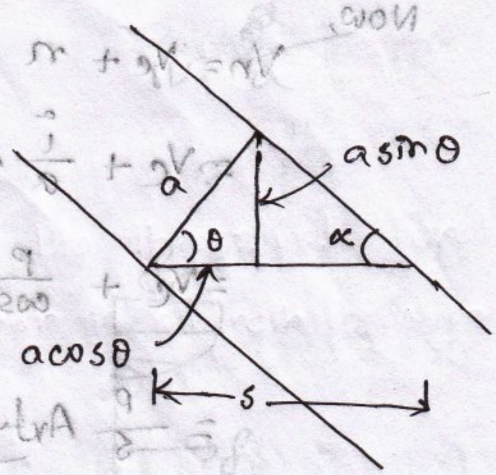

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for the total crack from figure (b)

$$\frac{p}{i} = \cos\theta \qquad \Rightarrow i = \frac{p}{\cos\theta}$$

For the crack in between two bar from figure (c)

$$s = a\cos\theta + \frac{a\sin\theta}{\tan\alpha}$$

$$\Rightarrow a = \frac{s}{\cos\theta + \frac{\sin\theta}{\tan\alpha}} = \frac{s}{\sin\theta(\cot\theta + \cot\alpha)}$$

if n = no of stirrup then $n = \frac{i}{a}$

Now,

$$V_n = V_c + n\, A_v f_y \sin\alpha$$

$$= V_c + \frac{i}{a} A_v f_y \sin\alpha$$

$$= V_c + \frac{p}{\cos\theta} \times \frac{\sin\theta(\cot\theta + \cot\alpha)}{s} \cdot A_v f_y \sin\alpha$$

$$= \frac{p}{s} A_v f_y \sin\alpha (1 + \tan\theta \cdot \cot\alpha) + V_c$$

$$\therefore V_u = \phi V_n = \phi \left[\frac{p}{s} A_v f_y \sin\alpha (1 + \tan\theta \cdot \cot\alpha)\right] + \phi V_c$$

Now, $p = d$ = effective depth, $\theta = 45°$ for diagonal cracks

$\alpha = 90°$ for vertical stirrup

$$V_u = \phi \cdot \frac{d A_v f_y}{s} + \phi V_c$$

$$\Rightarrow s = \frac{\phi A_v f_y d}{V_u - \phi V_c}$$

This is the expression.

(Derived). [Vertical এর জন্য 12 মার্কস)

for inclined spacing

$$V_u = \phi \frac{d}{s} A_v f_y (1 + \cot\alpha) + \phi V_c$$

$$\therefore s = \frac{\phi A_v f_y d (1 + \cot\alpha)}{V_u - \phi V_c}$$

(Derived).

Doubly rectangular beam

Doubly Reinforced Rectangular Beams

WSD method

{ 090063
AHSAN }

Doubly reinforced beam:

If a beam is subjected to excessive moment and the size of beam is limited in this case concrete stress may exceed the allowable limit and reinforcement is provided in compression zone to resist the excessive moment. Such a beam is known as doubly reinforced beam.

Formula:

$$* \quad M_1 = \frac{1}{2} f_c j k b d^2$$

$$* \quad M_2 = A_{s2} f_s (d-d')$$

$$= A_s' f_s' (d-d')$$

$\rightarrow$ দুইটার ভিতর minimum টা নিতে হবে

$$* \quad f_s' = 2 \times f_s \times \frac{k - \frac{d'}{d}}{1-k}$$

Remaining steel area, $A_{S2} = A_S - A_{S1}$

$= 5.08 - 3.04$

$= 2.04 \text{ in}^2$

$$f_s' = 2 f_s \times \frac{k - \frac{d'}{d}}{1-k}$$

$$= 2 \times 24000 \times \frac{0.375 - \frac{2.5}{18}}{1 - 0.375}$$

$= 18133.33$ psi

$= 18.13$ ksi $< f_s = 24$ ksi

$M_2 = A_s' f_s' (d - d') = 2.37 \times 18.13 \times (18 - 2.5)$

$= 666$ kips-in

$M_2 = A_{s2} f_s (d - d') = 2.04 \times 24 \times (18 - 2.5)$

$= 758.88$ kips-in

$\therefore M_2 =$ ~~758.88 kips~~ 666 kips-in

$\therefore$ Total allowable moment $= M_1 + M_2$

$= 1148.18 + 666$

$= 1814.18$ kips-in.

(Ans).

Problem-01: (Analysis)

A rectangular beam with $b = 12''$ and $d = 18''$. Tension reinforcement $A_s = 4\#10$ bars, compression reinforcement $A_s' = 3\#8$ bars. $d' = 2.5''$, $f_s = 24000$ psi, $f_c' = 4000$ psi. what is the allowable working moment capacity of the beam.

Solution:

$$A_s = 4 \times 1.27 = 5.08 \text{ in}^2$$

$$A_s' = 3 \times 0.79 = 2.37 \text{ in}^2$$

$$n = \frac{29 \times 10^6}{57000\sqrt{4000}} = 8.04 \simeq 8$$

$$r = \frac{f_s}{f_c} = \frac{24000}{1800} = 13.33$$

$$K = \frac{n}{n+r} = \frac{8}{8+13.33} = 0.375$$

$$J = 1 - \frac{k}{3} = 1 - \frac{0.375}{3} = 0.875$$

$$M_1 = \frac{1}{2} f_c jkbd^2$$

$$= \frac{1}{2} \times 1800 \times 0.875 \times 0.375 \times 12 \times (18)^2$$

$$= 1.15 \times 10^6 \text{ lb-in}$$

$$= 1148.18 \text{ k-in}$$

Corresponding reinforcement, $A_{s1} = \dfrac{M_1}{f_s jd}$

$$= \frac{1148.18 \times 1000}{24000 \times 0.875 \times 18}$$

$$= 3.04 \text{ in}^2$$

$$A_{s_1} = \frac{M_c}{f_s j d}$$

$$= \frac{1690 \times 10^3}{20000 \times 0.86 \times 20}$$

$$= 4.91 \text{ in}^2$$

$$M_2 = M - M_c = 2530 - 1690 = 840 \text{ kips in}$$

$$A_{s_2} = \frac{M_2}{f_s(d-d')} = \frac{840 \times 10^3}{20000 \times (20-3)}$$ ← Assume

$$= 2.47 \text{ in}^2$$

$$A_s = A_{s_1} + A_{s_2} = 4.91 + 2.47 = 7.38 \text{ in}^2$$

$$f_s' = 2 f_s \times \frac{k - \frac{d'}{d}}{1-k} = 2 \times 20000 \times \frac{0.42 - \frac{3}{20}}{1 - 0.42}$$

$$= 18620.69 \text{ psi} < f_s$$

$$\therefore f_s' < f_s$$

$$A_s' f_s' = A_{s_2} f_s$$

$$\Rightarrow A_s' = \frac{A_{s_2} f_s}{f_s'} = \frac{2.47 \times 20000}{18620.69}$$

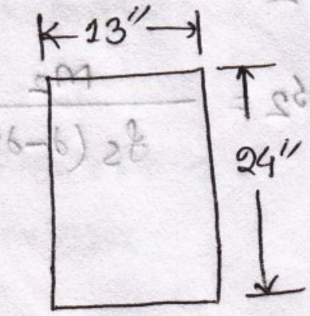
$$= 2.65 \text{ in}^2$$

(Ans)

Problem-02: (Design) → WSD

A rectangular beam is limited by architectural consideration to a width of 13 in and a total depth of 24 in. What reinforcement is required to resist a working moment of 2530 in kips. If $f_s = 20000$ psi and $f_c' = 4000$ psi

Solution:



$$n = \frac{E_s}{E_c} = \frac{29 \times 10^3}{57000\sqrt{4000}}$$

$$= 8.04 \simeq 8$$

$$r = \frac{f_s}{f_c} = \frac{20000}{1800} = 11.11$$

$$k = \frac{n}{n+r} = \frac{8}{8+11.11} = 0.42$$

$$J = 1 - \frac{k}{3} = 1 - \frac{0.42}{3} = 0.86$$

Assume, tensile reinforcement will be placed in two layers

$$d = t - 4 = 24 - 4 = 20''$$

$$M_c = \frac{1}{2} f_c jkbd^2$$

$$= \frac{1}{2} \times 1800 \times 0.86 \times 0.42 \times 13 \times (20)^2$$

$$= 1690 \text{ kip-in}$$

Since Design moment = 2530 kips in.

Since, M_c is less than design moment therefore the beam must be designed as doubly reinforced beam.

Doubly Reinforced Beam

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Formula: (USD method)

$$K = \frac{n}{n+r} \qquad r = \frac{f_s}{f_c} \qquad n = \frac{E_s}{E_c}$$

$$M_1 = \frac{1}{2} f_c j k b d^2$$

$$A_{s1} = \frac{M_1}{f_s j d}$$

$$A_{s2} = A_s - A_{s1}$$

$$f_s' = 2 \times f_s \times \frac{k - \frac{d'}{d}}{1-k} \leq f_s$$

* f_s' এর value যদি f_s এর চেয়ে বেশী থাকে তাহলে f_s এর যে মান দেওয়া থাকবে f_s এর মান সেটা ধরেই করতে হবে।

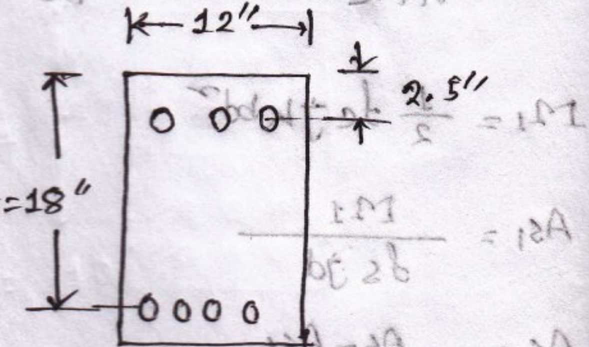
$$M_2 = A_s' f_s' (d-d')$$

$$= A_{s2} f_s (d-d')$$

$$M = M_1 + M_2$$

(1) A rectangular beam with $b = 12''$ and $d = 18''$, tension reinforcement $A_s = 4\#10$ bars. Compression reinforcement $A_s' = 3\#8$ bars. $d' = 2.5''$, $f_s = 24000$ PSI, $f_c' = 4000$ PSI. What is the allowable working moment capacity of the beam.

Solution:



$A_s = 4 \times 1.27 = 5.08 \text{ in}^2$

$A_s' = 3 \times 0.79 = 2.37 \text{ in}^2$

$n = \dfrac{E_s}{E_c} = \dfrac{29 \times 10^6}{57000\sqrt{4000}} = 8$

$r = \dfrac{f_s}{f_c} = \dfrac{24000}{0.45 \times 4000} = 13.33$

$K = \dfrac{n}{n + r}$

$= \dfrac{8}{8 + 13.33}$

$= 0.375$

$j = 1 - \dfrac{k}{3}$

$= 1 - \dfrac{0.375}{3} = 0.875$

$M_1 = \dfrac{1}{2} f_c j k b d^2$

$= \dfrac{1}{2} \times 0.45 \times 4000 \times 0.875 \times 0.375 \times (12) \times (18)^2$

$= 1148.175$ k-in

$A_{s1} = \dfrac{M_1}{f_s j d} = \dfrac{1148.175}{24 \times 0.875 \times 18}$

$= 3.04 \text{ in}^2$

Remaining steel area, $A_{S2} = A_S - A_{S1}$

$= 5.08 - 3.04 = 2.04 \text{ in}^2$

$$f_s' = 2 \times f_s \times \frac{k - \frac{d'}{d}}{1 - k}$$

$$= 2 \times 24000 \times \frac{0.375 - \frac{2.5}{18}}{1 - 0.375}$$

$= 18.13 \text{ ksi} < f_s = 24 \text{ ksi}$

$M_2 = A_s' f_s' (d - d') = 2.37 \times 18.13 \times (18 - 2.5)$

$= 666$ kips

$= A_{s2} f_s (d - d') = 2.04 \times 24000 \times (18 - 2.5)$

$= 758.88$ kips

Taking minimum moment, $M_2 = 666$ kips

$\therefore$ Total allowable moment $M_r = M_1 + M_2$

$= 1148.175 + 666$

$= 1814.175$ kip-in.

(Ans)

2005

2. A rectangular beam, b = 15", d = 28", is reinforced with 6-8# bar on tension side & 3-7# bar on compression side, concrete cover for compression side is 2.5". Calculate moment of resistance using $f_c' = 2500$ psi $f_s = 20000$ psi.

Solution:

$$A_s = 6 \times 0.79 = 4.74 \text{ in}^2$$

$$A_s' = 3 \times 0.6 = 1.8 \text{ in}^2$$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{2500}} = 10$$

$$r = \frac{f_s}{f_c} = \frac{20000}{0.45 \times 2500} = 17.78$$

$$k = \frac{n}{n+r} = \frac{10}{10+17.78} = 0.36$$

$$J = 1 - \frac{k}{3} = 1 - \frac{0.36}{3} = 0.88$$

$$M_1 = \frac{1}{2} f_c\, j k b d^2$$

$$= \frac{1}{2} \times 0.45 \times 2500 \times 0.88 \times 0.36 \times 15 \times (28)^2$$

$$= 2095.632 \text{ kip-in}$$

$$A_{s1} = \frac{M_1}{f_s\, jd} = \frac{2095.632}{20 \times 0.88 \times 28}$$

$$= 4.25 \text{ in}^2$$

$$A_{s2} = A_s - A_{s1} = 4.74 - 4.25$$

$$= 0.49 \text{ in}^2$$

$$f_s' = 2 \times f_s \times \frac{k - \frac{d'}{d}}{1 - k}$$

$$= 2 \times 20 \times \frac{0.36 - \frac{2.5}{28}}{1 - 0.36}$$

$$= 16.92 \text{ ksi} < f_s = 20 \text{ ksi}$$

$$M_2 = A_s' f_s' (d - d') = 1.8 \times 16.92 \times (28 - 2.5)$$

$$= 776.628 \text{ kip-in}$$

$$= A_{s_2} f_s (d - d') = 0.49 \times 20 \times (28 - 2.5)$$

$$= 249.9 \text{ kip-in}$$

$\therefore$ Allowable, $M_2 = 249.9$ kip-in

$\therefore$ Moment, $M = M_1 + M_2$

$$= 2095.632 + 249.9$$

$$= 2345.532 \text{ kip-in}$$

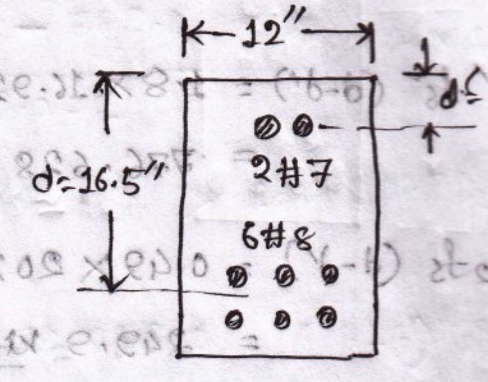
$$= 195.461 \text{ k-ft}$$

(Ans).

2006

3. A simply supported beam with $b = 12''$, $d = 16.5''$ is reinforced with 6-8# bars on tension side and 2-7# bars on compression side. If $f_c' = 2500$ psi, $f_s = 20000$ psi, $d' = 2.5''$. What uniform load can be sustained? Span = 19'

Solution:



$A_s = 6 \times 0.79 = 4.74\ in^2$

$A_s' = 2 \times 0.6 = 1.2\ in^2$

$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{2500}}$

$= 10.18 \simeq 10$

$r = \frac{f_s}{f_c} = \frac{20000}{0.45 \times 2500} = 17.78$

$K = \frac{n}{n+r} = \frac{10}{10+17.78} = 0.36$

$j = 1 - \frac{k}{3} = 1 - \frac{0.36}{3} = 0.88$

$M_1 = \frac{1}{2} f_c j K b d^2 = \frac{1}{2} \times 0.45 \times 2500 \times 0.88 \times 0.36 \times 12 \times (16.5)^2$

$= 582.18$ kips-in

$A_{s1} = \frac{M_1}{f_s j d} = \frac{582.18}{20 \times 0.88 \times 16.5} = 2.005\ in^2$

$A_{s2} = (A_s - A_{s1}) = 4.74 - 2.005 = 2.735\ in^2$

$f_s' = 2 f_s \times \frac{k - \frac{d'}{d}}{1-k} = 2 \times 20 \times \frac{0.36 - \frac{2.5}{16.5}}{1 - 0.36}$

$= 13.03$ ksi $< f_s = 20$ ksi

$M_2 = A_s' f_s' (d-d') = 1.2 \times 13.03 \times (16.5-2.5) = 218.904$ k-in

$= A_{s2} f_s (d-d') = 2.735 \times 20 \times (16.5-2.5) = 765.8$ k-in

∴ Allowable moment, $M_2 = 218.904$ k-in

∴ $M = M_1 + M_2 = 582.18 + 218.904$

$= 801.084$ k-in

$= 66.76$ k-ft

If total uniform load is ω then,

$$\frac{\omega L^2}{8} = 66.76$$

$$\Rightarrow \frac{\omega \times (19)^2}{8} = 66.76$$

$$\therefore \omega = 1.48 \text{ k/ft}$$

Now. Dead load, $\omega_D = \dfrac{12 \times (16.5+3.5)}{144} \times 150 = 250$ lb/ft

$= 0.25$ k/ft

$\omega = \omega_D + \omega_L$

$\Rightarrow \omega_L = \omega - \omega_D$

$= 1.48 - 0.25$

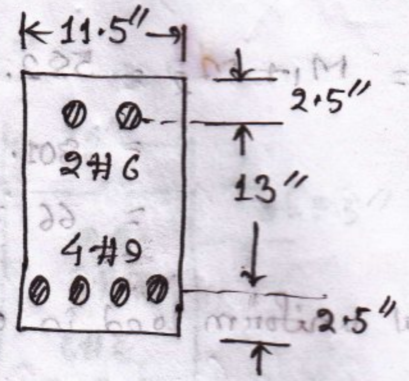
$= 1.23$ k/ft which can be sustained by the beam.

(Ans).

2007

4. A simply supported beam of span 18' is shown below. What uniform line load can be sustained by the beam if $f_s = 20$ KSI, $f_c' = 2.5$ KSI.

Solution:



$A_s = 4 \times 1 = 4 \text{ in}^2$

$A_s' = 2 \times 0.44 = 0.88 \text{ in}^2$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{2500}} = 10.175 \simeq 10$$

$$r = \frac{f_s}{f_c} = \frac{20}{0.45 \times 2.5} = 17.78$$

$$k = \frac{n}{n+r} = \frac{10}{10+17.78} = 0.36$$

$$j = 1 - \frac{k}{3} = 1 - \frac{0.36}{3} = 0.88$$

$$M_1 = \frac{1}{2} f_c jk bd^2 = \frac{1}{2} \times 0.45 \times 2.5 \times 0.88 \times 0.36 \times 11.5 \times (15.5)^2$$

$$= 492.34 \text{ k-in}$$

$$A_{s1} = \frac{M_1}{f_s jd} = \frac{492.34}{20 \times 0.88 \times 15.5} = 1.80 \text{ in}^2$$

$$A_{s2} = A_s - A_{s1} = 4 - 1.80 = 2.2 \text{ in}^2$$

$$f_s' = 2 \times f_s \times \frac{k - \frac{d'}{d}}{1-k} = 2 \times 20 \times \frac{0.36 - \frac{2.5}{15.5}}{1 - 0.36}$$

$$= 12.42 \text{ KSI} < f_s = 20 \text{ KSI}$$

$M_2 = A_s' f_s' (d-d') = 0.88 \times 12.42 \times (15.5-2.5) = 142.08$ k-in

$= A_{s2} f_s (d-d') = 2.2 \times 20 \times (15.5-2.5) = 572$ k-in

Allowable, $M_2 = 142.08$ k-in

$\therefore M = M_1 + M_2 = 492.34 + 142.08 = 634.42$ k-in

$= 52.87$ k-ft

Now,

$$\frac{wL^2}{8} = 52.87$$

$$\Rightarrow w = \frac{52.87 \times 8}{(18)^2} = 1.31 \text{ k/ft}$$

Dead load, $w_D = \dfrac{11.5 \times (2.5+13+2.5)}{144} \times 150$

$= 215.625$ lb/ft

$= 0.2156$ k/ft

$w = w_L + w_D$

$\Rightarrow w_L = w - w_D$

$= 1.31 - 0.2156$

$= 1.09$ k/ft.

(Ans)

II

Doubly reinforced beam: (USD method) ⇒ Analysis

1. A_s, $\rho = \frac{A_s}{bd}$ $\quad A_s'$, $\rho' = \frac{A_s'}{bd}$

2. $\rho_{max} = 0.85\beta_1 \frac{f_c'}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + 0.003}$

$\rho > \rho_{max}$ $\quad \therefore$ $\boxed{\text{Doubly reinforced beam}}$

3. $\bar{\rho}_{cy} = 0.85\beta_1 \frac{f_c'}{f_y} \times \frac{d'}{d} \times \frac{\varepsilon_u}{\varepsilon_u - \varepsilon_y} + \rho'$

$\boxed{\rho > \bar{\rho}_{cy}}$ হলে → Steel yield at failure

না হলে → $\boxed{\rho < \bar{\rho}_{cy} \text{ হলে},}$ → Steel will not yield at failure

$\rho > \bar{\rho}_{cy}$ (steel yield at failure):

* $a = \frac{(A_s - A_s')f_y}{0.85 f_c' b}$

* $M_n = A_s' f_y (d - d') + (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$

* $M_u = \phi M_n$

$\rho < \bar{\rho}_{cy}$ (steel will not yield at failure):

* $C_c = 0.85 f_c' ab$

* $C_s = A_s'(f_s' - 0.85 f_c')$

* $f_s' = E_s \varepsilon_u \frac{c - d'}{c}$

* $T = A_s f_y$

* $C = T$

$\Rightarrow C = C_c + C_s$

* $a = \beta_1 c$

* $M_n = A_s' f_y (d - d') + (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$

USD → Analysis (Doubly)

Prob-01: A rectangular beam has a width of 12" and effective depth of 24". Tension reinforcement consist of 6#10 bars in two rows. compression reinforcement consisting of 2 #8 bars in placed 2.5 in from the compression face of the beam. If $f_y = 60000$ psi and $f_c' = 5000$ psi what is the design moment capacity.

Solution:

$b = 12''$ $\quad d = 24''$ $\quad d' = 2.5''$

$A_s = 6 \times 1.27 = 7.62 \text{ in}^2$

$A_s' = 2 \times 0.79 = 1.58 \text{ in}^2$

$$\rho = \frac{A_s}{bd} = \frac{7.62}{12 \times 24} = 0.0265$$

$$\rho' = \frac{A_s'}{bd} = \frac{1.58}{12 \times 24} = 0.0055$$

i) $$\rho_{max} = 0.85 \beta_1 \frac{f_c'}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + 0.004}$$

$$= 0.85 \times 0.8 \times \frac{5}{60} \times \frac{0.003}{0.003 + 0.004}$$

$$= 0.0243$$

$\because \rho > \rho_{max}$ $\therefore$ The beam must be analyzed as doubly reinforced beam.

ii) $$\bar{\rho}_{cy} = 0.85 \beta_1 \frac{f_c'}{f_y} \cdot \frac{d'}{d} \cdot \frac{\varepsilon_u}{\varepsilon_u - \varepsilon_y} + \rho'$$

$$= 0.85 \times 0.8 \times \frac{5}{60} \times \frac{2.5}{24} \times \frac{0.003}{0.003 - 0.00207} + 0.0055$$

$$= 0.0245$$

$\because \bar{\rho}_{cy} < \rho$ $\therefore$ compression steel will yield at failure.

$$a = \frac{(A_s - A_s')\,f_y}{0.85 f_c' b}$$

$$= \frac{(7.62 - 1.58) \times 60}{0.85 \times 5 \times 12} = 7.11 \text{ in}$$

$$M_n = A_s' f_y (d - d') + (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$$

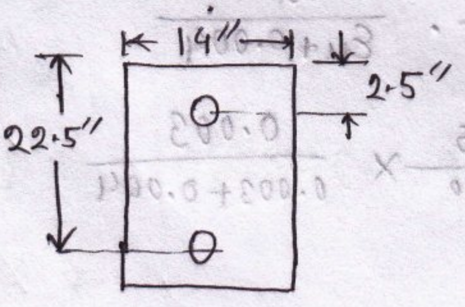
$$= 1.58 \times 60 \times (24 - 2.5) + (7.62 - 1.58) \times 60 \left(24 - \frac{7.11}{2}\right)$$

$$= 2038.2 + 7409.27$$

$$= 9447.47 \text{ k-in}.$$

$M_u = \phi M_n = 0.9 \times 9447.47 = 8502.72$ k-in. (Ans).

Prob-02: $A_s = 6\#10 = 7.62 \text{ in}^2$, $A_s' = 3\#8 = 2.37 \text{ in}^2$, $f_y = 60$ ksi, $f_c' = 5$ ksi, $M_n = ?$



Solution:

$$\rho = \frac{A_s}{bd} = \frac{7.62}{14 \times 22.5} = 0.0242$$

$$\rho' = \frac{A_s'}{bd} = \frac{2.37}{14 \times 22.5} = 0.0075$$

$$\rho_{max} = 0.85 \beta_1 \frac{f_c'}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + 0.004} = 0.85 \times 0.8 \times \frac{5}{60} \times \frac{0.003}{0.003 + 0.004}$$

$$= \cancel{0.0324}\ 0.0242$$

$\rho \simeq \rho_{max}$

∴ The beam will be analyzed as doubly reinforced beam.

$$\bar{\rho}_{cy} = 0.85\beta_1 \frac{f_c'}{f_y} \cdot \frac{d'}{d} \cdot \frac{\varepsilon_u}{\varepsilon_u - \varepsilon_y} + \rho'$$

$$= 0.85 \times 0.8 \times \frac{5}{60} \times \frac{2.5}{22.5} \times \frac{0.003}{0.003 - 0.00207} + 0.0075$$

$$= 0.0278$$

∴ $\rho < \bar{\rho}_{cy}$ ∴ Compression steel will not yield at failure.

$$C_c = 0.85 f_c' ab = 0.85 f_c' \beta_1 c b$$

$$= 0.85 \times 5 \times 0.8 \times c \times 14$$

$$= 47.6\, c$$

$$C_s = A_s' (f_s' - 0.85 f_c')$$

$$f_s' = E_s \varepsilon_u \cdot \frac{c - d'}{c} = 29000 \times 0.003 \times \frac{c - 2.5}{c}$$

$$C_s = 2.37 \left(87 \times \frac{c - 2.5}{c} - 0.85 \times 5 \right)$$

$$= \frac{206.19c - 515.475}{c} - 10.0725$$

$$C = T = A_s f_y = 7.62 \times 60 = 455.4$$

$$\Rightarrow C = C_c + C_s = 47.6c + \frac{206.19c - 515.475 - 10.0725c}{c} = 455.4$$

$$\Rightarrow c^2 = 47.6c^2 + 196.12c - 515.475 - 455.4$$

$$\Rightarrow 46.6c^2 + 196.12c - 515.475 - 455.4 = 0$$

$\therefore c =$

$C = T$

$\Rightarrow C_c + C_s = 455.4$

$\Rightarrow 47.6c + \dfrac{206.19c - 515.475 - 10.0725c}{c} = 455.4$

$\Rightarrow 47.6c^2 + \cancel{20}\, 196.12c - 515.475 - 455.4c = 0$

$\Rightarrow 47.6c^2 - 259.28c - 515.475 = 0$

$\therefore c = 7$ in

$a = \beta_1 c = 0.8 \times 7 = 5.6$ in

$M_n = A_s' f_y (d - d') + (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$

$= 2.37 \times 60 \times (22.5 - 2.5) + (7.62 - 2.37) \times 60 \times \left(22.5 - \frac{5.6}{2}\right)$

$= 2844 + 6205.5$

$= 9049.5$ k-in

$M_u = \phi M_n$

$= 0.9 \times 9049.5$

$= 8144.55$ k-in (Ans).

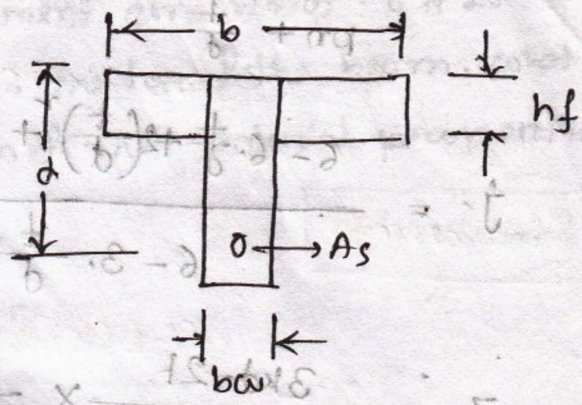
T-beam

T-beam

(Analysis - USD method)

090063
AHSAN

Formula:



1. $a = \dfrac{A_s f_y}{0.85 f_c' b}$

If $a > h_f$ then ~~+~~ T-beam confirmed

2. $\boxed{\text{For beam F}}$

$$A_{sf} = \frac{0.85 f_c' (b - b_w) h_f}{f_y}$$

$$M_{nF} = A_{sf} f_y \left(d - \frac{h_f}{2}\right)$$

3. $\boxed{\text{For beam W}}$

Remaining steel for web concrete.

$$A_{sw} = A_s - A_{sf}$$

$$M_{nW} = (A_s - A_{sf}) f_y \left(d - \frac{a}{2}\right)$$

$$M_n = M_{nF} + M_{nW}$$

Ultimate moment, ~~ϕ~~ $M_u = \phi M_n$

Analysis – WSD method

$$p = \frac{A_s}{bd}$$

$$k = \frac{pn + \frac{1}{2}\cdot\left(\frac{t}{d}\right)^2}{pn + \frac{t}{d}}$$

$$j = \frac{6 - 6\cdot\frac{t}{d} + 2\left(\frac{t}{d}\right)^2 + \left(\frac{t}{d}\right)^3 \times \frac{1}{2pn}}{6 - 3\cdot\frac{t}{d}}$$

$$z = \frac{3kd - 2t}{2kd - t} \times \frac{t}{3}$$

$jd = d - z$

$$M = A_s f_s jd$$

$$M = f_c\left(1 - \frac{t}{2kd}\right) bt\, jd$$

Average stress of concrete $= f_c\left(1 - \frac{t}{2kd}\right)$.

For T-beam:

$\rho_{w,max} = 0.75\rho_b + \rho_f$ $\qquad [\rho_{max} = 0.75\rho_b]$

$$\rho_w = \frac{A_s}{b_w d}$$

$$\rho_b = 0.85\beta_1 \frac{f_c'}{f_y}\left(\frac{87000}{87000 + f_y}\right)$$

$$\rho_f = \frac{A_{sf}}{b_w d}$$

$\rho_w < \rho_{w,max}$

4000 $\beta_1 = 0.85$, 0.8, $\beta = 0.425$, $\frac{c}{\beta_1} =$

Analysis - USD method

090063
AHSAN

CE-06

Problem-01:

A T beam is comprised of 28 in wide flange and 6 in deep cast monolithically with a web of 10 in that extends 24 in. below the bottom surface of the flange. Tensile reinforcement consists of 6 # 10 bars. The centroid of the bars is 26 in from the top of the beam. What is the design moment capacity of the beam if the material properties are $f_c' = 3000$ psi and $f_y = 60000$ psi.

Solution:

$b = 28"$ $h_f = 6"$ $b_w = 10"$ $A_s = 6 \times 1.27 = 7.62 \text{ in}^2$

$d = 26"$ $f_c' = 3000$ psi $f_y = 60000$ psi

$$a = \frac{A_s f_y}{0.85 f_c' b}$$

$$= \frac{7.62 \times 60000}{0.85 \times 3000 \times 28}$$

$$= 6.40 \text{ in}$$

$\because a > h_f \therefore$ It is a T-beam

For beam F

$$A_{sf} = \frac{0.85 f_c' (b - b_w) h_f}{f_y}$$

$$= \frac{0.85 \times 3000 \times (28 - 10) \times 6}{60000}$$

$$= 4.59 \text{ in}^2$$

$$M_{nF} = A_{sf}\, f_y \left(d - \frac{h_f}{2}\right)$$

$$= 4.59 \times 60000 \times \left(26 - \frac{6}{2}\right)$$

$$= 6.33 \times 10^6 \text{ lb-in}$$

$$= 6334.2 \text{ k-in}$$

Note : dt

* For single layer reinforcement
$d_t = d$

* For multiple layer reinforcement
$d_t > d$

For beam W

$$a = \frac{(A_s - A_{sf}) f_y}{0.85 f_c' b_w}$$

$$= \frac{(7.62 - 4.59) \times 60000}{0.85 \times 3000 \times 10}$$

$$= 7.13 \text{ in}$$

$$M_{n \cdot w} = (A_s - A_{sf}) f_y \left(d - \frac{a}{2}\right)$$

$$= (7.62 - 4.59) \times 60000 \times \left(26 - \frac{7.13}{2}\right)$$

$$= 4.07 \times 10^6 \text{ lb-in}$$

$$= 4079.59 \text{ k-in}$$

$$\therefore M_n = M_{nf} + M_{nw} = 6334.2 + 4079.59$$

$$= 10413.792 \text{ lb-in}$$

$$d_t = 30 - 2.5$$

$$d_t = 27.5 \; ?$$

$$c = \frac{a}{\beta_1}$$

$$=$$

$$\frac{c}{d_t} = \frac{\boxed{8.39}}{27.5} = 0.305 < 0.375 \quad \text{So, } \varepsilon_t > 0.005$$

$$\therefore \phi = 0.90$$

ultimate moment, $M_u = \phi M_n$

$= 0.90 \times 10413.792$

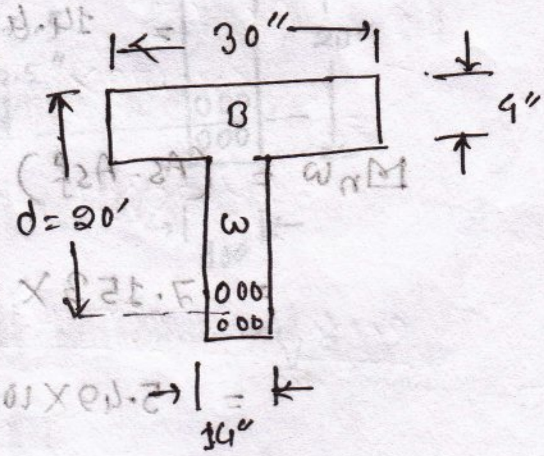
$= 9372.4128$ kips-in (Ans).

07/06

Problem 02:

A isolated T-beam is composed of a flange width of 30", web width 14", thickness 4", steel centroid 20", $f_y = 60000$ psi, $f_c' = 2500$ psi, $A_s = 6 \# 11$. Compute moment capacity.

Solution:



$$a = \frac{A_s f_y}{0.85 f_c' b}$$

$$= \frac{6 \times 1.57 \times 60000}{0.85 \times 2500 \times 30}$$

$$= 8.86 \text{ in}$$

$\because a > h_f$. It is T-beam

For beam F

$$A_{sf} = \frac{0.85 f_c' (b - b_w) h_f}{f_y}$$

$$= \frac{0.85 \times 2500 \times (30 - 14) \times 4}{60000}$$

$$= 2.267 \text{ in}^2$$

$$M_{nf} = A_{sf} f_y \left(d - \frac{h_f}{2}\right)$$

$$= 2.267 \times 60000 \times \left(20 - \frac{4}{2}\right)$$

$$= 2.448 \times 10^6 \text{ lb-in}$$

$$=$$

$\boxed{\text{for beam } w}$

$$a = \frac{(A_s - A_{sf}) f_y}{0.85 f_c' b_w}$$

$$= \frac{(6 \times 1.57 - 2.267) \times 60000}{0.85 \times 2500 \times 14}$$

$$= 14.43 \text{ in}^2$$

$$M_{nw} = (A_s - A_{sf}) f_y \left(d - \frac{a}{2}\right)$$

$$= 7.153 \times 60000 \times \left(20 - \frac{14.43}{2}\right)$$

$$= 5.49 \times 10^6 \text{ lb-in}$$

$$M_n = M_{nf} + M_{nw} = (2.448 + 5.49) \times 10^6$$

$$= 7.938 \times 10^6 \text{ lb-in}$$

$$M_u = \phi M_n$$

$$= 0.9 \times 7.938 \times 10^6$$

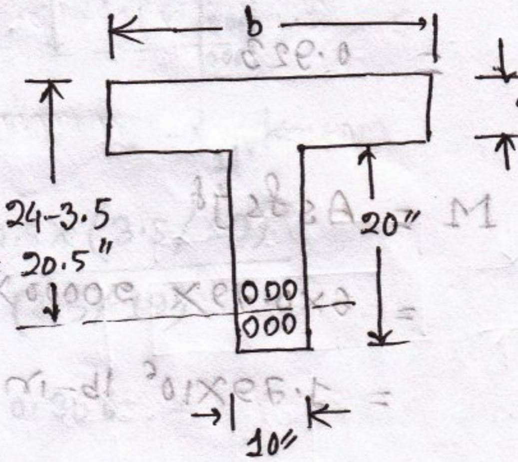
$$= 7.14 \times 10^6 \text{ lb-in}$$ (Ans).

Analysis - WSD method

Problem 3:

A floor slab 4" thick is supported by R.C beams 9' on centers. The beams are simple supported of 19' span. Web dimension = 10" X 20". As = 6 #8 bars in two rows 2 inch centre to centre vertically. The center of the lower row being $2\frac{1}{2}$" above the lower surface of the beam. $f_c' = 2500$ psi, $f_s = 20000$ psi. Find allowable working moment of the beam.

Solution:



$$b = \frac{L}{4} = \frac{19 \times 12}{4} = \boxed{57 \text{ in}}$$

$$b = 16t + b_w = 16 \times 4 + 10 = 74 \text{ in}$$

$$b = \text{centerline spacing} = 9' = 108"$$

$$\boxed{\therefore b = 57 \text{ in}}$$

$$\rho = \frac{A_s}{bd} = \frac{6 \times 0.79}{57 \times 20.5} = 0.004$$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{2500}} = 10.18 \simeq 10$$

$$k = \frac{np + \frac{1}{2}\left(\frac{t}{d}\right)^2}{np + \frac{t}{d}} = \frac{10 \times 0.004 + \frac{1}{2}\left(\frac{4}{20.5}\right)^2}{10 \times 0.004 + \frac{4}{20.5}}$$

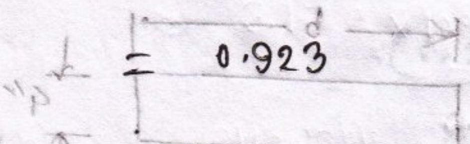
$$= \frac{0.059}{0.235} = 0.25$$

$kd = 0.25 \times 20.5 = 5.125'' > t = 4''$

Therefore the beam must be analyzed as a T-beam.

$$j = \frac{6 - 6\left(\frac{t}{d}\right) + 2\left(\frac{t}{d}\right)^2 + \left(\frac{t}{d}\right)^3 \times \frac{1}{2\rho n}}{6 - 3 \cdot \frac{t}{d}} \qquad \frac{t}{d} = \frac{4}{20.5} = 0.195$$

$$= \frac{6 - 6 \times 0.195 + 2(0.195)^2 + (0.195)^3 \times \frac{1}{2 \times 0.004 \times 10}}{6 - 3 \times 0.195}$$



$= 0.923$

$M = A_s f_s j d$

$= 6 \times 0.79 \times 20000 \times 0.923 \times 20.5$

$= 1.79 \times 10^6$ lb-in.

<u>check</u> <u>for concrete</u> <u>stress</u>:

$$f_c = \frac{M}{\left(1 - \frac{t}{2kd}\right) b t j d}$$

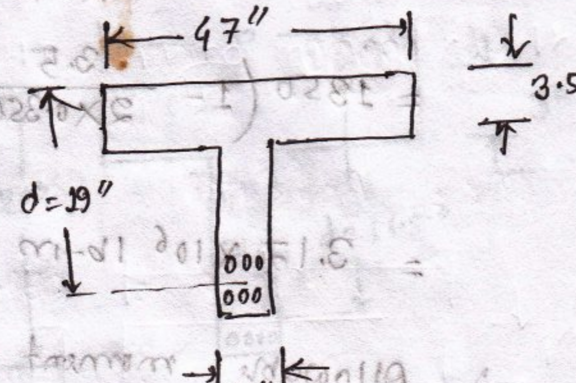
$$= \frac{1.79 \times 10^6}{\left(1 - \frac{4}{2 \times 5.125}\right) \times 20.5 \times 4 \times 0.923 \times 57}$$

$= 680.47$ PSI

Problem-4

A T-beam section with $b = 47''$, $b_w = 11''$, $h_f = 3.5''$, $d = 19''$ is reinforced with six no 10 bars in two rows calculate the moment of resistance of the beam if $f_c' = 3000$ psi and $f_y = 60000$ psi

Solution:



$$\rho = \frac{A_s}{bd} = \frac{6 \times 1.27}{47 \times 19}$$

$$= 0.0085.$$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9.28 \simeq 9$$

$k =$

$$K = \frac{np + \frac{1}{2}\left(\frac{t}{d}\right)^2}{np + \frac{t}{d}} = \frac{9 \times 0.0085 + 0.5 \times (3.5/19)^2}{9 \times 0.0085 + (3.5/19)}$$

$$= \frac{0.093}{0.261} = 0.356$$

$$j = \frac{6 - 6 \cdot \frac{t}{d} + 2\left(\frac{t}{d}\right)^2 + \left(\frac{t}{d}\right)^3 \cdot \frac{1}{2pn}}{6 - 3 \cdot \frac{t}{d}}$$

$$\left[\frac{t}{d} = \frac{3.5}{19} = 0.184\right.$$

$$= \frac{6 - 6 \times 0.184 + 2(0.184)^2 + (0.180)^3 \times \frac{1}{2 \times 0.0085 \times 9}}{6 - 3 \times 0.184}$$

$$= 1.015$$

$kd = 0.356 \times 19 = 6.764 > t = 3.5''$

Therefore the beam must be analysis as a T-beam.

Steel,

$$M = A_s f_s jd$$

$$= 6 \times 1.27 \times 24000 \times 1.015 \times 19$$

$$= 3.52 \times 10^{6}\ \text{lb-in}$$

$$f_s = 0.4 f_y = 0.4 \times 60000 = 24000\ \text{psi}$$

Concrete,

$$M = f_c \left(1 - \frac{t}{2kd}\right) bt\, jd$$

$$= 1350 \left(1 - \frac{3.5}{2 \times 0.356 \times 19}\right) \times 47 \times 3.5 \times 1.015 \times 19$$

$$= 3.17 \times 10^{6}\ \text{lb-in}$$

$$f_c = 0.45 f_c' = 0.45 \times 3000 = 1350\ \text{psi}$$

$\therefore$ Allowable moment $= 3.17 \times 10^{6}$ lb-in (Ans).

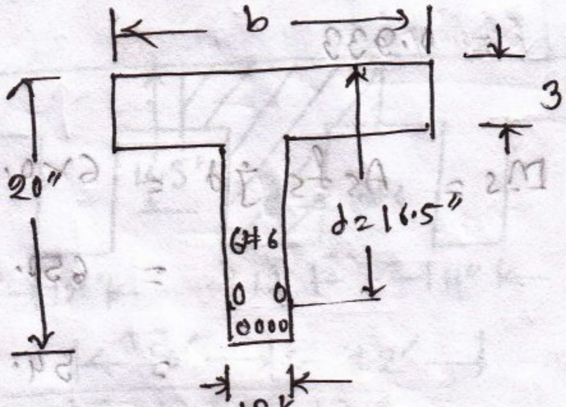
2004

Problem-5

WSD

An interior T-beam in floor system has clear span from face to face of columns of 18′ and the cross-section show below. concrete and steel strength are 3000 psi and 40000 psi. Beam spacing is 10′ c/c. Compute design moment capacity

Solution:



$b = \frac{L}{4} = \frac{18 \times 12}{4} = \boxed{54 \text{ in}}$

$b = 16t + b_w = 16 \times 3 + 12$
$= 60$ in

$b = c/c = 10' = 120$ in

$\therefore b = 54$ in

$f_c' = 3000$ psi
$f_y = 40000$ psi
$f_s = 0.4 f_y$
$= 16000$
$f_c = 0.45 f_c'$
$= 1350$ psi

$\rho = \frac{A_s}{bd} = \frac{6 \times 0.44}{54 \times 16.5} = 0.0029$

$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9.28 \simeq 9$

$k = \frac{np + \frac{1}{2}\left(\frac{t}{d}\right)^2}{np + \frac{t}{d}} = \frac{9 \times 0.0029 + 0.5 \times (3/16.5)^2}{9 \times 0.0029 + 3/16.5}$

$= \frac{0.043}{0.208} = 0.207$

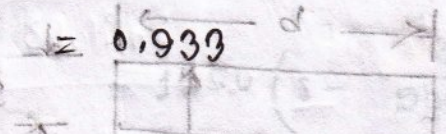
$kd = 0.207 \times 16.5 = 3.42 > t = 3''$

$\therefore$ T beam is ensured

$$j = \frac{6 - 6\cdot\frac{t}{d} + 2\left(\frac{t}{d}\right)^2 + \left(\frac{t}{d}\right)^3 \times \frac{1}{2pn}}{6 - 3\cdot\frac{t}{d}} \qquad \frac{t}{d} = \frac{3}{16.5} = 0.182$$

$$= \frac{6 - 6\times 0.182 + 2(0.182)^2 + (0.182)^3 \times \frac{1}{2\times 0.0029\times 9}}{6 - 3\times 0.182}$$

$$= 0.933$$



$$M_s = A_s f_s jd = 6\times 0.44\times 16000\times 0.933\times 16.5$$

$$= 650.27\times 10^3 \text{ lb-in}$$

$$= 54.18 \text{ k-ft}$$

$$M_c = f_c\left(1 - \frac{t}{2kd}\right) bdjt$$

$$= 1350\left(1 - \frac{3}{2\times 3.42}\right)\times 16.5\times 54\times 0.933\times 3$$

$$= 1.89\times 10^6 \text{ lb-in}$$

$$= 157.5 \text{ k-ft}$$

$\therefore$ working moment = 54.18 k-ft.

(Ans).

False-T (analysis)

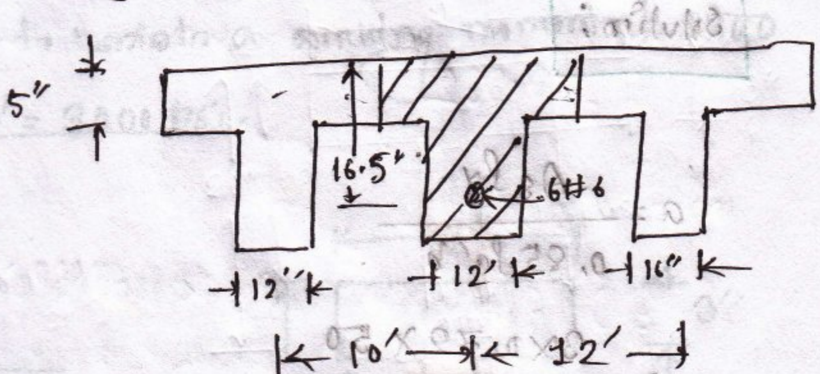
2005

Problem-6

An interior T-beam in floor system has clear span from face to face of columns of 18' and cross-section shown below, compute the $\boxed{\text{design moment}}$ capacity of beam using $f_c' = 3$ ksi and $f_y = 40$ ksi

$\boxed{\text{USD}}$

Solution:



$b = \frac{L}{4} = \frac{18\times 12}{4} = \boxed{54 \text{ in}}$

$b = 16t + b_w = 16\times 5 + 12$
$= 92$ in

$b = 5' + 6' = 11' = 132$ in

$\therefore \quad b = 54$ in

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{6\times 0.44\times 40}{0.85\times 3\times 54} = 0.767 \text{ in}$$

Since, $a < h_f = 5''$ so, the beam acts as a rectangular beam

$$M_n = A_s f_y\left(d - \frac{a}{2}\right) = 6\times 0.44\times\left(16.5 - \frac{0.767}{2}\right)\times 40000$$
$$= 42.55 \cancel{\text{lb-in}} \times 40000 = 1702000 \text{ lb-in}$$

$$c = \frac{a}{\beta_1} = \frac{0.767}{0.85} = 0.902$$

$$\frac{c}{d_t} = \frac{0.902}{16.5} = 0.05 < 0.375 \qquad \therefore \phi = 0.9$$

$$\therefore M_u = \phi M_n = 0.9\times \cancel{42.55} = 1.702\times 10^6 = 1.53\times 10^6 \text{ lb-in}$$
$$= 127.65 \text{ k-ft}$$

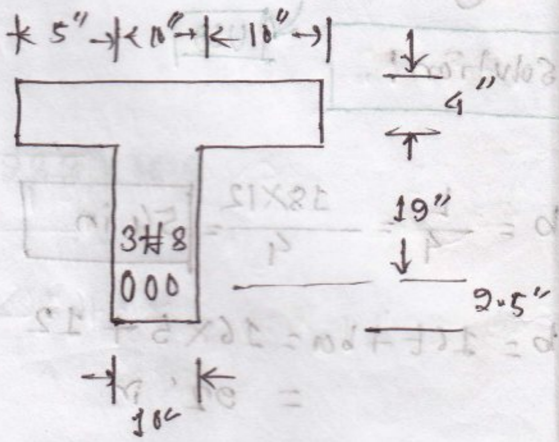
(Ans).

2005

Problem-7

1.b Find the ultimate moment of resistance of the section shown below if $f_c' = 2.5$ ksi, $f_y = 50$ ksi.

Solution:



$$a = \frac{A_s f_y}{0.85 f_c' b}$$

$$= \frac{3 \times 0.79 \times 50}{0.85 \times 2.5 \times 25}$$

$$= 2.23$$

$\therefore$ $a < h_f = 4''$ so, the beam acts a rectangular beam

$$M_u = \phi M_n$$

$$= \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$= 0.9 \times 3 \times 0.79 \times 50000 \left(23 - \frac{2.23}{2}\right)$$

$$= 2.33 \times 10^6 \text{ lb-in}$$

$$= 194.5 \text{ k-ft}$$

(Ans).

Design (WSD)

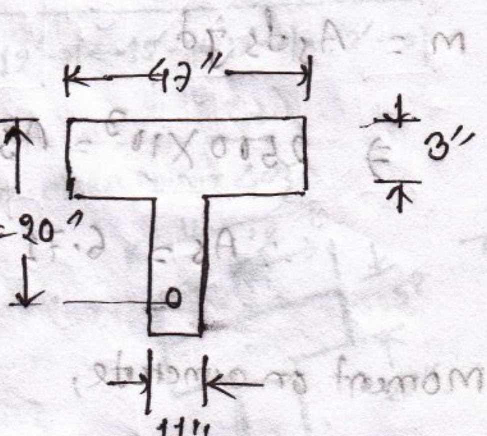
AHSAN
090063

2004, 2007

Problem-08

A floor system consist of a 3″ concrete slab supported by continuous T-beam of 24′ span, 47″ on centres web dimensions as determined by negative flexural requirements at the supports are $b_w = 11''$ and $d = 20''$. What tensile steel area is required at midspan to resists a working moment of 2500 kip-inch if $f_s = 20000$ psi and $f_c' = 3000$ psi.

Solution



$$n = \frac{E_s}{E_c} = \frac{29\times10^6}{57000\sqrt{3000}}$$

$$= 9.28 \simeq 9$$

$$\boxed{M = A_s f_s \left(d - \frac{h_f}{2}\right)}$$

$$\Rightarrow 2500\times10^3 = A_s \times 20000 \times \left(20 - \frac{3}{2}\right)$$

$$\therefore A_s = 6.76 \text{ in}^2$$

$$\rho = \frac{A_s}{bd} = \frac{6.76}{47\times20} = 0.007188$$

$$\rho n = 0.007188 \times 9$$
$$= 0.06469$$

$$\frac{t}{d} = \frac{3}{20} = 0.15$$

$$K = \frac{\rho n + \frac{1}{2}\left(\frac{t}{d}\right)^2}{\rho n + \frac{t}{d}} = \frac{0.06469 + \frac{1}{2}(0.15)^2}{0.06469 + 0.15}$$

$$= 0.354$$

$$Kd = 0.354\times20 = 7.07 > t = 3''$$

∴ The beam will be analyzed as a T-beam.

$$J = \frac{6 - 6\frac{t}{d} + 2\left(\frac{t}{d}\right)^2 + \left(\frac{t}{d}\right)^3 \times \frac{1}{2pn}}{6 - 3.\frac{t}{d}}$$

$$= \frac{6 - 6\times 0.15 + 2(0.15)^2 + (0.15)^3 \times \frac{1}{2\times 0.06469}}{6 - 3\times 0.15}$$

$$= 0.932$$

$$M = A_s f_s j d$$

$$\Rightarrow 2500\times 10^3 = A_s \times 20000 \times 0.932 \times 20$$

$$\therefore A_s = 6.71 \text{ in}^2$$

Moment on concrete,

$$M = f_c\left(1 - \frac{t}{2kd}\right) b t j d$$

$$\Rightarrow 2500\times 10^3 = f_c\left(1 - \frac{3}{2\times 7.02}\right)\times 47\times 3\times 0.932\times 20$$

$$\therefore f_c = 1207.37 < 1350$$

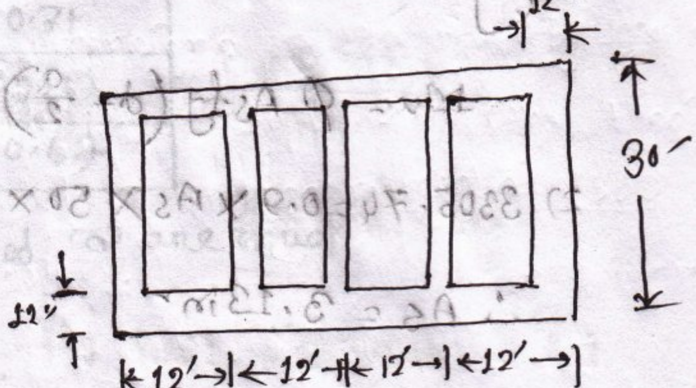
$\therefore$ Area of the steel $= 6.71 \text{ in}^2$ (Ans).

2007

Problem- 9 (USD)

Design an interior beam of the floor system shown between T-beam with following data: slab thickness = 5", LL = 80 psf, $f_c' = 3$ ksi, $f_y = 50$ ksi

Apply USD method.



Solution:

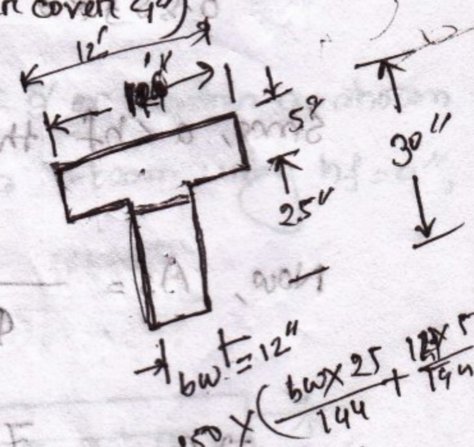
$h_f = 5''$ $b_w = 12''$

$c/c = 12'$ $L = 30-1-1$

$= 28'$

Let, $h = 30''$

$d = 30-4 = 26''$ (assuming two layer of steel with clear cover 4")



i) $b = \frac{L}{4} = \frac{28 \times 12}{4} = 84''$

ii) $b = 16t + b_w = 16 \times 5 + 12 = 92''$

iii) $b = c/c = 12 \times 12 = 144''$

$\therefore b = 84''$

$D.L = \left(\frac{c/c \times h_f}{144} + \frac{25 \times b_w}{144}\right) \times 150 = \left(\frac{144 \times 5}{144} + \frac{25 \times 12}{144}\right) 150$

$= 1062.5$ plf

$L.L = 80$ psf $= 80 \times c/c = 80 \times 12 = 960$ plf

$w_u = 1.2 \times D.L + 1.6 \times L.L$

$= 1.2 \times 1062.5 + 1.6 \times 960$

$= 2811$ lb/ft

$$M_u = \frac{w_u L^2}{8} = \frac{2811 \times (28)^2}{8} = 275478 \text{ lb-ft}$$

$$= 3305.74 \text{ k-in}$$

Assuming $a = 5'' = h_f$

$$M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$\Rightarrow 3305.74 = 0.9 \times A_s \times 50 \times \left(26 - \frac{5}{2}\right)$$

$$\therefore A_s = 3.13 \text{ in}^2$$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{3.13 \times 50}{0.85 \times 3 \times 84} = 0.73 < h_f$$

Since, $a < h_f$ the beam act as a rectangular beam.

Now, $$A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)} = \frac{3305.74}{0.9 \times 50 \times (26 - 0.5a)}$$

$$\Rightarrow A_s = \frac{73.46}{26 - 0.5a} \quad \ldots \ldots (i)$$

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{A_s \times 50}{0.85 \times 3 \times 84}$$

$$\Rightarrow a = 0.233 A_s \quad \ldots \ldots (ii)$$

Using (i) and (ii) by trial and error, we get,

assumed a	$A = \frac{73.46}{26-0.5a}$	check $a = 0.233 As$
4	3.06	0.71
0.71	2.86	0.67
0.67	2.86	0.67

At 3rd trial assumed 'a' and checked 'a' are equal

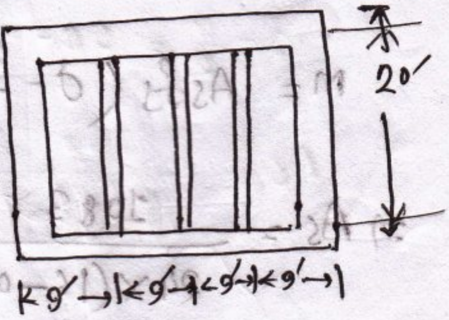
$\therefore As = 2.86\ in^2$ (Ans).

2008

Problem-10 (WSD)

The floor slab is supported by beams spaced at 9' on centres as shown in the figure. Design anyone of the interior beam as T-beam using $h_f = 4''$, $b_w = 12''$, LL = 150 psf, $f_c' = 3$ ksi, $f_y = 60$ ksi.

Solution:



$c/c = 9'$ $h_f = 4''$ · $b_w = 12''$

$L = 20 - \frac{1}{2}\left(\frac{12}{12}\right) - \frac{1}{2}\left(\frac{12}{12}\right) = 19'$

Let, $h = 20''$ $d = 20'' - 4'' = 16''$

Calculation for b,

i) $\frac{L}{4} = \frac{19 \times 12}{4} = 57$ in

ii) $16t + b_w = 16 \times 4 + 12 = 76''$

iii) $c/c = 9 \times 12 = 108''$

$\therefore b = 57$ in

$$D.L = \left(\frac{c/c \times h_f}{144} + \frac{16 \times b_w}{144} \right) 150$$

$$= \left(\frac{108 \times 4}{144} + \frac{16 \times 12}{144} \right) 150$$

$$= 650 \text{ plf}$$

$$LL = 150 \times 9 = 1350 \text{ plf}$$

$$w_u = 650 + 1350 = 2000 \text{ plf}$$

$$M = \frac{wL^2}{8} = \frac{2000 \times (19)^2}{8} = 90250 \text{ lb-ft} = 1083 \text{ k-in}$$

$$n = \frac{29 \times 10^6}{57000 \sqrt{3000}} = 9.28 \simeq 9$$

$$M = A_s f_y \left(d - \frac{h_f}{2} \right)$$

$$\Rightarrow A_s = \frac{1083}{24 \times (16 - 0.5 \times 4)} = 3.22 \text{ in}^2$$

$$\rho = \frac{A_s}{bd} = \frac{3.22}{57 \times 16} = 0.0035$$

$$\rho n = 0.0035 \times 9 = 0.0315$$

$$k = \frac{\rho n + \frac{1}{2} \left(\frac{t}{d} \right)^2}{\rho n + \frac{t}{d}} = 0.22$$

$kd = 0.22 \times 16 = 3.56 < h_f$

So the beam acts as rectangular.

Problem-11

A floor system consist of 3 in concrete slab supported by continuous T beam with a 24 ft span 47 in on centers, web dimension are $b_w = 11$ in and $d = 20$, what tensile steel area is required at midspan to resist a factored moment of 6400 in-kips if $f_c' = 3000$ psi and $f_y = 60000$ psi.

Solution:

$$b = \frac{L}{4} = \frac{24 \times 12}{4} = 72 \text{ in}$$

$$b = 16t + b_w = 16 \times 3 + 11 = 59 \text{ in}$$

$$b = c/c = 47 \text{ in}$$

$$\therefore b = 47 \text{ in}$$

$$d - \frac{a}{2} = 20 - \frac{3}{2} = 18.5 \text{ in}$$

$$A_s = \frac{M_u}{\phi f_y \left(d - \frac{a}{2}\right)} = \frac{6400}{0.9 \times 60 \times (18.5}$$

$$= 6.41 \text{ in}^2$$

$$\rho = \frac{A_s}{bd} = \frac{6.41}{47 \times 20} = 0.00682$$

Lintel

Design of Lintel

090063
AHSAN

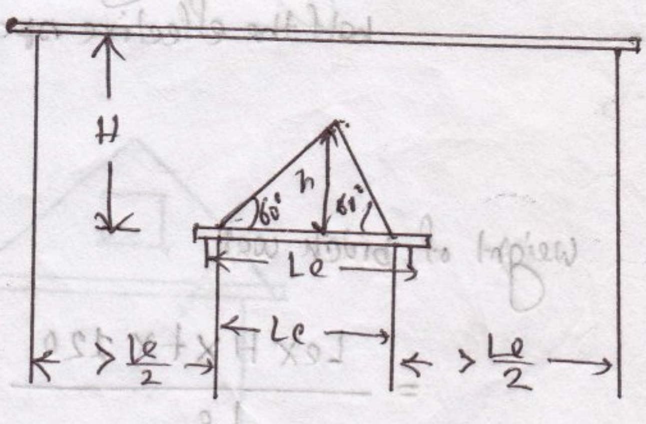
Lintel :

A lintel may be defined as a beam provided over an opening usually for door, window etc in a wall.

Computation of load for design of lintel :

Case I $\Rightarrow$ When the length of wall on either side of the opening is more than half the effective span of the lintel.

Le = Clear span
Le = Effective span



In this case only the weight of masonry contain in an equilateral triangle is transferred on the lintel.

$$h = \frac{1}{2} Le \tan 60^\circ$$

Volume = $\frac{1}{2} \times Le \times h \times t$ → Thickness of the brick

Total load = $\frac{1}{2} \times Le \times h \times t \times 120$

↓ unit weight of brick

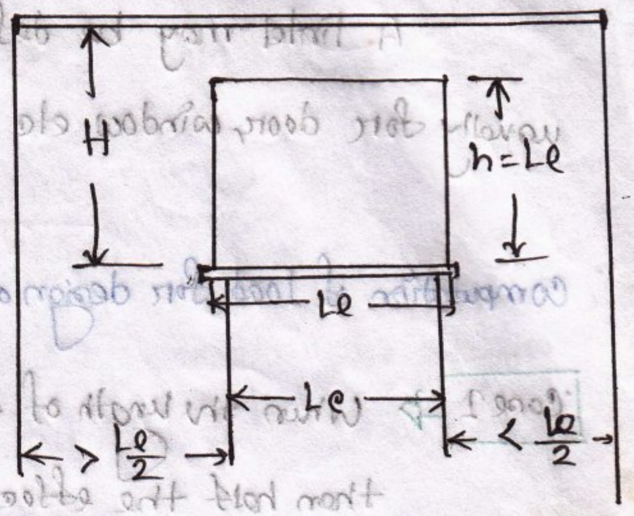
$\boxed{h < H}$

$\boxed{\text{case 2}} \Rightarrow$ When the length of wall on one side of the opening is less than half the effective span of the lintel.

weight of brick wall

$$= \frac{Le \times h \times t \times 120}{Le}$$

$$= h \times t \times 120$$

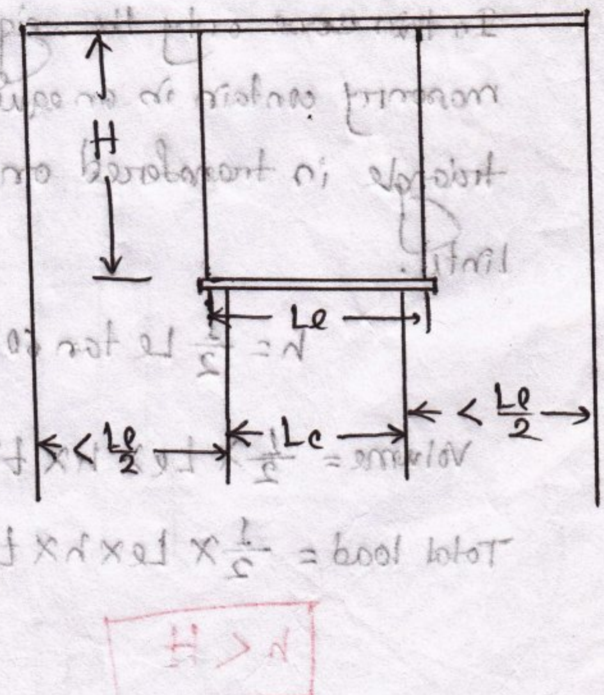


$\boxed{\text{case-3}} \Rightarrow$ When the length of wall on both side of the opening is less than half the effective span of the lintel

weight of brick wall

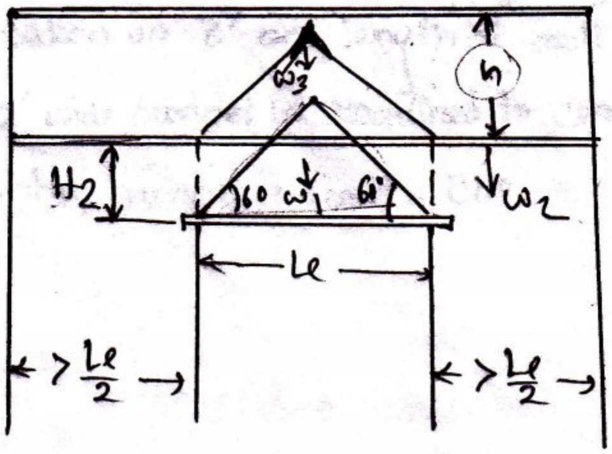
$$= \frac{Le \times H \times t \times 120}{Le}$$

$$= H \times t \times 120$$



Case-4 ⇒ when a slab transfers load to lintel this case may arrise if h is greater than H.

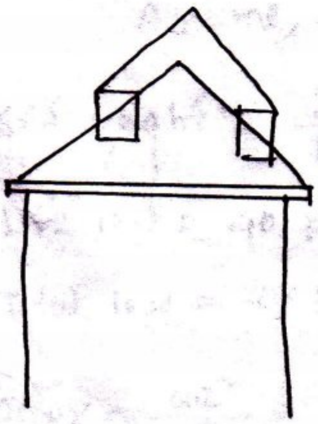
Loads to be considered in this case,

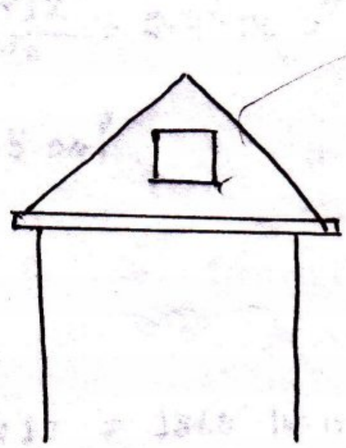


1. $\omega_1 = H_2 \times Le \times t \times 120$
2. ω_2 = Design load of slab
3. $\omega_3 = \frac{1}{2} \times Le \times h \times t \times 120$

$\boxed{h > H}$

Case-5 ⇒ when the wall above the lintel has openings





Example-01:

Design a RC Lintel over a window opening 6′ wide. The window is to be centrally located on 10″ thick brick wall. Height of the brickwall above the lintel may be taken as 6′ and length of wall on both sides of the opening is 2.5′. A 2′ wide sunset is required to cast monolithic with the lintel. Design the sunset as well. Use $f_c' = 3000$ psi and $f_s = 24000$ psi.

Solution:

1. Relevent properties:

$J = 0.86 \quad k = 0.39$ (Assume)

2. Load calculation:

$$\text{Assume, } t = \frac{L}{10} = \frac{2 \times 12}{10} = 2.4'' \simeq 3''$$

$$\text{Self weight} = \frac{3}{12} \times 150 = 37.5 \text{ psf}$$

Live load = 40 plf. ?

$\therefore$ Total load = 77.5 plf

lb/ft.ft

$$M_{max} = \frac{wL^2}{2} = \frac{77.5 \times (2)^2}{2} \times 12 = 1860 \text{ lb-in}$$

$$V_{max} = wL = 77.5 \times 2 = 155 \text{ lb}$$

3. Depth check:

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{1860}{229 \times 12}} = 0.82 \text{ in} < 2 \text{ in (ok)} \; ?$$

$$R = \frac{1}{2} f_c jk = \frac{1}{2} \times \cancel{3000}^{1350} \times 0.86 \times 0.39 = 229 \text{ psi}$$

Actual, $d = t - c.c - \frac{\phi}{2} = 3 - 1 = 2''$

4. Reinforcement calculation:

$$A_s = \frac{M}{f_s j d}$$

$$= \frac{1860}{24000 \times 0.86 \times 2}$$

$$= 0.045 \text{ in}^2$$

$A_{s\,min} = 0.0018\,bt = 0.0018 \times 12 \times 3 = 0.065 \text{ in}^2$

$\because A_{s\,min} > A_s$

$\therefore A_s = 0.065 \text{ in}^2$

#3 bar is used, $S = \frac{0.11 \times 12}{0.065} = 20.31 \text{ in}$

$S_{max} = 3t = 3 \times 3 = 9 \text{ in}$

Therefore, use #3 bars @ 9 in c/c

5. Distribution reinforcement:

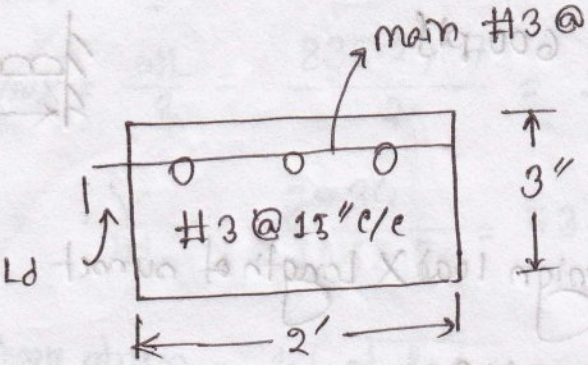
$A_{st} = 0.0018\,bt = 0.065 \text{ in}^2$

#3 bar is used, $S = 20.31 \text{ in}$

$S_{max} = 5t = 5 \times 3 = 15 \text{ in}$

Therefore, use #3 bars @ 15 in c/c

Bond check:



Design of lintel:

width of opening = 3 ft

Consider 12" bearing on each side

$\therefore$ Effective span $= \frac{12''}{2} + 6' + \frac{12''}{2}$

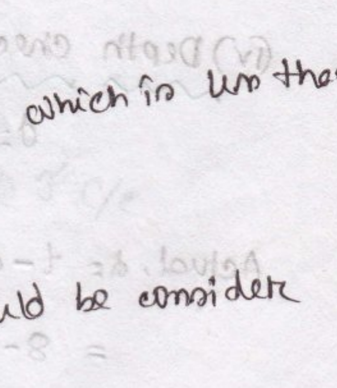
$= 7$ ft

Length of brick wall on each side of opening = 2.5 ft which is less than $\frac{L_e}{2} = 3.5$ ft

Case no 3 and weight of the wall above the lintel should be consider

(i) Load calculation:

Assume size of the lintel (10" X 8")

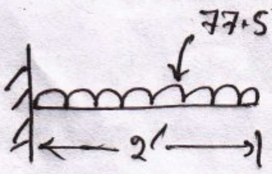


Therefore self weight of lintel $= \frac{10 \times 8}{12 \times 12} \times 150$

$= 83.3$ plf

(ii) weight of brickwall:

$$\text{Total weight} = H \times t \times 120$$
$$= 6 \times \frac{10}{12} \times 120$$
$$= 600 \text{ plf}$$



(iii) Load from sunset:

Load from sunset = Design load X Length of sunset

$$= 77.5 \times 2$$
$$= 155 \text{ lb/ft}$$

Total load = $83.3 + 600 + 155 = 838.3$ plf

$$M_{max} = \frac{wL^2}{8} = \frac{838.3 \times (7)^2}{8} = 5134.8 \text{ lb-ft}$$

(iv) Depth check:

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{5134.8 \times 12}{229 \times 10}} = 5.2 \text{ in}$$

Actual, $d = t - c.c - \phi_s - \frac{\phi}{2}$

$= 8 - 2.5 = 5.5$ in (OK)

(v) Reinforcement calculation:

$$A_s = \frac{M}{f_s j d} = \frac{5134.8 \times 12}{24000 \times 0.86 \times 5.5}$$
$$= 0.54 \text{ in}^2$$

Use 2 #5 bars

$$A_s = 0.62 \text{ in}^2$$

Shear check:

$$V_{max} = \frac{wL}{2} = \frac{838.2 \times 7}{2} = 2934 \text{ lb}$$

$$v = \frac{V}{bd} = \frac{2934}{10 \times 5.5} = 53.35 \text{ psi}$$

Allowable shear stress $= 1.1\sqrt{f_c'}$

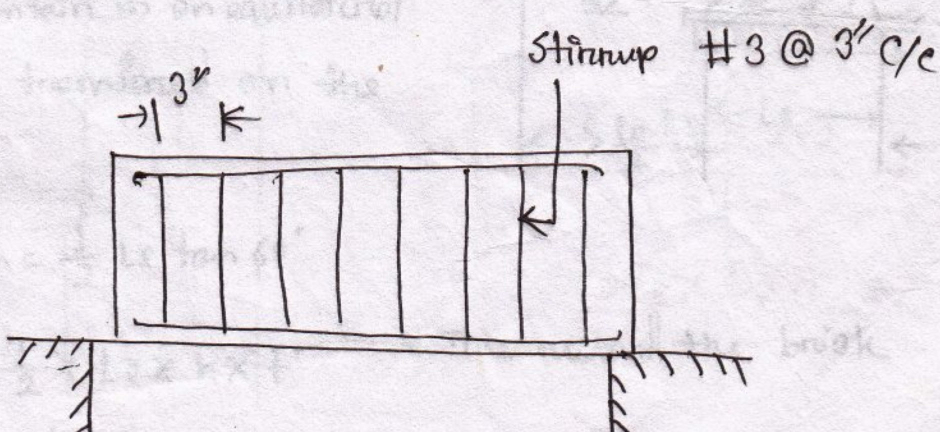
$$= 1.1\sqrt{3000}$$

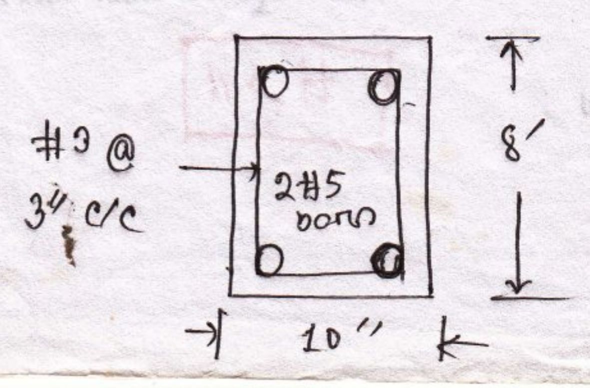
$$= 60.25 \text{ psi}$$

$\therefore v <$ Vallowable

Therefore, stirrup are not required

Use #3 stirrup @ 3 in c/c





Ex-01:

Design a RC lintel over a window opening 6′ wide. The window is to be centrically located on 10″ thick brick wall. Hight of the brickwall above the lintel may be taken as 6′ and length of wall on both sides of the opening is 2.5′. A 2′ wide sunshade is required to cast monolithic with the lintel. Design the sunshade as well. use $f_c' = 3000$ psi and $f_s = 24000$ psi. L.L = 40 plf.

Solution:

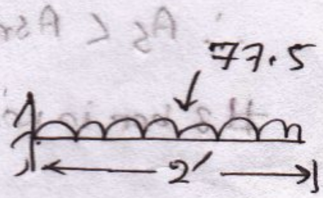
Design of sunshade

i) Relevent properties:

$$n = \frac{29\times10^6}{57000\sqrt{3000}} = 9.28 \simeq 9 \qquad r = \frac{f_s}{f_c} = \frac{24}{0.45\times3} = 17.78$$

$$k = \frac{9}{9+17.78} = 0.34 \qquad j = 1 - \frac{0.34}{3} = 0.89$$

ii) Load calculation:



Assume $t = \frac{L}{10} = \frac{2\times12}{10} = 2.4'' \simeq 3''$

Self weight $= \frac{t}{12}\times150 = \frac{3}{12}\times150 = 37.5$ psf $= 37.5$ plf.

L.L = 40 plf

$\therefore$ Total load $= 37.5+40 = 77.5$ plf

iii) moment calculation:

$$M_{max} = \frac{WL^2}{2} = \frac{77.5\times(2)^2}{2} = 155 \text{ lb.ft}$$

$$= 1860 \text{ lb-in}$$

iv) Depth check:

$$d = \sqrt{\frac{M}{Rb}} \qquad R = \frac{1}{2} f_c j k$$

$$= \frac{1}{2} \times 0.45 \times 3000 \times 0.89 \times 0.34 = 204.255$$

$$= \sqrt{\frac{1860}{204.255 \times 12}} = 0.87 \text{ in}$$

Actual $d = t - c.c - \frac{\phi}{2} = 3 - 1 = 2'' > d$ (OK)

v) Reinforcement calculation:

$$A_s = \frac{M}{f_s j d} = \frac{1860}{24000 \times 0.89 \times 2} = 0.044 \text{ in}^2$$

~~Spacing, #3, $s = \frac{0.11 \times 12}{0.044} = 30$ in c/c~~

$A_{s\,min} = \cancel{3t = 3\times}\ 0.0018bt = 0.0018 \times 12 \times 3 = 0.0648$

$\therefore A_s < A_{s\,min}$

#3 bar is used, $s = \frac{0.11 \times 12}{0.0648} = 20.37''$ c/c

Max^m spacing $= 3t = 3 \times 3 = 9''$ c/c

$\therefore$ Use #3 bar @ $9''$ c/c

vi) Distribution reinforcement:

$A_{st} = 0.0018bt = \cancel{20}\ 0.0648\ \cancel{\text{c/c}}\ \text{in}^2$

#3 bar is used, $s = 20.37''$ c/c

Max^m spacing $= 5t = 5 \times 3 = 15''$ c/c

$\therefore$ Use #3 bars @ $15''$ c/c

vii) Bond check:

$$V_d = \frac{V_{max}}{\Sigma_0 jd}$$

$$= \frac{155}{1.57 \times 0.89 \times 2}$$

$$= 55.46 \text{ lb}$$

$$V_{max} = WL$$

$$= 77.5 \times 2$$

$$= 155 \text{ lb}$$

$$\Sigma_0 = \pi\phi \frac{b}{spacing}$$

$$= \pi \times \frac{3}{8} \times \frac{12}{9}$$

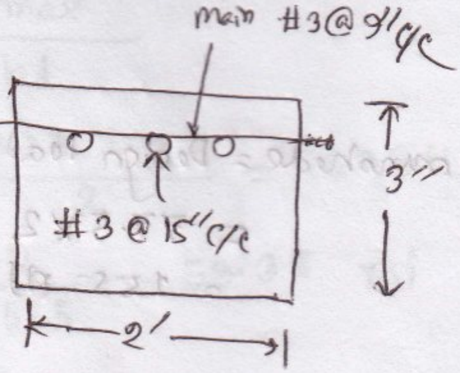
$$= 1.57$$

$$V_{allowable} = \frac{3.4\sqrt{f_c'}}{\phi}$$

$$= \frac{3.4\sqrt{3000}}{\frac{3}{8}} = 496.60$$

$\therefore$ $V_d < V_{allowable}$. (OK).

viii) Working diagram:



$\boxed{\text{Design of lintel:}}$

Consider 12'' bearing on each side.

Effective span $= \frac{12''}{2} + 6' + \frac{12''}{2} = 7\ ft$

Length of brick wall on each side of opening is 2.5 ft which is less than

$\frac{L\ell}{2} = \frac{7}{2} = 3.5'$

i) Load calculation:

Assume size of the lintel $(b \times h) = 10'' \times 8''$

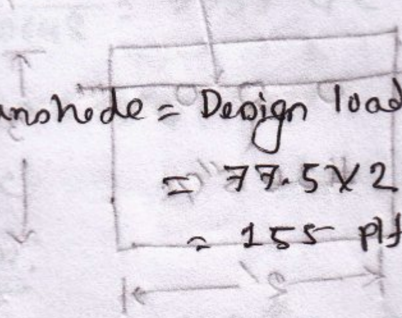
Self weight of lintel $= \frac{10 \times 8}{144} \times 150 = 83.3\ plf$

ii) Weight of brick wall:

Total weight $= H \times t \times 120 = 8 \times 3 \times$

$= 6 \times \frac{10}{12} \times 120 = 600\ plf$

iii) Load from sunshade:



Load from sunshade = Design load X Length of sunshade

$= 77.5 \times 2$

$= 155\ plf$

$\therefore$ Total load $= 83.3 + 600 + 155 = 838.3\ plf$

$M_{max} = \frac{wL^2}{8} = \frac{838.3 \times (7)^2}{8} = 5134.59\ lb\text{-}ft$

iv) Depth check:

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{5134.59 \times 12}{204.255 \times 12}} = 5.01''$$

Actual, $d = h - c.c - \frac{\phi}{2} - \frac{\phi}{2}$

$$= h - c.c - \frac{\phi}{2} - \phi_s$$

$$= 8 - 1.5 - \frac{1}{2}\left(\frac{8}{8}\right) - \frac{4}{8}$$

$$= 8 - 2.5$$

$$= 5.5'' > d \text{ (ok)}$$

v) Reinforcement calculation:

$$A_s = \frac{M}{f_s j d} = \frac{5134.59 \times 12}{24000 \times 0.89 \times 5.5} = 0.52 \text{ in}^2$$

Use 2 #5 bars $A_s = 0.62 \text{ in}^2$

vi) Shear check:

$$v = \frac{V_{max}}{bd}$$

$$V_{max} = \frac{wL}{2} = \frac{838.3 \times 7}{2} = 2934 \text{ lb}$$

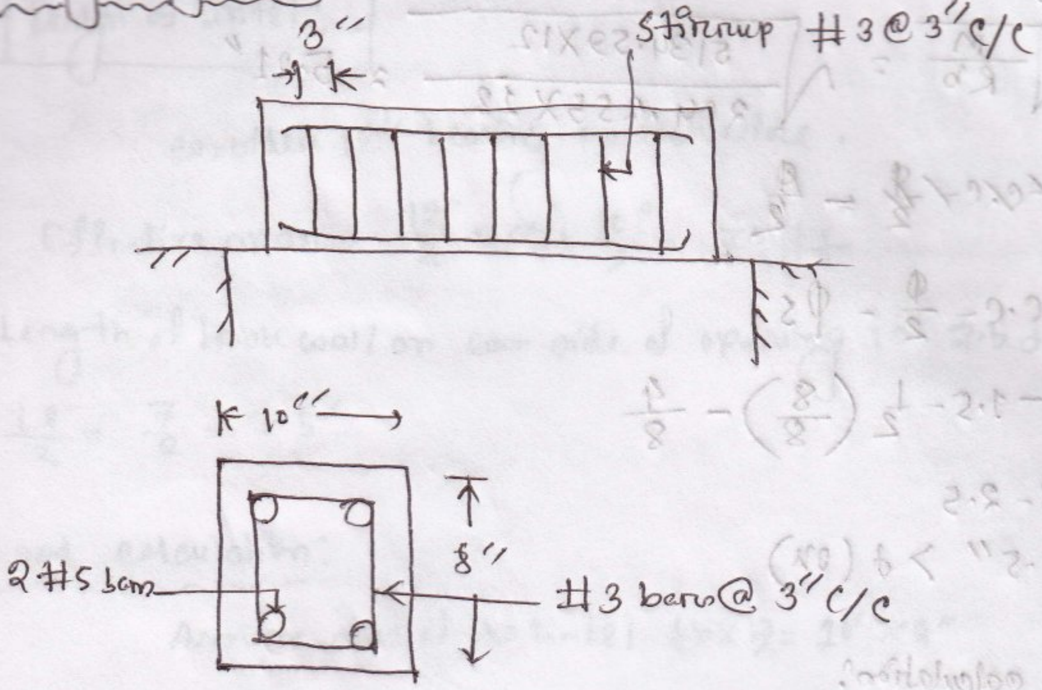
$$v = \frac{2934}{10 \times 5.5} = 53.35 \text{ psi}$$

$$v_{allowable} = 1.1\sqrt{f_c'} = 1.1\sqrt{3000} = 60.25 \text{ psi}$$

$\therefore v < v_{allowable}$ (ok)

Therefore stirrup are not required

working diagram:



2. Design a RC Lintel over a window opening of 6 ft height of wall above lintel may be considered as 8 ft. The window is to be centrally located in 10" thick brick wall. A 2 ft wide sunshade is required to be cast monolithic with lintel. Self weight of sunshade 40 psf. $f_c' = 3000$ psi, $f_s = 18000$ psi, $f_y = 40000$ psi, Length of wall on both sides of opening = 4'. Design the sunshade as well.

Solution:

$\boxed{\text{Sunshade design}}$

Assume, $t = \frac{L}{10} = \frac{2 \times 12}{10} = 2.4 \approx 3''$

i) Load calculation:

Self weight $= \frac{t}{12} \times 150 = \frac{3}{12} \times 150 = 37.5$ plf

L.L = 40 psf

∴ Total load = 77.5 psf

ii) Moment calculation:

$$M_{max} = \frac{wL^2}{2} = \frac{77.5 \times (2)^2}{2} = 155 \text{ lb-ft}$$

iii) Depth check:

$$d = \sqrt{\frac{M}{Rb}}$$

$$= \sqrt{\frac{155 \times 12}{234.9 \times 12}}$$

$$= 0.81''$$

$$n = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9$$

$$r = \frac{18}{0.45 \times 3} = 13.33$$

$$k = \frac{9}{9 + 13.33} = 0.4 \quad J = 0.87$$

$$R = \frac{1}{2} f_c J k$$

$$= \frac{1}{2} \times 0.45 \times 3000 \times 0.87 \times 0.4$$

$$= 234.9$$

Actual $d = \cancel{c.c - \frac{\phi}{2}}$ $t - c.c - \frac{\phi}{2} = 3 - 1 = 2'' > d$ (OK)

iv) Reinforcement calculation:

$$A_s = \frac{M_s}{f_s jd} = \frac{155 \times 12}{0.87 \times 2 \times 18000} = 0.059 \text{ in}^2/\text{ft}$$

$$A_{s\,min} = 0.0020\,bt = 0.0020 \times 12 \times 3 = 0.072 \text{ in}^2/\text{ft}$$

$\therefore A_{s\,min} > A_s$

$\therefore$ Use # 3 bar Spacing $= \frac{0.11 \times 12}{0.072} = 18.33''$ c/c

max^m spacing $= 3t = 3 \times 3 = 9''$ c/c

$\therefore$ Use #3 bar @ $9''$ c/c

v) Distribution reinforcement:

$$A_{st} = 0.0020\,bt = 0.072 \text{ in}^2/\text{ft}$$

max^m spacing $= 5t = 5 \times 3 = 15''$ c/c

Spacing $= \frac{0.11 \times 12}{0.072} = 18.33''$ c/c

$\therefore$ Use # 3 bars @ $15''$ c/c

vi) Bond check:

$$V_d = \frac{V_{max}}{\Sigma_0 jd}$$

$V_{max} = wL = 77.5 \times 2 = 155$ lb

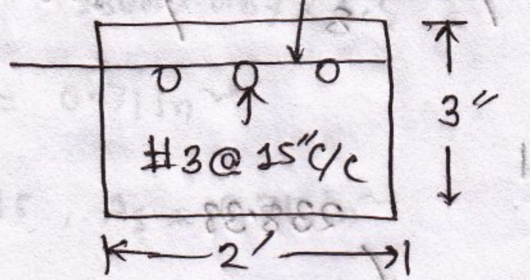
$\Sigma_0 = \pi \phi \frac{b}{\text{spacing}} = \pi \times \frac{3}{8} \times \frac{12}{9} = 1.57$

$$\therefore V_d = \frac{155}{1.57 \times 0.87 \times 2} = 56.74$$

$V_{allowable} = \frac{3.4\sqrt{f_c'}}{\phi} = \frac{3.4\sqrt{3000}}{\frac{3}{8}} = 496.60$

$\therefore V_d < V_{allowable}$

$\therefore$ Bond check is ok



Design of Lintel

Assume 12" bearing on each side

Effective span = 6+0.5+0.5 = 7 ft

Length of brick wall on each side of opening = 4' which is greater than

$\frac{L_e}{2} = \frac{7}{2} = 3.5$ ft

1) Load calculation:

Assume size of the lintel $(b \times h) = 10" \times 8"$

Self weight of lintel $= \cancel{\frac{1}{2}} \times \cancel{t} \times \cancel{h} \times \cancel{L_e} \times \cancel{120}$

$= \cancel{\frac{1}{2}} \times \frac{10 \times 8}{144} \times 150 = 83.33$ psf

Total weight $= \frac{1}{2} \times t \times h \times L_e \times 120$

$= \frac{1}{2} \times \frac{10}{12} \times \cancel{8} \times \cancel{3.5} \times 120 \times 6.06 \times 7$

$= 2121$ lb

$h = \frac{L_e}{2} \tan 60°$

$= 3.5 \times \tan 60°$

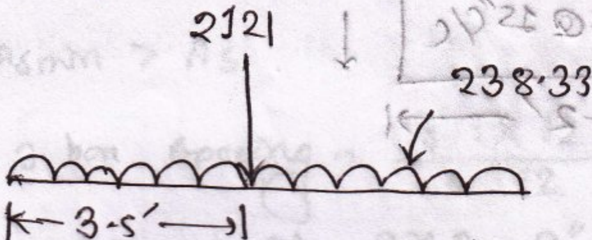
$= 6.06$

- Load of sunshade = 77.5X2 = 155 psf

∴ Total load = 83.33 + 2121 + 155 = 2359.33 psf

$$M_{max} = \frac{wL^2}{8} = \frac{2359.33 \times (6)^2}{8} = 10616.985$$

Load distribution:



$$M_{max} = \frac{238.33 \times 7^2}{8} + \frac{2121 \times 7}{4} = 5171.5 \text{ lb-ft}$$

$$V_{max} = \frac{238.33 \times 7}{2} + \frac{2121}{2} = 1895 \text{ lb}$$

Depth check:

$$d = \sqrt{\frac{M}{Rb}} = \sqrt{\frac{5171.5 \times 12}{235 \times 12}}$$

$$= 5.13''$$

Actual $d = h - c.c - \frac{1}{2}\phi - \phi_s$

$= 8 - 2.5$

$= 5.5'' > d$ (ok)

Reinforcement calculation:

$$A_s = \frac{M}{f_s j d}$$

$$= \frac{5127.3 \times 12}{18000 \times 0.87 \times 5.5}$$

$$= 0.71 \text{ in}^2$$

$2\#4 + 1\#5$, $A_s = 0.71 \text{ in}^2$

Shear check:

$$v = \frac{V_{max}}{b d_{ac}}$$

$$= \frac{1895}{10 \times 5.5} = 34.5 \text{ psi}$$

$v_{allowable} = 1.1\sqrt{f_c'} = 1.1\sqrt{3000} = 60.24 \text{ psi}$

$\therefore v < v_{allowable}$

Stirrup are not required but practically it is provided.

Slab

Slab

(1 Sheet must)

AHSAN
090063

SADIK
090108

Minimum thickness of R.C slab:

Support condition	Thickness
* Simply supported	$t = \frac{L}{20}$
* One end continuous	$t = \frac{L}{24}$
* Both end "	$t = \frac{L}{28}$
* Cantilever	$t = \frac{L}{10}$

** Minimum thickness of slab usually not less than 3.5 in

** Minimum clear cover = 0.75 in

Shrinkage reinforcement:

i) For f_y = 40 and 50 ksi $A_s = 0.0020\ bt$

ii) For f_y = 60 ksi $A_s = 0.0018\ bt$

For beam, $d = t - c.c - \frac{\phi}{2}$

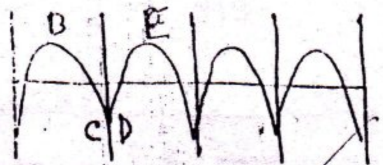
Moment co-efficient:

* At interior support, $C = \frac{1}{9}$

* At exterior " $A = \frac{1}{24}$

* At mid span $B = \frac{1}{14}$

$D = \frac{1}{11}$ $E = \frac{1}{16}$



SBR'090097

W.S.D. method

1) **Load calculation**

* D.L
* L.L

WF = D.L + L.L

ii) Moment calculation

iii) **Depth check**

$$d = \sqrt{\frac{M}{Rb}}$$

$$\text{Actual } d = t - c.c - \frac{\phi'}{2} > d \text{ (ok)}$$

iv) **Reinforcement calculation**

$$A_s = \frac{M}{f_s j d}$$

Max^m spacing = 3t

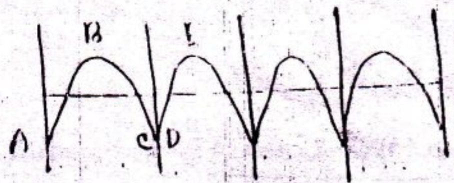
$A_{s\,min} = 0.0018\,bt$

v) **Distribution reinforcement**

$A_{st} = 0.0018\,bt$

Max^m spacing = 5t

USD method



i) **Load calculation**

* D.L
* L.L

WF = 1.2 × D.L + 1.6 L.L

ii) **Moment calculation:**

$$A = \frac{1}{24} wL^2$$

$$B = -\frac{1}{14} wL^2$$

$$C = -\frac{1}{9} wL^2$$

$$D = -\frac{1}{11} wL^2$$

$$E = -\frac{1}{16} wL^2$$

iii) **Depth check:**

$$\rho_{max} = 0.85\,\beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.004}$$

$$M_u = \phi \rho f_y b d^2 \left(1 - 0.59 \times \frac{\rho f_y}{f_c'}\right)$$

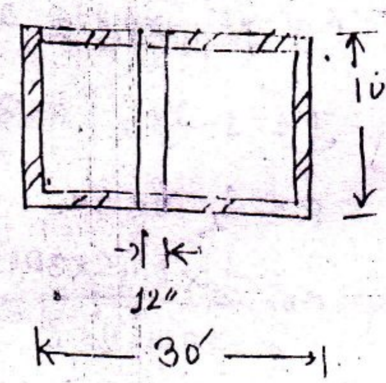
iv) **Reinforcement calculation:**

$$a = \frac{A_s f_y}{0.85 f_c' b}$$

$$A_s = \frac{M}{\phi A_s f_y \left(d - \frac{a}{2}\right)}$$

WSD method

Design a isolated slab 10'×30' supported on brick walls on all four sides. The slab should be designed to carry a minimum live load of 40 psf. Design the slab using $f_c' = 3000$ psi and $f_s = 24000$ psi



Solution:

Support condition = Simply supported

Span L = 10' (Shortest distance)

Load calculation:

$$t = \frac{L}{20} = \frac{10\times12}{20} = 6 \text{ in}$$

i) Dead load $= \frac{t}{12}\times150 = \frac{6}{12}\times150 = 75$ psf

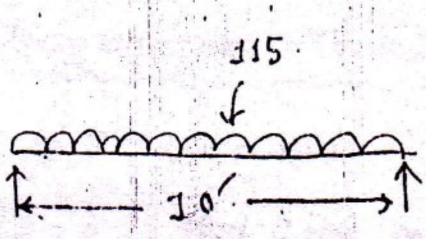
ii) Live load = 40 psf

$\therefore$ Total load = 75 + 40 = 115 psf

Max^m shear $= \boxed{\frac{wL}{2}} = \frac{115\times10}{2} = 575$ lb

Max^m moment $= \boxed{\frac{wL^2}{8}} = \frac{115\times(10)^2}{8}$

$= 1437.5$ lb-ft



b) Depth check:

$$d = \sqrt{\frac{M}{Rb}}$$

$$= \sqrt{\frac{1437.5 \times 12}{204.255 \times 12}}$$

$$= 2.65 \text{ in}$$

$$r = \frac{f_s}{f_c} = \frac{24000}{0.45 \times 3000} = 17.78$$

$$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9.28 \approx 9$$

$$k = \frac{9}{9+17.78} = 0.34$$

$$J = 1 - \frac{k}{3} = 0.89$$

$$R = \frac{1}{2} f_c jk$$

$$= \frac{1}{2} \times 0.45 \times 3000 \times 0.89 \times 0.34$$

$$= 204.255$$

Actual, $d = t - c.c - \frac{\phi}{2}$

$= 6 - 1 = 5$ in $> d$ (ok)

c) Reinforcement calculation:

$$A_s = \frac{M}{f_s jd} = \frac{1437.5 \times 12}{24000 \times 0.89 \times 5} = 0.16 \text{ in}^2/\text{ft}$$

Spacing: #3, $S = \frac{0.11 \times 12}{0.16} = 8.25''$ c/c

Max^m spacing $= 3t = 3 \times 6 = 18$ in

Use #3 bars @ 8.25" c/c

$A_{s\,min} = 0.0018\, bt = 0.0018 \times 12 \times 6 = 0.13 \text{ in}^2$

d) Distribution reinforcement:

$A_{st} = 0.0018\, bl = .13 \text{ in}^2$

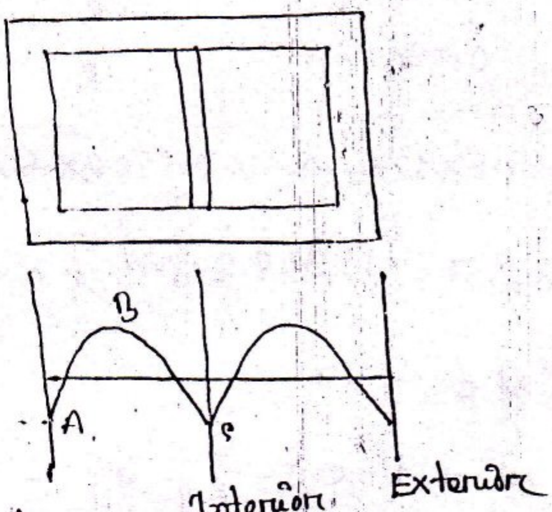
Spacing, #3 bars, $S = \frac{0.11 \times 12}{.13} = 10.15'' \simeq 10''$.

Max^m spacing $= 5t = 5 \times 6 = 30$ in

Use #3 bars @ 10" c/c

USD revised

A reinforced concrete slab is built integrally with its support consists of two equal spans each having clear span of 15 ft. working live load is 110 psf. Design the slab. $f_c' = 4$ ksi and $= 60$ ksi.



lution:

upport condition = Both end continuous

$$t = \frac{L}{28} = \frac{15 \times 12}{28} = 6.43 \simeq 6.5''$$

ad calculation:

$$D.L = \frac{t}{12} \times 150 = \frac{6.5}{12} \times 150 = 81.25 \text{ psf}$$

$L.L = 110$ psf.

$\therefore$ Total load, $\omega_F = 1.2 \times D.L + 1.6 \times L.L$

$$= 1.2 \times 81.25 + 1.6 \times 110 = 273.5 \text{ psf}$$

oment calculation:

At interior support, $-M_C = \frac{1}{9} \omega L^2 = \frac{1}{9} \times 273.5 \times (15)^2 = 6837.5$ lb-ft

At mid span, $+M_B = \frac{1}{14} \omega L^2 = \frac{1}{14} \times 273.5 \times (15)^2 = 4395.54$ lb-ft

At exterior support, $-M_A = \frac{1}{24} \omega L^2 = \frac{1}{24} \times 273.5 \times (15)^2 = 2564.06$ lb-ft

Depth check:

$$M_u = \phi \rho f_y b d^2 \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right) \quad \cdots (1)$$

$$\rho_{max} = 0.85 \beta_1 \frac{f_c'}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + 0.004}$$

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.004}$$

$$= 0.0206$$

$(1) \Rightarrow$

$$6837.5 \times 12 = 0.9 \times 0.0206 \times 60000 \times 12 \times d^2 \times \left(1 - 0.59 \times \frac{0.0206 \times 60000}{4000}\right)$$

$$\Rightarrow 82050 = 13348.8\, d^2 \times 0.818$$

$$\therefore d = 2.74''$$

Actual, $d = t - c.c - \frac{\phi}{2} = 6.5 - 1 = 5.5 > d$ (ok)

Reinforcement calculation:

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{A_s \times 60}{0.85 \times 4 \times 12} = 1.47 A_s$$

$$M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$\Rightarrow 6837.5 \times 12 = 0.9 \times A_s \times 60000 \times \left(5.5 - \frac{1.47 A_s}{2}\right)$$

$$\Rightarrow 82050 = 54000 A_s (5.5 - 0.735 A_s)$$

$$\Rightarrow 82150 = 297000 A_s - 39690 A_s^2$$

$$\therefore A_s = 0.28 \text{ in}^2$$

...ri support, $A_s = 0.28 \text{ in}^2$

...d span
$$A_s = \frac{M_u}{\phi f_y (d - \frac{a}{2})} = \frac{1395.5 \times 12}{0.9 \times 60000 \times (5.5 - \frac{1.47 A_s}{2})}$$
$$= 0.18 \text{ in}^2$$

At exterior support, $$A_s = \frac{2564.01 \times 12}{0.9 \times 60000 \times (5.5 - \frac{1.47 A_s}{2})}$$
$$= 0.11 \text{ in}^2$$

Distribution reinforcement:

$$A_{s\,min} = \boxed{0.0018\, bt} = 0.0018 \times 12 \times 6.5 = 0.14 \text{ in}^2$$

Spacing calculation:

At interior support, $S = \frac{0.11 \times 12}{0.28} = 4.33 \text{ in c/c}$ $4.71'' \simeq 4.75'' \text{ c/c}$

At mid span, $S = \frac{0.11 \times 12}{0.18} = 7.33'' \simeq 7.25'' \text{ c/c}$

At exterior support, $S = \frac{0.11 \times 12}{0.11} = 12'' \text{ c/c}$

Bond check: (VSD)

$$U_d = \frac{1.15 V}{\Sigma_0 (d - a/2)}$$

(USD) $$U_{allow} = \frac{3.4 \sqrt{f_c'}}{\phi} \qquad U_d = \frac{V}{\Sigma_0 (d - a/2)}$$

$$U_{allowable} = \frac{6.7 \sqrt{f_c'}}{\phi} = \frac{6.7 \sqrt{f_c'}}{3/8}$$

$$\Sigma_0 = \pi \times \phi \times \frac{b}{spacing}$$
$$= \pi \times \frac{\# bar}{8} \times \frac{12}{spacing}$$

$U_d < U_{allowable}$ ∴ Bond check is ok.

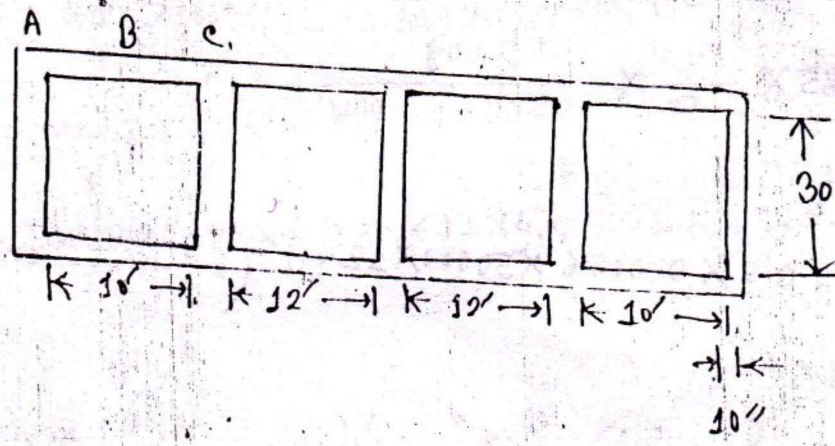
Shear check

$$U_d = \frac{V_{max}}{bd} = \frac{wl/2}{bd} \quad (WSD)$$
$$U_d = \frac{1.5 V_{max}}{bd} = \frac{1.5\, wl/2}{bd} \quad (USD)$$

$$U_{allowable} = 1.1 \sqrt{f_c'} \quad (WSD)$$
$$= 2 \phi \sqrt{f_c'} \quad (USD) \qquad \phi = 0.75$$

~~08~~ ⇒ USD method

Design the slab shown in figure with $f_c' = 3$ ksi and $f_y = 50$ ksi, $L.L = 60$ psf.



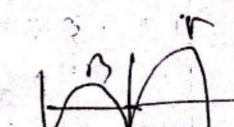
Solution:

Support condition = Both end continuous [illegible]

$$t = \frac{L}{28} = \frac{12 \times 12}{28} = 5.14'' \simeq 5.5''$$

Load calculation:

i) Dead load $= \frac{t}{12} \times 150 = \frac{5.5}{12} \times 150 = 68.75$ psf



ii) $L.L = 60$ psf.

$\therefore$ Total load, $w_F = 1.2 \times 68.75 + 1.6 \times 60 = 178.5$ psf $= 178.5$ plf

[Assuming a strip of 12" width]

Moment calculation:

For $L = 10'$,

For exterior support, $-M_A = \frac{1}{24} wL^2 = -\frac{1}{24} \times 178.5 \times (10)^2 = 743.75$ lb-ft

For mid span, $+M_B = \frac{1}{14} wL^2 = \frac{1}{14} \times 178.5 \times (10)^2 = 1275$ lb-ft

For interior support, $-M_C = \frac{1}{10} wL^2 = \frac{1}{10} \times 178.5 \times (10)^2 = 1785$ lb-ft.

continuous ~~do~~ তাই $C = \frac{1}{10}$

At interior supports, $M_D = \frac{1}{11}$ ...
At middle of " , $+M_E = \frac{1}{16}wL^2 = 1606.5$ lb-ft

Depth check:

$$\boxed{M_u = \phi \rho f_y b d^2 \left(1 - \frac{\rho f_y}{f_c'} \times 0.59\right)} \quad (1)$$

$$\rho_{max} = 0.85 \times \beta_1 \times \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.004}$$

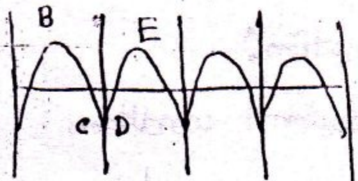
$$= 0.85 \times 0.85 \times \frac{3}{50} \times \frac{0.003}{0.003 + 0.004}$$

$$= 0.0186$$

$$(1) \Rightarrow \quad 2336.72 \times 12 = 0.9 \times 0.0186 \times 50000 \times 12 \times d^2 \left(1 - \frac{0.0186 \times 50}{3} \times 0.59\right)$$

$$\therefore d = 1.8''$$

Actual $d = t - c.c - \frac{\phi}{2} = 5.5 - 1 = 4.5'' > d$ (ok)



Reinforcement calculation:

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{A_s \times 50}{0.85 \times 3 \times 12} = 1.634 A_s \text{ in}^2$$

$$M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$\Rightarrow 2336.72 \times 12 = 0.9 \times A_s \times 50000 \left(4.5 - \frac{1.634 A_s}{2}\right)$$

$$\Rightarrow 28040.64 = 45000 A_s (4.5 - 0.817 A_s)$$

$$\Rightarrow 28040.64 = 202500 A_s - 36765 A_s^2$$

$$\therefore A_s = 0.14 \text{ in}^2$$

At point A, $A_s = \frac{743.75 \times 12}{0.9 \times 50000 \times (4.5 - 0.817 A_s)} = 0.04 \text{ in}^2$

At point B, $A_s = \frac{1275 \times 12}{0.9 \times 50000 \times (4.5 - 0.817 A_s)} = 0.08 \text{ in}^2$

C, $A_s = \dfrac{3783 \times 12}{0.9 \times 50000 \times (4.5 - 0.817 A_s)} = 0.108\ in^2$

point D, $A_s = \dfrac{2336.72 \times 12}{0.9 \times 50000 \times (4.5 - 0.817 A_s)} = 0.14\ in^2$

At point E, $A_s = \dfrac{1606.5 \times 12}{0.9 \times 50000 \times (4.5 - 0.817 A_s)} = 0.10\ in^2$

Distribution reinforcement:

$A_{s\,min} = 0.0020\ bt = 0.0020 \times 12 \times 5.5 = 0.132\ in^2$

A Spacing:

At point A, $S = \dfrac{\cancel{0.04} \times 12 \times 0.11}{0.04} = 33''\ c/c$

At point B, $S = \dfrac{0.11 \times 12}{0.08} = 16.5''\ c/c$

At point C, $S = \dfrac{0.11 \times 12}{0.108} = 12.22'' \simeq 12.25''\ c/c$

At point D, $S = \dfrac{0.11 \times 12}{0.14} = 9.43'' \simeq 9.5''\ c/c$

At point E, $S = \dfrac{0.11 \times 12}{0.10} = 13.2''\ c/c$

maximum spacing $= 3t = 3 \times 5.5 = 16.5''\ c/c$

for distribution reinforcement, $S = \dfrac{0.11 \times 12}{0.132} = 10''\ c/c$

maximum spacing $= 5t = 5 \times 5.5 = 27.5''\ c/c$

At point A, B, C & E , $A_s < A_s$ (distribution)

Extra top bar at A $= 0.13 - 0.04 = 0.09\ m^2 = 1\ \#13$ bar

B $= 0.13 - 0.08 = 0.05\ m^2 = 1\ \#13$ bar

" " C $= 0.13 - 0.11 = 0.02\ m^2 = 1\ \#13$ bar

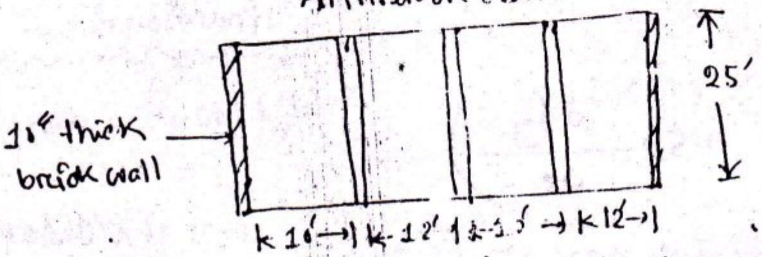
" " E $= 0.13 - 0.10 = 0.03\ m^2 = 1\ \#13$ bar

$\therefore$ Total 4 #13 bars.

11

Design the slab shown in figure below. Assume L.L = 100 psf, f'_c = 4000 psi and f_y = 60000 psi.

All interior beam are of 12 in width



Solution:

Support condition = Simple supported

$$\boxed{t = \frac{l}{20}} = \frac{12 \times 12}{20} = 7.2 \text{ in} \approx 7.5 \text{ in}$$

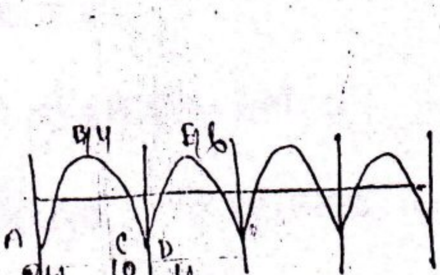
Load calculation:

I) Dead load $= \frac{t}{12} \times 150 = \frac{7.5}{12} \times 150 = 93.75$ psf

II) Live load = 100 psf

$\therefore$ Total load $w_u = 1.2 \times 93.75 + 1.6 \times 100$
$= 272.5$ psf

Moment calculation:



for L = 10',

For exterior support, $\boxed{-M_A = \frac{1}{24} wl^2}$
$= \frac{1}{24} \times (272.5) \times (10)^2 = 1135.42$ lb-ft

For mid span, $\boxed{+M_B = \frac{1}{14} wl^2} = \frac{1}{14} \times 272.5 \times (10)^2 = 1946.43$ lb-ft

For interior support $\boxed{-M_C = \frac{1}{10} wl^2} = \frac{1}{10} \times 272.5 \times (10)^2 = 2725$ lb-ft

for L = 12',

At point D, $\boxed{-M_D = \frac{1}{11} wl^2} = \frac{1}{11} \times 272.5 \times (12)^2 = 3567.27$ lb-ft

At point E, $\boxed{+M_E = \frac{1}{16} wl^2} = \frac{1}{16} \times 272.5 \times (12)^2 = 2452.5$ lb-ft

Depth check:

$$\rho_{max} = 0.85\,\beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.004}$$

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.004}$$

$$= 0.0206$$

$$M_u = \phi \rho f_y b d^2 \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)$$

$$\Rightarrow 3567.27 \times 12 = 0.9 \times 0.0206 \times 60000 \times 12 \times d^2 \left(1 - 0.59 \times \frac{0.0206 \times 60000}{4000}\right)$$

$$\Rightarrow 42807.24 = 13348.8 \times d^2 \times 0.8177$$

$$\therefore d = 1.98''$$

Actual $d = t - c.c - \frac{\phi}{2} = 7.5 - 1 = 6.5\text{ in} > d$ (ok)

Reinforcement calculation:

$$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{A_s \times 60}{0.85 \times 4 \times 12} = 1.47\,A_s$$

$$M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$\Rightarrow 3567.27 \times 12 = 0.9 \times A_s \times 60000 \times \left(6.5 - \frac{1.47 A_s}{2}\right)$$

$$\Rightarrow 42807.24 = 351000\,A_s - 39690\,A_s^2$$

$$\therefore A_s = 0.12\text{ in}^2$$

At point A, $A_s = \dfrac{1135.42 \times 12}{0.9 \times 60000 \times (6.5 - 0.735 A_s)} = 0.04$

At point B, $A_s = \dfrac{1946.43 \times 12}{0.9 \times 60000 \times (6.5 - 0.735 A_s)} = 0.07$

At point C, $A = \dfrac{2725 \times 12}{0.9 \times 60000 \times (6.5 - 0.735 A_s)} = 0.09$

$A_s = \dfrac{3567.27 \times 12}{0.9 \times 60000 \times (6.5 - 0.735\, A_s)} = 0.12 \text{ in}^2$

At E, $A_s = \dfrac{2457.1 \times 12}{0.9 \times 60000 \times (6.5 - 0.735\, A_s)} = 0.08 \text{ in}^2$

Distribution reinforcement:

$A_{s\,min} = 0.0018\, bt = 0.0018 \times 12 \times 7.5 = 0.162 \text{ in}^2$

Spacing calculation:

At point A, $S = \dfrac{0.11 \times 12}{0.04} = 33 \text{ in } c/c$

At point B, $S = \dfrac{0.11 \times 12}{0.07} = 18.86 \simeq 18.75 \text{ in } c/c$

At point, C, $S = \dfrac{0.11 \times 12}{0.09} = 14.67 \simeq 14.75'' c/c$

At point D, $S = \dfrac{0.11 \times 12}{0.12} = 11'' c/c$

At point E, $S = \dfrac{0.11 \times 12}{0.08} = 16.5'' c/c$

Maxm spacing $= 3t = 3 \times 7.5 = 22.5'' c/c$

for distribution reinforcement, $S = \dfrac{0.11 \times 12}{0.162} = 8.15 \simeq 8.25'' c/c$

maxm spacing $= 5t = 5 \times 7.5 = 37.5'' c/c$

At point A, B, C, D & E $\quad A_s < A_s$ (distribution)

Extra top bar at A $= 0.162 - 0.04 = 0.12$ = 1 #3 bars

" " B $= 0.162 - 0.07 = 0.09$ = 1 #3 bars

" " C $= 0.162 - 0.9 = 0.07$ = 1 #3 bars

" " D $= 0.162 - 0.12 = 0.04$ = 1 #3 bars

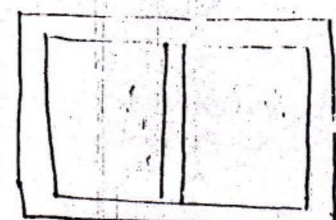
" " E $= 0.162 - 0.08 = 0.08$ = 1 #3 bar.

CE-07

(b) Design a reinforced concrete slab by using USD method. The slab is built integrally with its support and consist of two equal spans each with a clear span of 12 ft. The service live load is 80 psf. Given that $f_c' = 3000$ psi, $f_y = 60000$ psi.

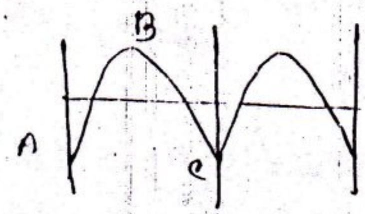
Solution:

Support condition = Both end continuous



$$\boxed{t = \frac{L}{28} = \frac{12 \times 12}{28}} = 5.14'' \simeq 5.5''$$

Load Calculation:



i) $D.L = \frac{t}{12} \times 150 = \frac{5.5}{12} \times 150 = 68.75$ psf

ii) $L.L = 80$ psf

$\therefore$ Total load $w_F = 1.2 \times 68.75 + 1.6 \times 80$

$= 210.5$ psf.

Moment calculation:

At exterior support, $\boxed{-M_A = \frac{1}{24} wL^2} = \frac{1}{24} \times 210.5 \times (12)^2 = 1263$ psf

At mid span, $\boxed{+M_B = \frac{1}{14} wL^2} = \frac{1}{14} \times 210.5 \times (12)^2 = 2165.14$ psf

At interior support, $\boxed{-M_C = \frac{1}{9} wL^2} = \frac{1}{9} \times 210.5 \times (12)^2 = 3368$ psf

Depth check:

$$\rho_{max} = 0.85 \beta_1 \frac{f_c'}{f_y} \times \frac{\varepsilon_u}{\varepsilon_u + 0.004}$$

$$= 0.85 \times 0.85 \times \frac{3}{60} \times \frac{0.003}{0.003 + 0.004}$$

$$= 0.0155$$

$$M_u = \phi \rho f_y b d^2 \left(1 - 0.59 \frac{\rho f_y}{f'_c}\right)$$

$$\Rightarrow 3368 \times 12 = 0.9 \times 0.0155 \times 60000 \times 12 \times d^2 \times \left(1 - 0.59 \times \frac{0.0155 \times 60000}{3000}\right)$$

$$\Rightarrow 40416 = 10044\, d^2 \times 0.817$$

$$\therefore d = 2.22 \text{ in}$$

Actual $d = t - c.c - \frac{\phi}{2} = 5.5 - 1 = 4.5'' > d$ (OK)

Reinforcement calculation:

$$a = \frac{A_s f_y}{0.85 f'_c b} = \frac{A_s \times 60}{0.85 \times 3 \times 12} = 1.96 A_s$$

$$\therefore M_u = \phi A_s f_y \left(d - \frac{a}{2}\right)$$

$$\Rightarrow 3368 \times 12 = 0.9 \times A_s \times 60000 \times \left(4.5 - \frac{1.96 A_s}{2}\right)$$

$$\Rightarrow 40416 = 243000 A_s - 52920 A_s^2$$

$$\therefore A_s = 0.17 \text{ in}^2$$

At point A: $A_s = \dfrac{12 \cdot 3 \times 12}{0.9 \times 60000 \times (4.5 - 0.98 A_s)} = 0.06 \text{ in}^2$

At point B: $A_s = \dfrac{216 \cdot 14 \times 12}{0.9 \times 60000 \times (4.5 - 0.98 A_s)} = 0.11 \text{ in}^2$

At point C, $A_s = \dfrac{3368 \times 12}{0.9 \times 60000 \times (4.5 - 0.98 A_s)} = 0.17 \text{ in}^2$

Distribution reinforcement:

$$A_{s\,min} = 0.0018 bt = 0.0018 \times 12 \times 5.5 = 0.12 \text{ in}^2$$

Spacing calculation:

At point A, $S = \frac{0.11 \times 12}{0.06} = 22$ in c/c

" B, $S = \frac{0.11 \times 12}{0.11} = 12''$ c/c

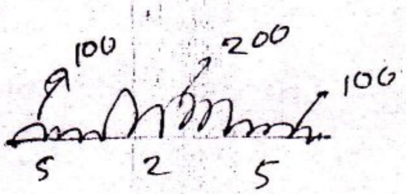
C, $S = \frac{0.11 \times 12}{0.17} = 7.76'' \simeq 7.75''$ c/c

Maxm spacing $= 3t = 3 \times 5.5 = 16.5''$ c/c

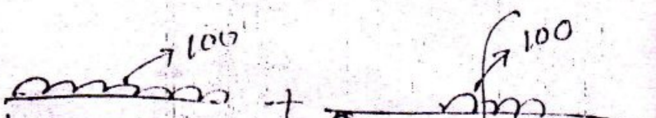
For distribution reinforcement, $S = \frac{0.11 \times 12}{0.12} = 11''$ c/c

∴ maxm spacing $= 5t = 5 \times 5.5 = 27.5''$ c/c

Design of Landing



$$M_{max} = \frac{w \times l^2}{8} + w \times \frac{L}{2} - \frac{w \times a^2}{2}$$

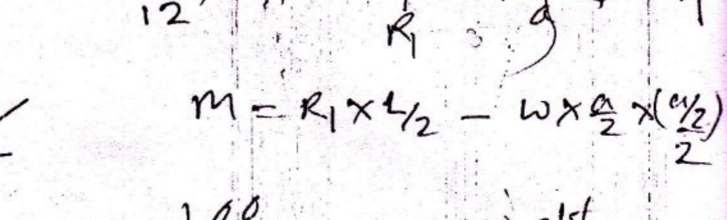


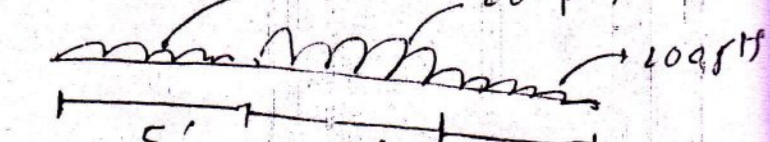
$$M = R_1 \times L/2 - w \times \frac{a}{2} \times \frac{(a/2)}{2}$$

$$= \frac{100 \times 12^2}{8} + 100 \times 6 - \frac{100 \times 1^2}{2}$$

$$= 1800 + 600 - 50$$

$$= 2350 \text{ lb ft}$$





$$d_{Actual} = 8 - c.c - \frac{\phi}{2}$$

$$= 8 - 0.75 - \frac{1}{2}\left(\cancel{\frac{\text{bar dia}}{8}}\right)$$ bar dia (ϕ)

#4 [illegible]

$$= 8 - 0.75 - \frac{1}{2} \times \left(\frac{4}{8}\right)$$

ϕ = bar dia

$= \frac{\#}{8}$

$$= 8 - 0.75 - 0.25 = 8 - 1 = 7$$

Stir-up

Stirrup

AHSAN
090063

1. A simply supported rectangular beam 16 in wide having an effective depth of 22 in carries a total factored load of 9.4 kips/ft on a 20 ft clear span. Using vertical U stirrups with $f_y = 60000$ psi design the web reinforcement for the beam, $f_c' = 4000$ psi

Solution:

$$V_{ud} = \frac{WL}{2} - \frac{d}{12} W_u$$

$$= \frac{9.4 \times 20}{2} - \frac{22}{12} \times 9.4$$

$$= 76.77\text{K}$$

$$V_c = 2\sqrt{f_c'}\, b_w d$$

$$= 2\sqrt{4000} \times 16 \times 22 = 44.52\text{ K}$$

$$\phi V_c = 0.75 \times 44.52 = 33.39\text{ K}$$

$$\frac{1}{2}\phi V_c = 0.5 \times 33.39 = 16.7\text{ K}$$

Now, Spacing, $S = \dfrac{\phi A_v f_y d}{V_{ud} - \phi V_c}$

$$= \frac{0.75 \times 0.22 \times 60\cancel{00} \times 22}{76.77 - 33.39}$$

$$= 5.02$$

$$\simeq 5 \text{ in } (S_{min})$$

$$\phi V_s = V_u - \phi V_c$$

$$= 76.77 - \cancel{0.75}\ 33.39$$

$$= 43.38\text{ K}$$

$$4\phi\sqrt{f_c'}\, b_w d =$$

$$= 4 \times 0.75 \times \sqrt{4000} \times 16 \times 22$$

$$= 66.78\text{ K}$$

$$\therefore \phi V_s < 4\phi\sqrt{f_c'}\, b_w d$$

$$S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'}\, b_w d} = \frac{0.22 \times 60000}{0.75\sqrt{4000} \times 16 \times 22} = \cancel{0.79}\ 17.39 \text{ in}$$

$$S_{max} = \frac{A_v f_y}{50 b_w} = \frac{0.22 \times 60000}{50 \times 16} = 16.5 \text{ in}$$

$$S_{max} = \frac{d}{2} = \frac{22}{2} = 11''$$

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

$\therefore$ Accepted $S_{max} = 11''$

$$11 = \frac{\phi A_v f_y d}{V_{ud} - \phi V_c}$$

$$\Rightarrow V_{ud} - \phi v_c = \frac{0.75 \times 0.22 \times 60\cancel{000} \times 22}{11}$$

$$\therefore V_{ud} = \cancel{0.9}\ 19.8 + 33.39 = 53.19^k$$

Assume, spacing $= 8''$ $\left(S_{mt} = \frac{S_{max} + S_{min}}{2}\right)$

$$8 = \frac{\phi A_v f_y d}{V_{ud} - \phi v_c}$$

$$\Rightarrow V_{ud} = \frac{0.75 \times 0.22 \times 60 \times 22}{8} + 33.39$$

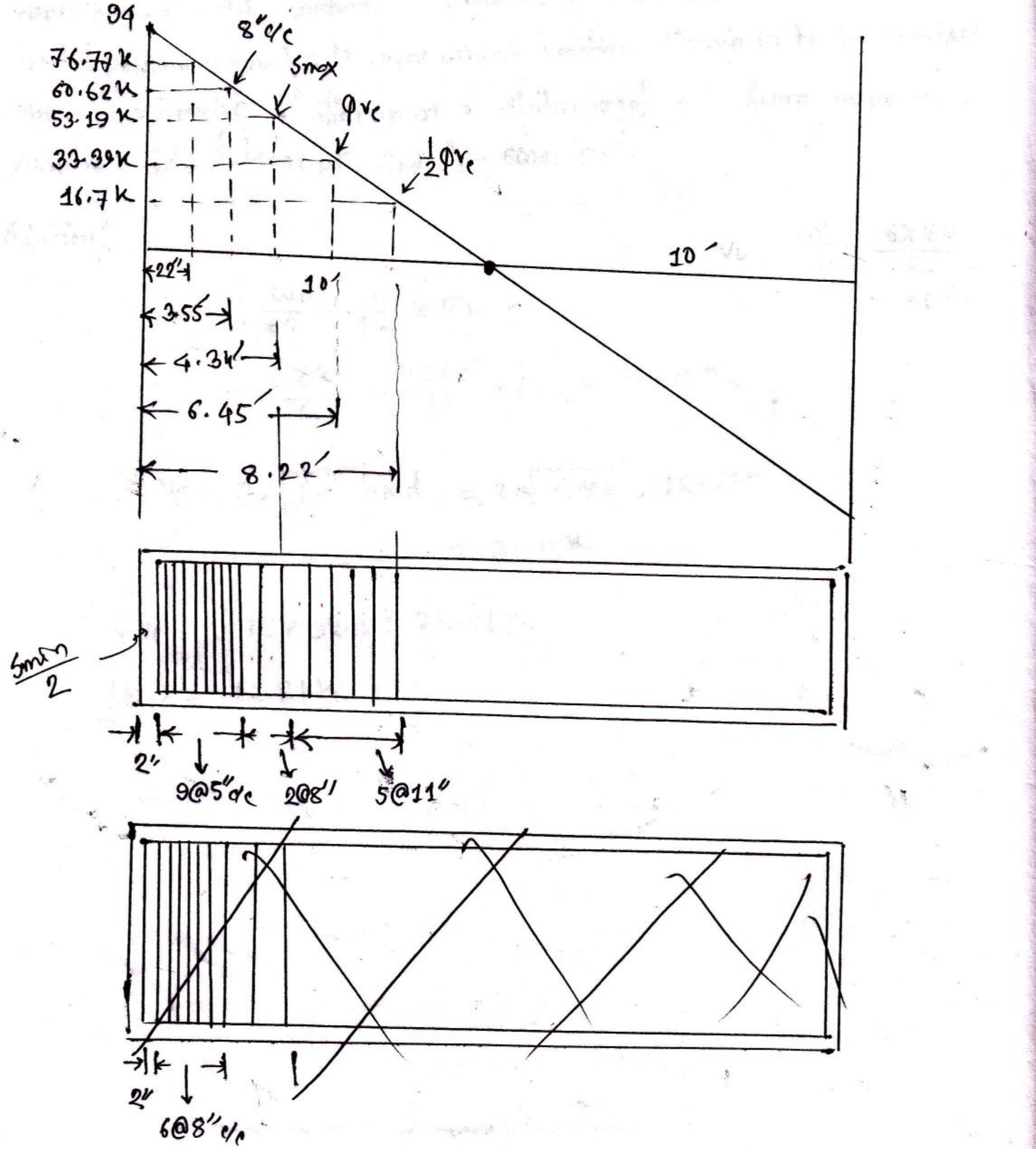
$$= 60.62^k$$

$8''$ c/c distance, $\frac{94}{10} = \frac{\cancel{76}\ 60.62}{10 - x}$ $\therefore x = 3.55'$

S_{max} ″, $\frac{94}{10} = \frac{53.19}{10 - x}$ $\therefore x = 4.34'$

ϕv_c ″, $\frac{94}{10} = \frac{33.39}{10 - x}$ $\therefore x = 6.45'$

$\frac{1}{2}\phi v_c$ ″, $\frac{94}{10} = \frac{16.7}{10 - x}$ $\therefore x = 8.22'$


94
76.77 K
60.62 K
53.19 K
33.99K
16.7 K
8" c/c
Smax
φvc
1/2 φvc
22"
10'
10'
3.55
4.34'
6.45'
8.22'
Smin/2
2"
9@5" c/c
2@8"
5@11"
2"
6@8" c/c

CE-10

4. (b) A simply supported rectangular beam 12 in wide and 22.5 in effective depth carries a total factored load of 6 kip/ft over an effective span of 20 ft. Determine the length over which vertical stirrup is to be provided. Obtain also spacing of stirrup at a distance of 3 ft from support. Assume, $f_c' = 4000$ psi and $f_y = 60000$ psi.

Solution:

$$V_u = \frac{wL}{2} = \frac{6 \times 20}{2} = 60^k$$

$$V_{ud} = \frac{wL}{2} - \frac{d}{12} \times w_u$$

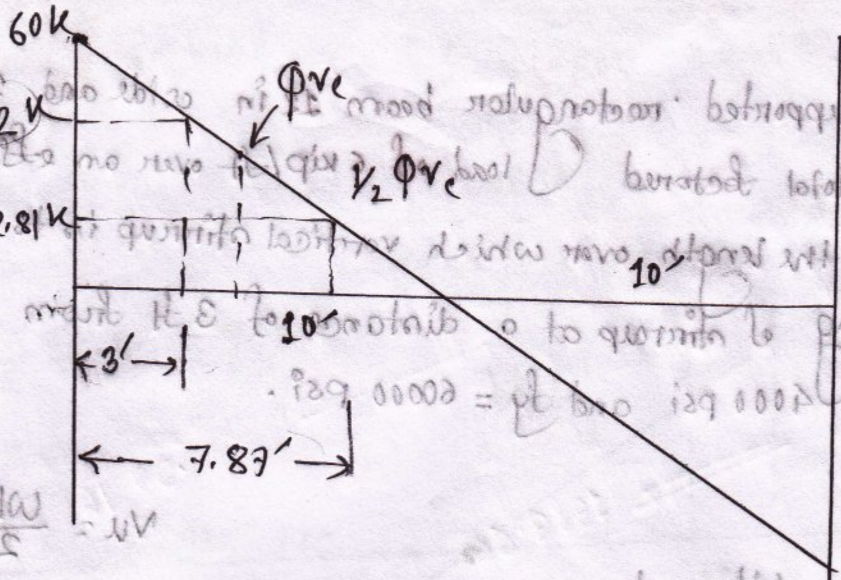
$$= \frac{6 \times 20}{2} - \frac{22.5}{12} \times 6 = 48.75^k$$

$$V_c = 2\sqrt{f_c'}\, b_w d = 2\sqrt{4000} \times 12 \times 22.5$$

$$= 34.15^k$$

$$\phi V_c = 0.75 \times 34.15 = 25.61^k$$

$$\frac{1}{2}\phi V_c = 12.81^k$$



Distance on $\frac{1}{2}\phi V_c$, $\quad \frac{60}{10} = \frac{12.81}{10-x} \quad \therefore x = 7.87'$

Shear at 3 ft,

$$\frac{60}{10} = \frac{V_{ud}}{10-3} \quad \therefore V_{ud} = 42^{k}$$

Spacing,

$$s = \frac{\phi A_v f_y d}{V_{ud} - \phi V_c}$$

$$= \frac{0.75 \times 0.22 \times 60 \times 22.5}{42 - 25.61}$$

$$= 13.59'' \simeq 14'' \quad \text{(Ans)}.$$

2. If $V_u - \phi V_c = 3\phi\sqrt{f_c'}\, b_w d$. $w_u = 9.4$ K/ft. Find out the dimensions of the beam. $d = 2f$, $f_c' = 4000$ psi $f_y = 60000$ psi $b_w = 16''$

$L = 20$

Solution:

$$\phi V_s = V_{ud} - \phi V_c$$

$$\Rightarrow V_{ud} = \phi V_c + \phi V_s$$

$$\Rightarrow \frac{w_u L}{2} - \frac{d}{12} w_u = 2\phi\sqrt{f_c'}\, b_w d + 3\phi\sqrt{f_c'}\, b_w d$$

$$\Rightarrow \frac{9.4 \times 20}{2} - \frac{d}{12} \times 9.4 = 5\phi\sqrt{f_c'}\, b_w d$$

$$\Rightarrow \cancel{92.43}\ 94 - 0.78d = \frac{5 \times 0.75 \times \sqrt{4000} \times b_w \times d}{1000}$$

$$d = \frac{94}{0.78 + 0.237 b_w}$$

b_w	d	$\frac{d}{b}$ ratio
16	20.56	1.29
15	21.68	1.45
14	22.94	1.64
14.5	22.29	1.54

$\therefore$ $b_w = 14.5''$ $d = 22.29''$

$h = 22.29'' + 2.5'' = 24.79''$. (Ans)

CE 09 | 08

3. (b) $k = 1/10/ft$ A 10 ft span cantilever beam is to carry a service dead load of 1.73 k/ft including its self weight and a service live load of 3.5 k/ft. Find the sectional dimension of the beam so that $V_s \le 3\sqrt{f_c'}\,b_w d$. Using #3 stirrup with $f_c' = 3000$ psi and $f_y = 50000$ psi design completely the beam for web reinforcement,

Solution:

$L = 10'$ $D.L = 1.73$ k/ft $L.L = 3.5$ k/ft

$W_u = 1.2 \times D.L + 1.6 \times L.L = 7.676$ k/ft

$\phi V_s = V_{ud} - \phi V_c$

$\Rightarrow V_{ud} = \phi V_c + \phi V_s$

$\Rightarrow \frac{W_u L}{2} - \frac{d}{12} W_u = 2\sqrt{f_c'}\,\phi b_w d + 3\phi\sqrt{f_c'}\,b_w d$

$\Rightarrow \frac{7.676 \times 10}{2} - \frac{d}{12} \times 7.676 = \frac{5\phi\sqrt{3000} \times b_w \times d}{1000}$

$\Rightarrow 38.38 = d(0.64 + .2054\,b_w)$

$\Rightarrow d = \frac{38.38}{0.64 + .2054\,b_w}$

b_w	d	$\frac{d}{b}$ ratio
16	9.79	0.6
14	10.93	0.78
12	12.38	1.03
10	14.27	1.43
9.5	14.83	1.5

$b_w = 9.5''$ $\quad d = 14.83''$

$h = 14.83 + 2.5 = 17.33''$.

$V_{ud} = \frac{WL}{2} - \frac{d}{12} w_u = \frac{7.676 \times 10}{2} - \frac{14.83}{12} \times 7.676$

$= 38.38 - 9.49 = 28.89\,k$

$V_c = 2\sqrt{f_c'}\, b_w d = 2\sqrt{3000} \times 9.5 \times 14.83 = 15.43\,k$

$\phi V_c = 0.75 \times 15.43 = 11.57\,k$

$\frac{1}{2}\phi V_c = 0.5 \times 11.57 = 5.785\,k$

$\phi V_s = V_{ud} - \phi V_c = 28.89 - 11.57 = 17.32\,k$

$\phi 4\sqrt{f_c'}\, b_w d = 4\sqrt{3} \times 9.5 \times 14.83 = 976.08\,k \times 0.75$
$\times 0.75$

$\therefore \phi V_s < 4\sqrt{f_c'}\, b_w d$

Spacing, $\quad S_{min} = \frac{\phi A_v f_y d}{V_{ud} - \phi V_c} = \frac{0.75 \times 0.22 \times 50 \times 14.83}{17.32}$

$= 7.06 \simeq 7''\ c/c$

$S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'}\, b_w} = \frac{0.22 \times 50000}{0.75\sqrt{3000} \times 9.5} = 28.19 \simeq 28''\ c/c$

$S_{max} = \frac{A_v f_y}{50 b_w} = \frac{0.22 \times 50000}{50 \times 9.5} = 23.16 \simeq 23''\ c/c$

$S_{max} = \frac{d}{2} = \frac{14.83}{2} = 7.42 \simeq 7''\ c/c$

$S_{max} = 24''\ c/c$

$\therefore$ Accepted $S_{max} = 7''\ c/c$

CE-06

3. (b) A rectangular beam is to carry a service dead load of 1.6 k/ft including its own weight and a service live load of 3.2 k/ft on a simple span of 20 ft. Select the width and effective depth of the beam in which web reinforcement provides shear strength $V_s = 2V_c$. Use $f_c' \leq 4000$ psi. Find spacing of vertical stirrup at a distance of 4 ft from support if $f_y = 40000$ psi

Solution:

$D.L = 1.6$ k/ft $\quad L.L = 3.2$ k/ft $\quad L = 20'$

$W_u = 1.2 \times 1.6 + 1.6 \times 3.2 = 7.04$ k/ft

$\phi V_s = V_{ud} - \phi V_c$

$\Rightarrow V_{ud} = \phi V_s + \phi V_c$

$\Rightarrow \dfrac{W_u L}{2} - \dfrac{d}{12} W_u = 2\phi V_c + \phi V_c$

$\Rightarrow \dfrac{7.04 \times 20}{2} - \dfrac{d}{12} \times 7.04 = \dfrac{3 \times 0.75 \times 2\sqrt{f_c'}\, b_w d}{1000}$

$\Rightarrow 70.4 - 0.587\, d = \dfrac{3 \times 0.75 \times 2 \times \sqrt{4000}\, b_w d}{1000}$

$= 0.28\, b_w d$

$\Rightarrow d = \dfrac{70.4}{0.587 + 0.28\, b_w}$

b_w	d	$\frac{d}{b}$
12	17.83	1.49
12.5	12.22	1.37
11.5	18.49	1.6

$\therefore V_{ud} = 32.93$

$b_w = 12''$ $\quad d = 17.83''$

$h = 17.83 + 2.5 = 20.33''$

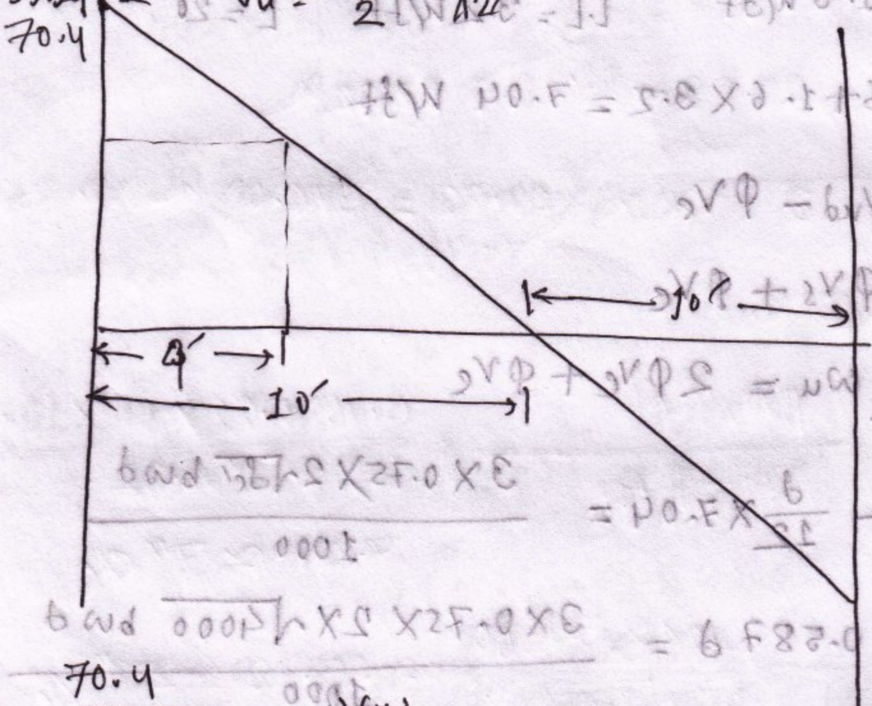
$V_c = 2\sqrt{f_c'}\, b_w d = 2\sqrt{4000} \times 12 \times 17.83$

$= 27064.04 = 27.06\,k$

$\phi V_c = 0.75 \times 27.06 = 20.3\,k$

$\frac{1}{2}\phi V_c = 10.15\,k$

$\cancel{59.94}\,k$ $\quad V_u = \frac{wL}{2} - \frac{d}{12}w = 70.4 - \cancel{10.46} = \cancel{59.94}\,k$



$\frac{\overset{70.4}{\cancel{59.94}}}{10} = \frac{V_{ud}}{10-4}$

$\therefore V_{uy} = 35.964\,k$

$s = \frac{\phi A_v f_y d}{V_{ud} - \phi V_c} = \frac{0.75 \times 0.22 \times 40 \times 17.83}{35.964 - 20.3}$

$= 7.51 \simeq 8''\ c/c$

CE-07

5. (b) $b = 10''$ $d = 20''$ Distributed load $= 6\ K/ft$

$L = 20'$ $f_y = 50\ ksi$ $f_c' = 3\ ksi$

$$V_{ud} = \frac{\omega L}{2} - \frac{d}{12}\omega = \frac{6 \times 20}{2} - \frac{20}{12} \times 6 = 50\ K$$

$$V_c = 2\sqrt{f_c'}\ b_w d = 2\sqrt{3000} \times 10 \times 20 = 21.91^K$$

$$\phi V_c = 0.75 \times 21.91 = 16.43^K$$

$$\tfrac{1}{2}\phi V_c = 8.22^K$$

$$S_{min} = \frac{\phi A_v f_y d}{V_{ud} - \phi V_c} = \frac{0.75 \times 0.22 \times 50 \times 20}{50 - 16.43} = 4.92'' \simeq 4''$$

$$\phi V_s = V_{ud} - \phi V_c = 50 - 16.43 = 33.57^K$$

$$\phi 4\sqrt{f_c'}\ b_w d = 4\sqrt{3000} \times 10 \times 20 \times 0.75 = 43.81^K \times 0.75$$

$$\therefore \phi V_s < 4\phi\sqrt{f_c'}\ b_w d$$

$$S_{max} = \frac{A_v f_y}{0.75\sqrt{f_c'}\ b_w} = \frac{0.22 \times 50000}{0.75 \times 10 \times \sqrt{3000}} = 26.77''$$

$$S_{max} = \frac{A_v f_y}{50 b_w} = \frac{0.22 \times 50000}{50 \times 10} = 22''$$

$$S_{max} = \frac{d}{2} = \frac{20}{2} = 10''$$

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

$$\therefore \text{Accepted } S_{max} = 10''$$

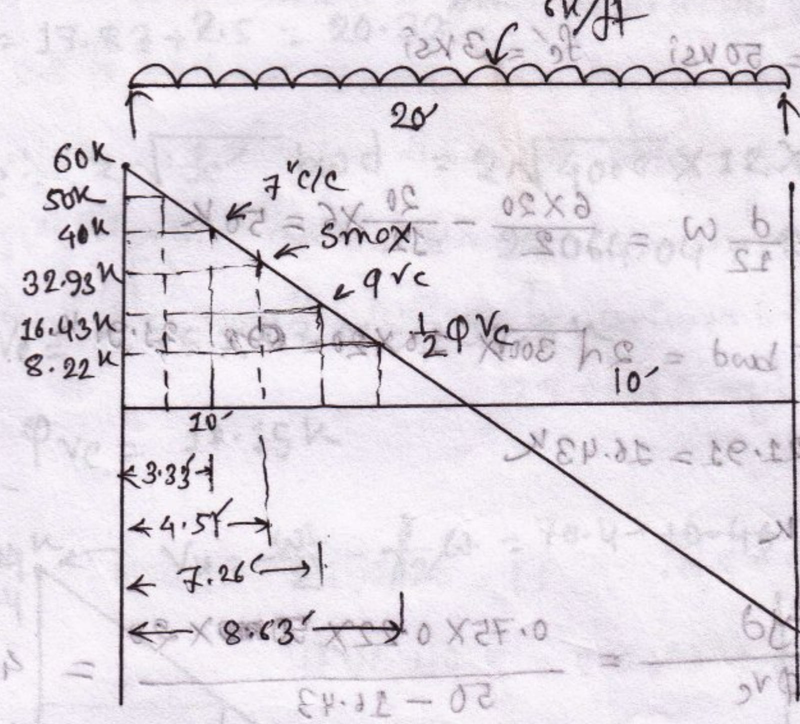
$$10 = \frac{\phi A_v f_y d}{V_{ud} - \phi V_c} \Rightarrow 10 = \frac{0.75 \times 0.22 \times 50 \times 20}{V_{ud} - 16.43}$$

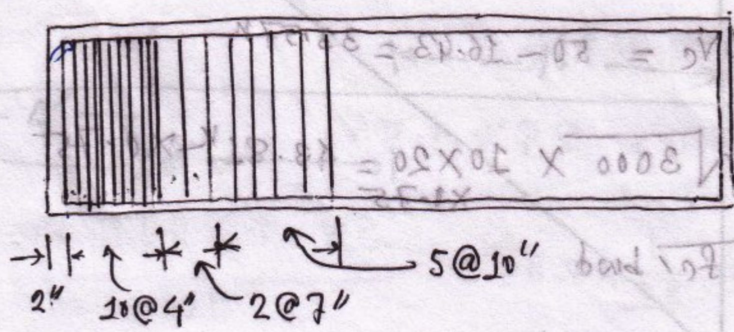
$$\therefore V_{ud} = 32.93^K$$

$$7 = \frac{0.75 \times 0.22 \times 50 \times 20}{V_u - 16.43}$$

$\therefore V_u = 40^k$

$$S_{int} = \frac{S_{min} + S_{max}}{2} = \frac{4 + 10}{2} = 7''$$





$\frac{60}{10} = \frac{40}{10-x}$ $\therefore x = 3.33$

$\frac{60}{10} = \frac{32.93}{10-x}$ $\therefore x = 4.57'$

$\frac{60}{10} = \frac{16.43}{10-x}$ $\therefore x = 7.26'$

$\frac{60}{10} = \frac{8.22}{10-x}$ $\therefore x = 8.63'$

Stair

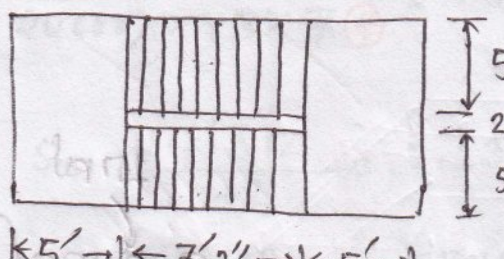
Staircase

(1 set must)

AHSAN
090063

01. Design a stair as shown in fig with the following data:

L.L = 100 psf   Rise = 7"   Thread = 10.75", $f_c' = 3$ ksi $f_y = 60$ ksi



Load Calculation:

a) Slab: Assume, the thickness of waist slab = 8"

Dead load of waist slab on inclined area, $\omega_1 = \frac{t}{12} \times 150$

$$= \frac{8}{12} \times 150 = 100 \text{ psf}$$

i) Dead load of slab on plane $\Rightarrow w = \omega_1 \frac{\sqrt{T^2+R^2}}{T}$

$$= 100 \times \frac{\sqrt{(10.75)^2 + (7)^2}}{10.75}$$

$$= 119.33 \text{ psf}$$

ii) Dead load on step $= \frac{R}{2} \times 150 = \frac{7}{12 \times 2} \times 150 = 43.75$ psf

iii) L.L = 100 psf

$\therefore$ Total load $= 119.33 + 43.75 + 100 = 263.08$ psf

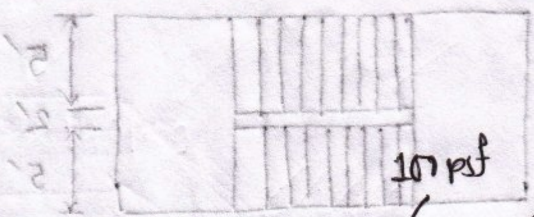
b) Landing:

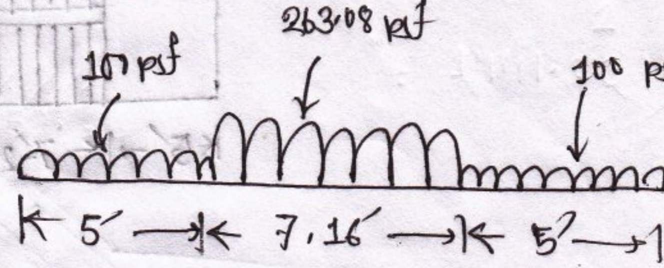
i) Dead load on landing $= \frac{t}{12} \times 150 = \frac{8}{12} \times 150 = 100$ psf

ii) L.L = 100 psf

$\therefore$ Total load on landing = 100 + 100 = 200 psf

c) Design of flight:

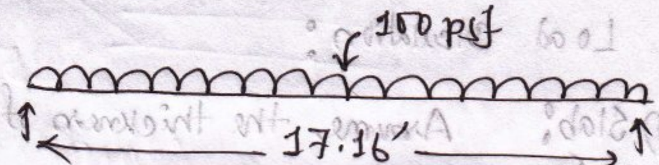




(i) $M_{max} = \frac{\omega L^2}{8}$

$= \frac{100 \times (17.16)^2}{8}$

$= 3680.82$ lb-ft

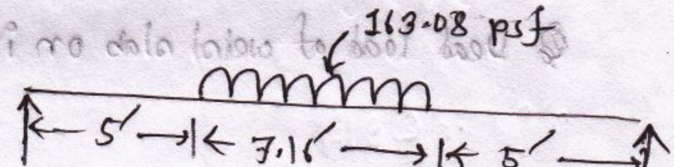


(ii) $M_{max} = 583.83 \times 8.58 -$

$163.08 \times 7.16 \times 3.58 \times \frac{3.58}{2}$

$= 5009.26 - 1045.05$

$= 3964.21$ lb-ft



$\frac{\omega L}{2} = \frac{163.08}{2} \times 7.16$

$= 583.83$

$\therefore M_{max} = 3680.82 + 3964.21 = 7645.03$ lb-ft

d) Depth check:

$d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{7645.03 \times 12}{234 \times 12}}$

$= 5.72''$

$R = \frac{1}{2} f_c j k = 234$

$r = \frac{f_s}{f_c} = \frac{0.4 \times 60}{0.45 \times 3} = 17.78$

$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9$

$k = \frac{n}{n+r} = 0.36 \quad j = 0.88$

Actual, $d = t - c.c - \frac{1}{2}\phi$

$= 8 - 1 = 7'' > 5.72''$ (OK)

e) Reinforcement calculation:

$A_s = \frac{M}{f_s j d} = \frac{7645.03 \times 12}{24000 \times 0.88 \times 7} = 0.62 \text{ in}^2$

Spacing, #3, $S = \frac{0.11 \times 12}{0.62} = 2.13''$

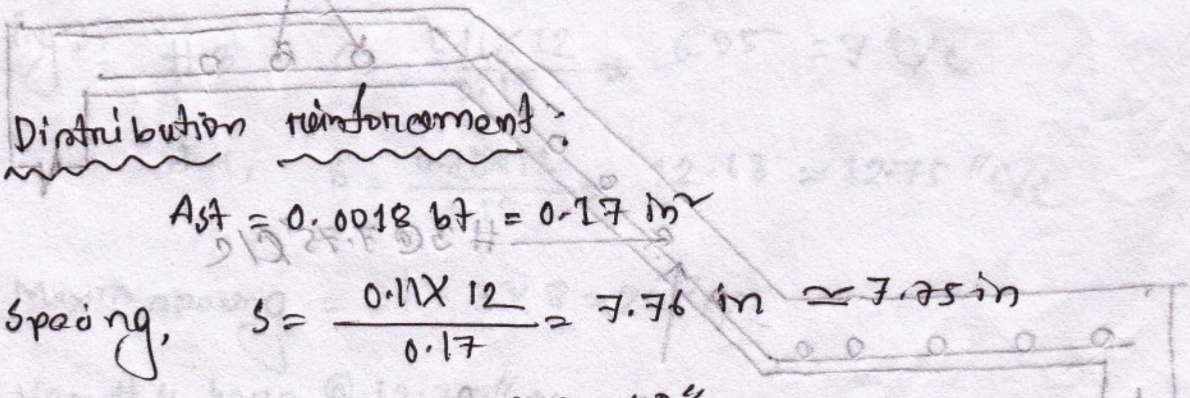
#4, $S = \frac{0.2 \times 12}{0.62} = 3.87''$

#5, $S = \frac{0.31 \times 12}{0.61} = 6.1''\phi$

$\therefore$ Maximum spacing $= 3t = 3 \times 8 = 24''$

$\therefore$ Use #5 bars @ 6" c/c

$A_{s\,min} = 0.0018\ bt = 0.0018 \times 12 \times 8 = 0.17 \text{ in}^2$



f) Distribution reinforcement:

$A_{st} = 0.0018\ bt = 0.17 \text{ in}^2$

Spacing, $S = \frac{0.11 \times 12}{0.17} = 7.76 \text{ in} \simeq 7.75 \text{ in}$

Max^m spacing $= 5t = 5 \times 8 = 40''$

g) Bond check:

$$V_d = \frac{V_{max}}{\Sigma_o\, jd} \quad (OK)$$

$$\Sigma_o = \pi\phi \frac{b}{spacing} = \pi \times \frac{5}{8} \times \frac{12}{6} = 3.93$$

$$V_{max} = \frac{wl}{2} = \frac{\cancel{263.08 \times 17.16}}{\cancel{2}} = \cancel{2257.23}\ 16$$

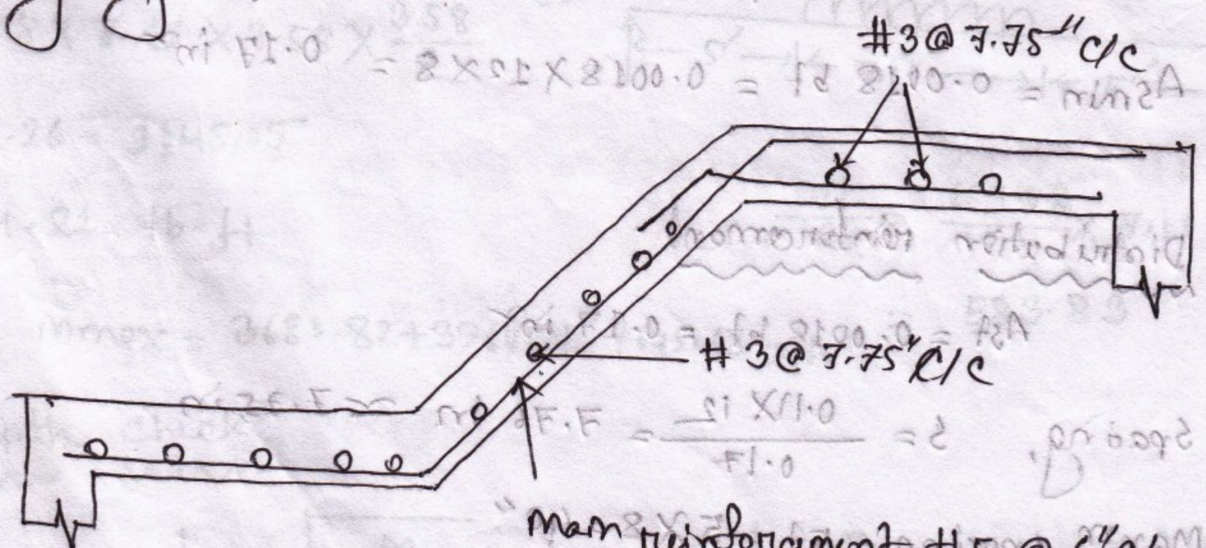
$$V_{max} = \frac{263.08 \times 7.16 + 100\times5 + 100\times5}{2} = 1441.83$$

$$\therefore V_d = \frac{\cancel{2257.23}\ 1441.83}{3.93 \times 0.88 \times 7} = \cancel{93.24}\ 59.56\ 16$$

$$V_{allowable} = \frac{3.4\sqrt{f_c'}}{\phi} = \frac{3.4\sqrt{3000}}{5/8} = 297.96$$

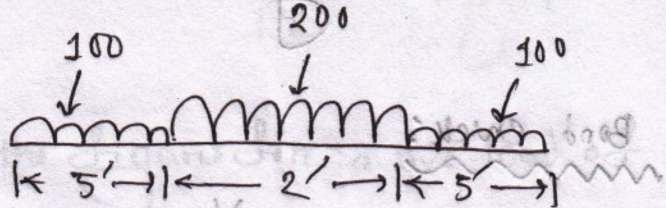
$\therefore$ Vallowable > Vd (OK)

h) Working diagram:



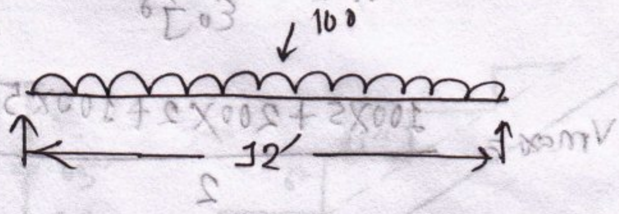
* working diagram এর জন্য Design of landing দিবে

Design of landing:



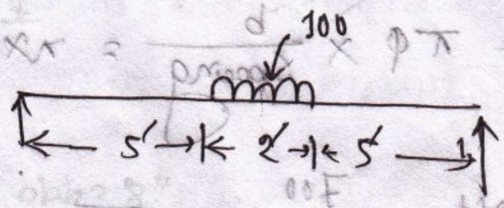
$$M_{max} = \frac{WL^2}{8}$$

$$= \frac{100 \times (12)^2}{8} = 1800 \text{ lb-ft}$$



$$M_{max} = 100 \times (5+1) - 100 \times 1 \times \frac{1}{2}$$

$$= 550 \text{ lb-ft}$$



$$\therefore M = 1800 + 550 = 2350 \text{ lb-ft}$$

$$\frac{WL}{2} = \frac{100 \times 2}{2} = 100$$

Reinforcement calculation:

$$A_s = \frac{M}{f_s j d} = \frac{2350 \times 12}{0.4 \times 60000 \times 0.88 \times 7} = 0.19 \text{ in}^2$$

Spacing. $\#3, \; s = \frac{0.11 \times 12}{0.19} = 6.95 = 7'' c/c$

$\#4, \; s = \frac{0.20 \times 12}{0.19} = 12.63 \simeq 12.75'' c/c$

Maxm spacing $= 3t = 3 \times 8 = 24'' c/c$

Use #4 bars @ $12.75'' c/c$

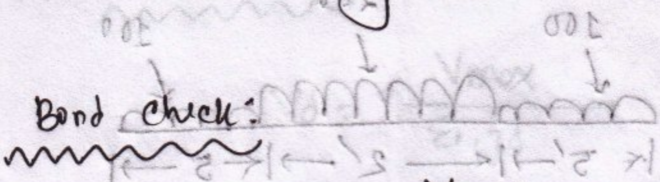
$A_{s\,min} = 0.0018\, bt = 0.0018 \times 12 \times 8 = 0.17 \text{ in}^2$

Distribution reinforcement:

$$A_{st} = 0.0018\, bt = 0.17 \text{ in}^2$$

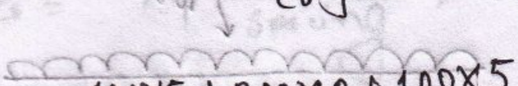
Spacing, $s = \frac{0.11 \times 12}{0.17} = 7.76 \simeq 7.75'' c/c$

Max^m spacing $= 5t = 5 \times 8 = 40'' c/c$



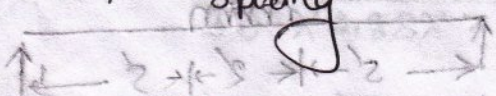
Bond check:

$$V_d = \frac{V_{max}}{\Sigma_o j d}$$



$$V_{max} = \frac{100 \times 5 + 200 \times 2 + 100 \times 5}{2} = 700 \text{ lb}$$

$$\Sigma_o = \pi \phi \times \frac{b}{\text{Spacing}} = \pi \times \frac{4}{8} \times \frac{12}{12.75} = 1.48$$



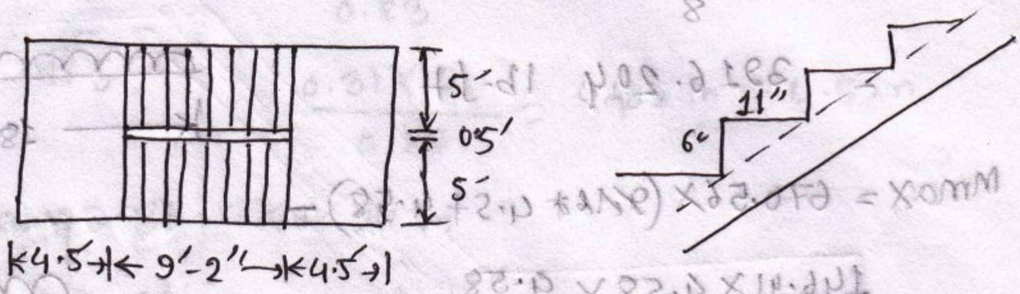
$$V_d = \frac{700}{1.48 \times 0.88 \times 7} = 76.78 \text{ lb}$$

$$V_{allowable} = \frac{3.4\sqrt{f_c'}}{\phi} = \frac{3.4 \times \sqrt{3000}}{\frac{4}{8}} = 372.45 \text{ lb}$$

$\therefore V_d < V_{allowable}$ (ok).

CE-11

Design the stair shown in the figure for a live load of 90 psf. Use $f_c' = 3000$ psi and $f_y = 50000$ psi.



Solution:

a) slab: Assume, the thickness of waist slab = 8"

Dead load of waist slab on inclined $w_1 = \frac{t}{12} \times 150 = \frac{8}{12} \times 150 = 100$ psf

a) Dead load of slab on plane, $w = w_1 \times \frac{\sqrt{T^2+R^2}}{T} = 100 \times \frac{\sqrt{(11)^2+(6)^2}}{11}$

$= 113.91$ psf

b) Dead load of step $= \frac{R}{2} \times 150 = \frac{6}{12 \times 2} \times 150 = 37.5$ psf

c) L.L = 90 psf

$\therefore$ Total load $= 113.91 + 37.5 + 90 = 241.41$ psf

b) Landing:

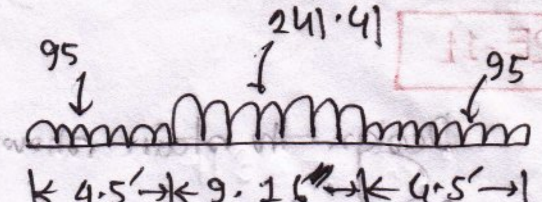
i) ~~Total load~~ Dead load on landing $= \frac{t}{12} \times 150 = \frac{8}{12} \times 150 = 100$ psf

ii) L.L = 90 psf

$\therefore$ Total load $= 100 + 90 = 190$ psf

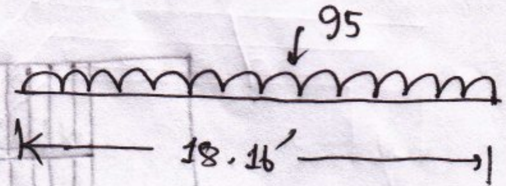
c) Design of flight:

$M_{max} = \frac{wl^2}{8}$



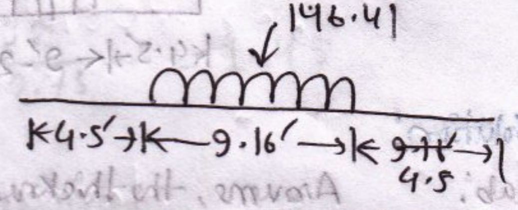
$= \frac{95 \times (18.16)^2}{8}$

$= 3916.204$ lb-ft



$M_{max} = 670.56 \times (\cancel{9.16} + 4.5 + 4.58) -$

$146.41 \times 4.58 \times \frac{4.58}{2}$



$= 6088.68 - 1535.58$

$\frac{WL}{2} = \frac{146.41 \times 9.16}{2} = 670.56$

$= 4553.10$ lb-ft

$\therefore TM = 3916.204 + 4553.10 = 8469.31$ lb-ft

d) Depth check:

$d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{8469.31 \times 12}{223.16 \times 12}}$

$= 6.16$ in

Actual $d = t - c.c - \frac{1}{2}\phi$

$= 8 - 1 = 7$ in $> d$

(OK)

$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9$

$r = \frac{f_s}{f_c} = \frac{0.4 \times 50000}{0.45 \times 3000} = 14.81$

$k = \frac{9}{9 + 14.81} = 0.38$

$J = 1 - \frac{k}{3} = 0.87$

$R = \frac{1}{2} f_c j k$

$= \frac{1}{2} \times 0.45 \times 3000 \times 0.87 \times 0.38$

$= 223.16$

e) Reinforcement calculation:

$$A_s = \frac{M}{f_s j d} = \frac{8419.31 \times 12}{0.4 \times 50000 \times 0.87 \times 7} = 0.83\ in^2$$

Spacing, s, #3, $s = \frac{0.11 \times 12}{0.83} = 1.59\ in$

#5, $s = \frac{0.31 \times 12}{0.83} = 4.48\ in \simeq 4.5\ in$

$\therefore$ Max^m spacing $= 3t = 3 \times 8 = 24\ in$

Use #5 bars @ 4.5 in c/c

$As_{min} = 0.0018\ bt = 0.0018 \times 12 \times 8 = 0.17\ in^2$

f) Distribution reinforcement:

$$A_{st} = 0.0018bt = 0.17\ in^2$$

Spacing, #3, $s = \frac{0.11 \times 12}{0.17} = 7.76\ in$

$\therefore$ Max^m spacing $= 5t = 5 \times 8 = 40\ in$

g) ~~Shear~~ Bond check:

$$V_d = \frac{V_{max}}{\Sigma_0\ j d}$$

$$V_{max} = \cancel{\frac{wl}{2}} = \cancel{\frac{241.41 \times 18.76}{2}} = \cancel{2182\ lb} = \frac{246.41 \times 9.16 + 95 \times 4.5 + 95 \times 4.5}{2} = 1556.06\ lb$$

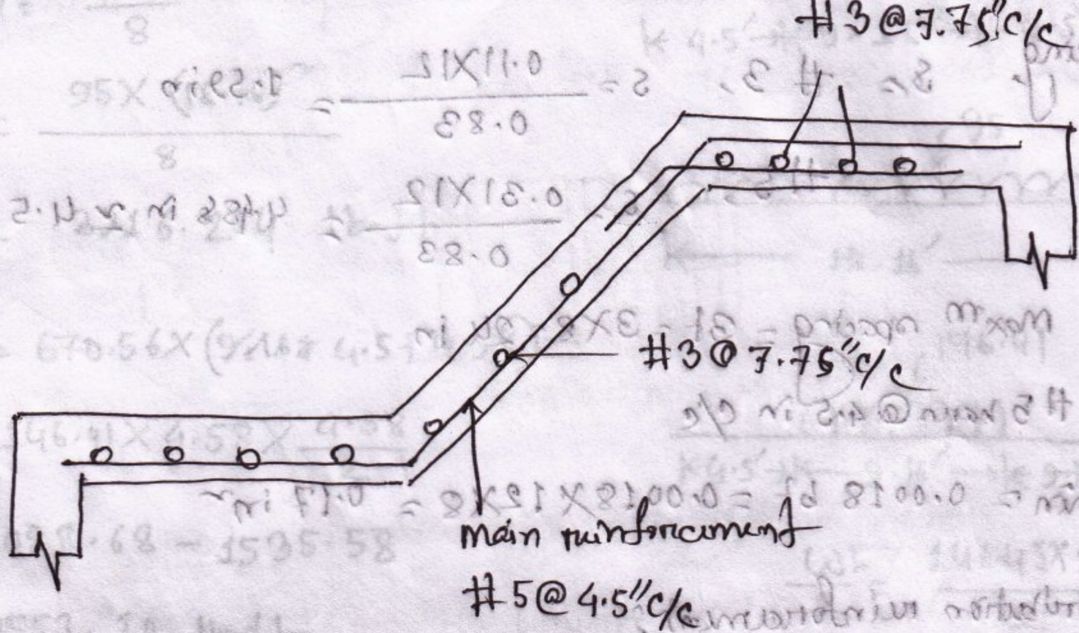
$$\Sigma_0 = \pi \phi \frac{b}{spacing} = \pi \times \frac{5}{8} \times \frac{12}{4.5} = 5.24$$

$$V_d = \frac{\cancel{2182}\ 1556.06}{5.24 \times 0.87 \times 7} = \cancel{68.69\ lb}\ 48.76\ lb$$

$$V_{allowable} = \frac{3.4 \times \sqrt{f_c'}}{\phi} = \frac{3.4\sqrt{3000}}{5/8} = 297.96$$

$\therefore V_d < V_{allowable}$ (OK).

h) working diagram:



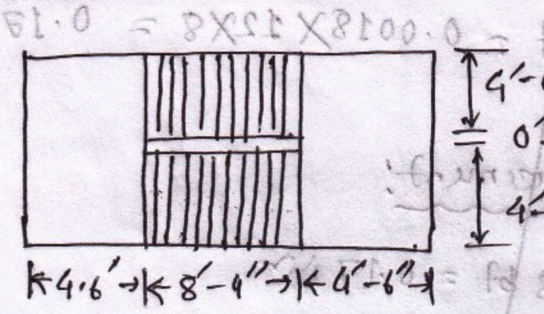
$$V_d = \frac{2078.50}{4.96 \times 0.87 \times 7} = 68.81 \text{ lb}$$

$$V_{allowable} = \frac{3.4\sqrt{f_c'}}{\phi} = \frac{3.4 \times \sqrt{3000}}{\frac{5}{8}} = 297.96$$

$\therefore V_{allowable} > V_d$ (OK).

CE-09

Design the stair case shown in the figure which carries a uniform liveload of 107 psf. Use $f_c' = 3000$ psi and $f_y = 50000$ psi. Assume the rise of the step to be 6 inch.



Solution: Assume thickness of waist slab = 8"

Dead load of waist slab on inclined area $= \frac{t}{12} \times 150 = \frac{8}{12} \times 150 = 100$ psf

i) Dead load of slab on plane $W_1 = W \times \frac{\sqrt{T^2 + R^2}}{T} = 100 \times \frac{\sqrt{(10)^2 + (6)^2}}{10}$

$= 116.62$ psf

ii) Dead load of step $= \frac{R}{2} \times 150 = \frac{6}{12 \times 2} \times 150 = \cancel{\frac{450}{2}}\ 37.5$ psf

iii) L.L = 107 psf

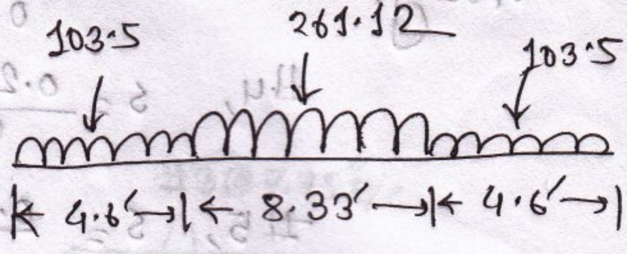
$\therefore$ Total load $= 116.62 + \cancel{450}\ 37.5 + 107 = \cancel{673.62 \text{ psf}}\ 261.12$ ps

i) Dead load of landing $= \frac{t}{12} \times 150 = \frac{8}{12} \times 150 \approx 100$ psf

ii) L.L = 107 psf

$\therefore$ Total load = 100 + 107 = 207 psf

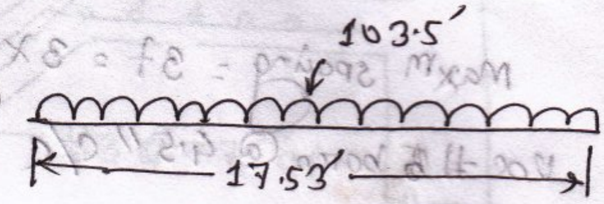
Design of flight:



(i) $M_{max} = \frac{wl^2}{8}$

$= \frac{103.5 \times (17.53)^2}{8}$

$= 3975.71$ lb-ft

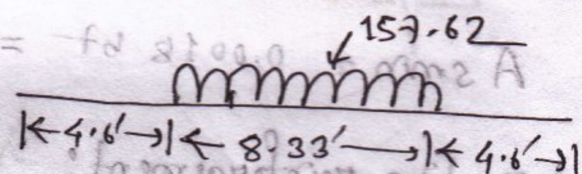
(i) 

(ii) $M_{max} = 656.49 \times (4.6 + 4.165) -$

$157.12 \times 4.165 \times \frac{4.165}{2}$

$= 5754.13 - 1367.13$

$= 4387$ lb-ft

(ii) 

$\frac{wL}{2} = \frac{157.12 \times 8.33}{2}$

$= 656.49$

$\therefore M = 3975.71 + 4387 = 8362.71$ lb-ft

Depth check:

$d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{8362.71 \times 12}{223.155 \times 12}}$

$= 6.12''$

Actual, d = t - c.c - $\frac{1}{2}\phi$

$= 8 - 1 = 7$ in > d

(ok)

$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000 \times \sqrt{3000}} = 9.28 \approx 9$

$r = \frac{f_s}{f_c} = \frac{0.4 \times 50000}{0.45 \times 3000} = 14.81$

$k = \frac{9}{9 + 14.81} = 0.38$

$J = 1 - \frac{0.38}{3} = 0.87$

$R = \frac{1}{2} f_c J k = \frac{1}{2} \times 0.45 \times 3000 \times 0.87 \times 0.38$

$= 223.155$

Reinforcement calculation:

$$A_s = \frac{M}{f_s jd} = \frac{8362.71 \times 12}{0.4 \times 50000 \times 0.87 \times 7} = 0.82\ in^2$$

Spacing, #3 · $S = \frac{0.11 \times 12}{0.82} = 1.61\ in$

#4, $S = \frac{0.2 \times 12}{0.82} = 2.93\ in$

#5, $S = \frac{0.31 \times 12}{0.82} = 4.54\ in \simeq 4.5\ in$

Max^m spacing $= 3t = 3 \times 8 = 24''$

Use #5 bars @ 4.5'' c/c

$A_{s\,min} = 0.0018\ bt = 0.0018 \times 12 \times 8 = 0.17\ in^2$

Distribution reinforcement:

$A_{st} = 0.0018\ bt = 0.0018 \times 12 \times 8 = 0.17\ in^2$

Spacing, #3, $S = \frac{0.11 \times 12}{0.17} = 7.76 \simeq 7.75\ in$

Max^m spacing $5t = 5 \times 8 = 40''$

Bond check:

$$V_d = \frac{V_{max}}{\varepsilon_0\, jd}$$

$$V_{max} = \frac{wl}{2} = \frac{\cancel{261.12 \times 17.53}}{2} = \cancel{2288.72}\ lb = \frac{261.12 \times 8.33 + 103.5 \times 4.6 \times 2}{2} = 1563.66\ lb$$

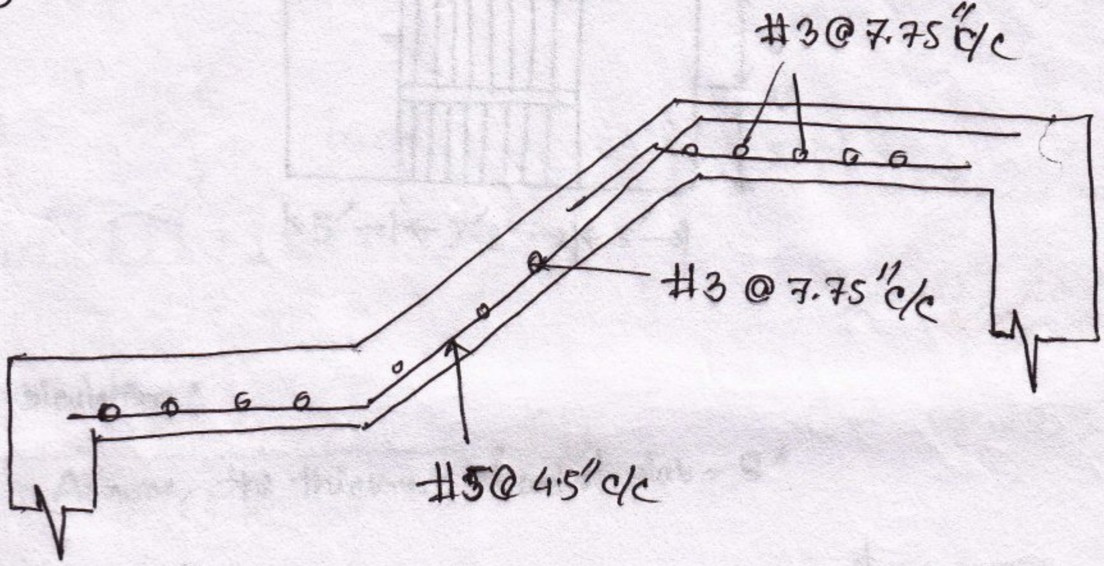
$$V_{allowable} = \frac{3.4\sqrt{f_c'}}{\phi} = \frac{3.4 \times \sqrt{3000}}{\frac{5}{8}} = 297.96\ lb$$

$$\varepsilon_0 = \pi\phi \frac{b}{spacing} = \pi \times \frac{5}{8} \times \frac{12}{4.5} = 5.24$$

$$V_d = \frac{\cancel{2288.72}\ 1563.66}{5.24 \times 0.87 \times 7} = \cancel{71.72\ lb}\ 48.99\ lb$$

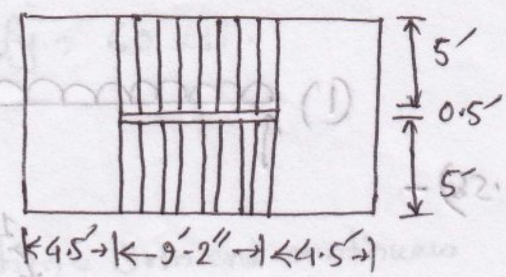
$\therefore \cancel{V_d > V_a}$ $V_{allowable} > V_d$ (OK).

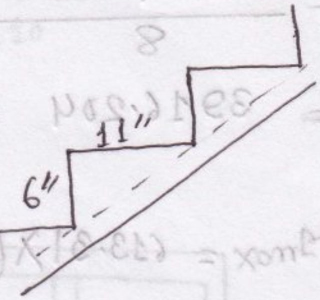
Working diagram:



CE-11

Design the stair shown in the figure for a live load of 90 psf. Use $f_c' = 3000$ psi and $f_y = 50000$ psi





Solution:

a) Slab: Assume, thickness of the waist slab = 8"

Dead load of waist slab on inclined area $w_1 = \frac{t}{12} \times 150 = \frac{8}{12} \times 150 = 100$ psf

i) Dead load of slab on plane, $w = w_1 \frac{\sqrt{T^2+R^2}}{T} = 100 \times \frac{\sqrt{(11)^2+(6)^2}}{11}$

$= 113.91$ psf

ii) Dead load of step $= \frac{R}{2} \times 150 = \frac{6}{2 \times 12} \times 100 = 25$ psf

iii) L.L = 90 psf

$\therefore$ Total load = $113.91 + 25 + 90 = 228.91$ psf

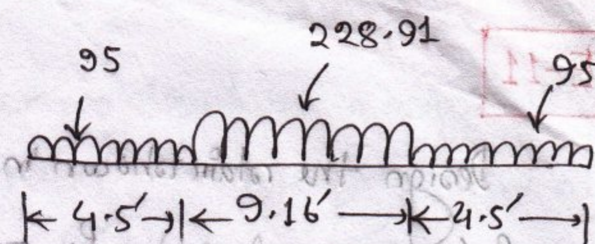
b) Landing:

i) Dead load on landing = $\frac{t}{12} \times 150 = \frac{8}{12} \times 150 = 100$ psf

ii) L.L = 90 psf

$\therefore$ Total load = $100 + 90 = 190$ psf

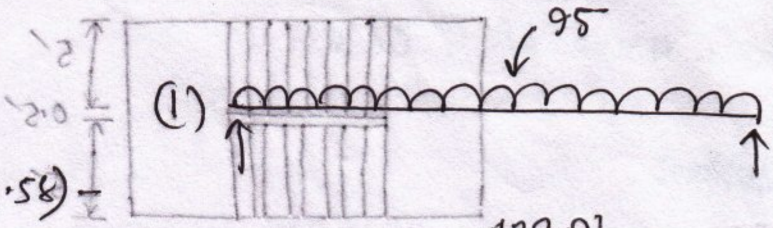
(ix) Design of flight:



(i) $M_{max} = \frac{wL^2}{8}$

$= \frac{95 \times (18.16)^2}{8}$

$= 3916.204$ lb-ft

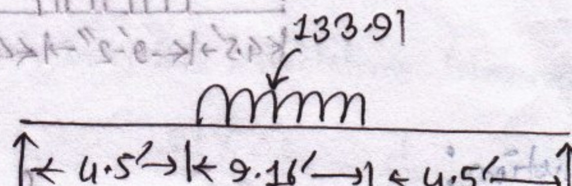


(ii) $M_{max} = 613.31 \times (4.5 + 4.58) -$

$133.91 \times 4.58 \times \frac{4.58}{2}$

$= 5568.85 - 1404.47$

$= 4164.38$ lb-ft



$\frac{wL}{2} = \frac{133.91 \times 9.16}{2} = 613.31$

$\therefore M = \frac{3916.204 + 4164.38}{}$

$= 8080.58$ lb-ft

d) Depth check:

$d = \sqrt{\frac{M}{Rb}}$

$= \sqrt{\frac{8080.58 \times 12}{223.155 \times 12}}$

$= 6.02''$

Actual, $d = t - c.c - \frac{1}{2}\phi$

$= 8 - 1 = 7'' > 6.02''$ (ok)

$n = \frac{E_s}{E_c} = \frac{29 \times 10^6}{57000\sqrt{3000}} = 9.28 \simeq 9$

$r = \frac{f_s}{f_c} = \frac{0.4 \times 50000}{0.45 \times 3000} = 14.81$

$k = \frac{9}{9 + 14.81} = 0.38$

$j = 1 - \frac{0.38}{3} = 0.87$

$R = \frac{1}{2} f_c j k = \frac{1}{2} \times 0.45 \times 3000 \times 0.87 \times 0.38$

$= 223.155$