## Serviceability requirements:

$$Design \rightarrow \begin{cases} \rightarrow strength\ requirements \\ \rightarrow servceability\ requirements \end{cases}$$

## *servceability requirements*

1. Control of cracking
2. Control of deflection

## *Control of cracking:*

Types of cracks:

1. Flexural cracks
2. Diagonal tension cracks(shear cracks)
3. Shrinkage cracks

# Flexural cracks

Factors affecting crack width:

1. Proper distribution of flexural reinforcements reduce crack width.
2. The use of deformed bars reduce crack width.
3. Crack width is directly proportional to steel stress(fs).
4. Crack width increases as concrete cover increases.

To limit surface cracks to a width that is generally acceptable in practice, the ACI code provision for spacing of reinforcement closest to a surface in tension shall not exceed that given by:

$$S = \frac{95000}{fs} - 2.5C_C \leq 300\left(\frac{252}{fs}\right)..ACI\ eq10-4, sec10.6.4$$

S:C/C spacing of flexural tension reinforcement *nearest* to the extreme *tension* face,(mm),[where there is only one bar nearest to the extreme tension face, S is the width of the extreme tension face]

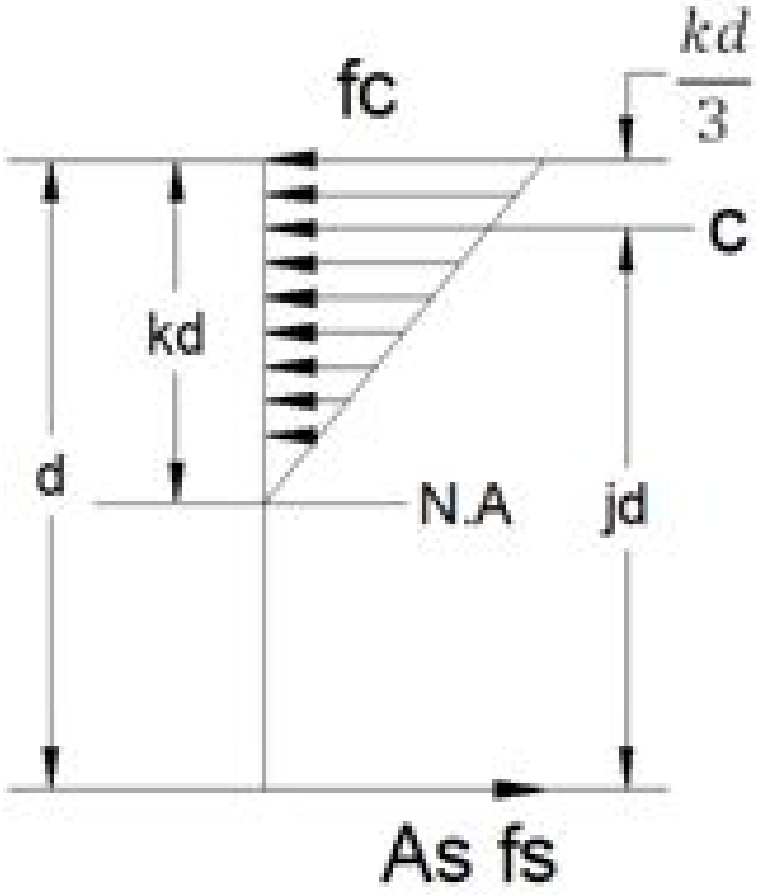
Cc: clear cover from the nearest surface in tension to the surface of the flexural tension reinforcement, mm

fs: calculated stress in reinforcement at service loads, MPa

$$fs = \frac{M}{A_s\, jd}$$

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

$$k = \sqrt{(2n\rho) + (n\rho)^2} - n\rho$$

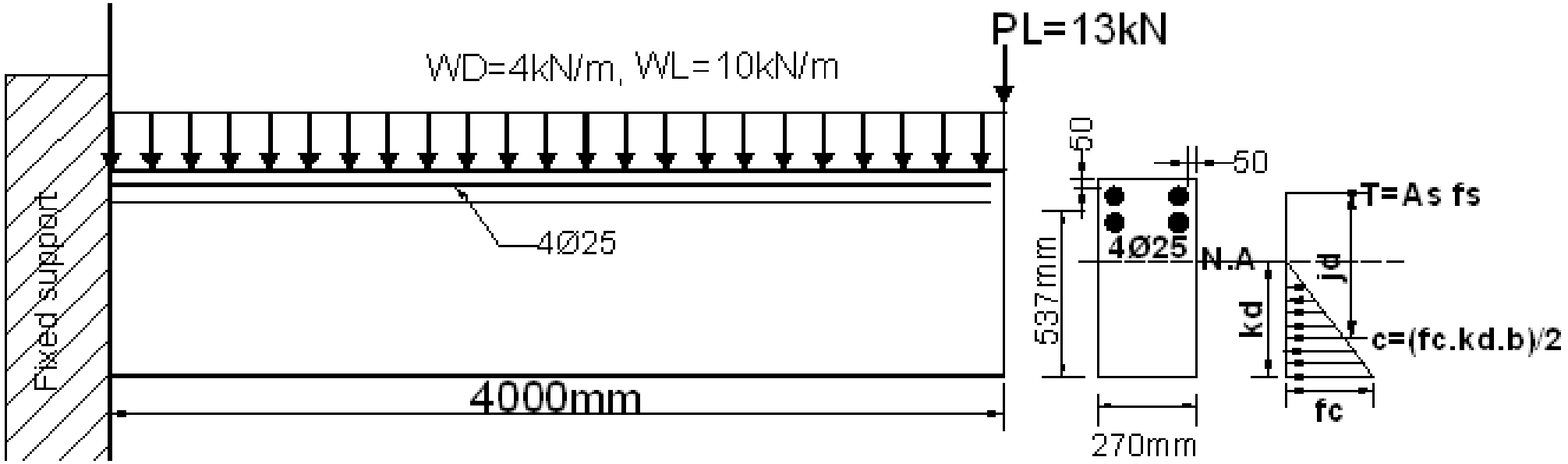



***ACI code allow to use fs=0.6fy**

*** Cracks are to be checked for service load**

# EX1:

fy=300MPa, fc'=20MPa.Determine if beam meets the crack control criteria in the ACI code.



Solution:

$$\rho = \frac{4 * 491}{270 * 537} = 0.0135$$

$$Es = 200000MPa$$

$$Ec = 4700\sqrt{fc'} = 4700\sqrt{20} = 21019MPa$$

$$n = \frac{Es}{Ec} = \frac{200000}{21019} = 9$$

$$k = \sqrt{(2n\rho) + (n\rho)^2} - n\rho$$

$$k = \sqrt{(2 * 9 * 0.0135) + (9 * 0.0135)^2} - 9 * 0.0135 = 0.38$$

$$j = 1 - \frac{k}{3} = 1 - \frac{0.38}{3} = 0.87$$

$$jd = 0.87 * 537 = 469mm$$

$$Mext = 13 * 4 + (4 + 10) * 4 * \frac{4}{2} = 164kN.m$$

$$fs = \frac{M}{A_s\, jd} = \frac{0.164}{1963 * 10^{-6} * 0.469}$$

$$= 178MPa\ compare\ with\ 0.6fy = 180MPa$$

Cc=50mm

$$Smax_{c/c} = \frac{95000}{fs} - 2.5C_C = \frac{95000}{178} - 2.5 * 50 = 409mm$$

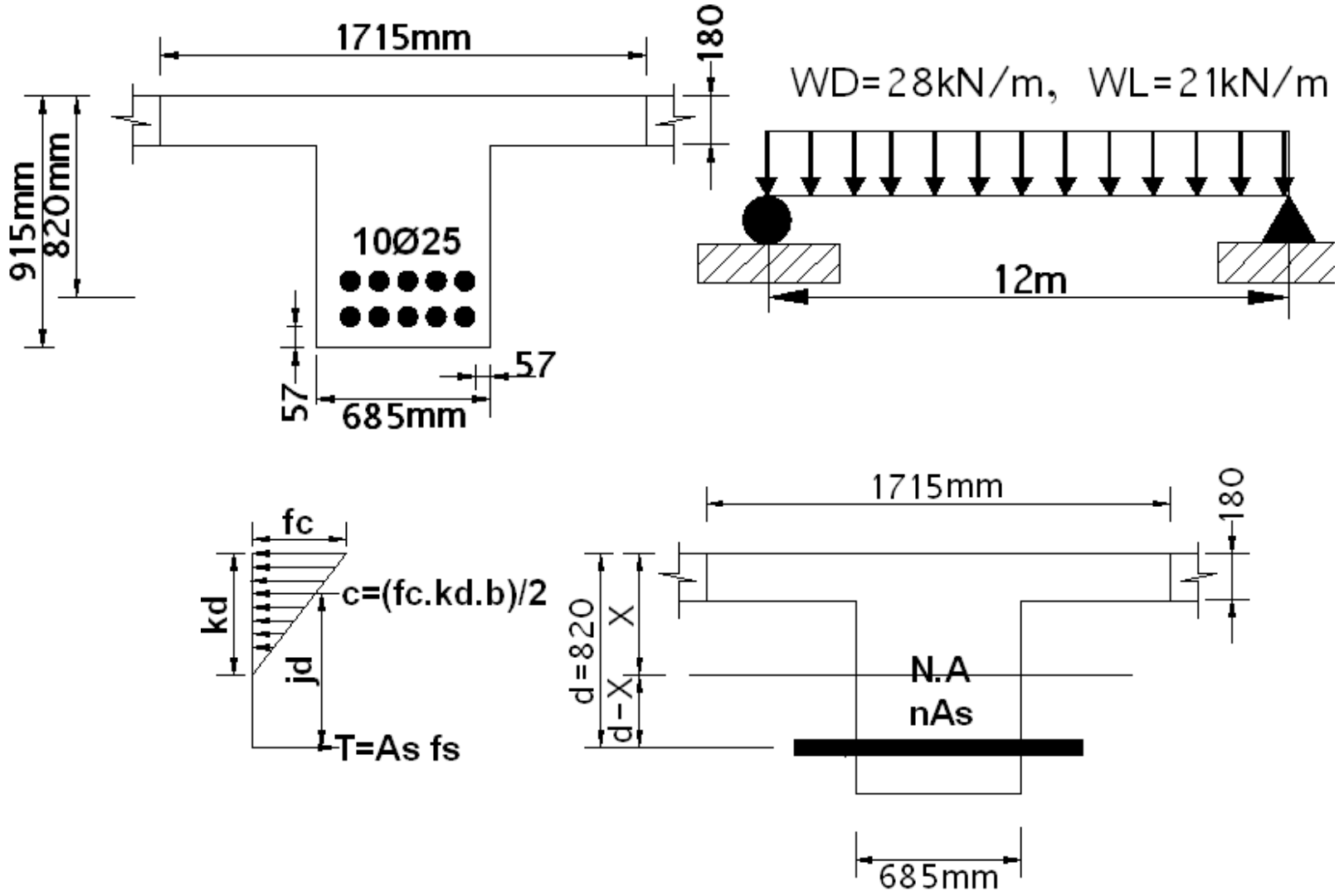
$$\leq 300\left(\frac{252}{fs}\right) = 300\left(\frac{252}{178}\right) = 425mm$$

$$\therefore Smax_{c/c} = 409mm$$

$$S_{c/c} = \frac{270-2*50-2*\frac{25}{2}}{2-1} = 145mm < Smax_{c/c} = 409mm \rightarrow \therefore \text{the}$$

beam meets the crack control criteria in the ACI code

# EX2: fy=414MPa, fc'=28MPa
# Determine if beam meets the crack control criteria in the ACI code.



Solution:

As=10Ø25=4910mm$^2$

$$Es = 200000MPa$$

$$Ec = 4700\sqrt{fc'} = 4700\sqrt{28} = 24870MPa$$

$$n = \frac{Es}{Ec} = \frac{200000}{2487} = 8$$

Location of NA

$$\sum M_{NA} = 0$$

$$1715 * 180\left(x - \frac{180}{2}\right) + 685 * (x - 180) * \frac{(x - 180)}{2}$$

$$= 8 * 4910(820 - x)$$

$$34205x^2 + 224672x - 48889040 = 0 \rightarrow x = kd = 172mm$$

$$jd = d - \frac{kd}{3} = 820 - \frac{172}{3} = 762mm$$

$$Mext = \frac{Wl^2}{8} = \frac{(28 + 21) * 12^2}{8} = 882kN.m$$

$$Mint = As\ fs\ jd \rightarrow fs = \frac{M}{As\ \ jd} \rightarrow fs = \frac{882 * 10^{-3}}{4910 * 10^{-6} * 0.762}$$

$$= 236MPa$$

Cc=57mm

$$Smax_{c/c} = \frac{95000}{fs} - 2.5C_C = \frac{95000}{236} - 2.5 * 57 = 260mm$$

$$\leq 300\left(\frac{252}{fs}\right) = 300\left(\frac{252}{236}\right) = 321mm$$

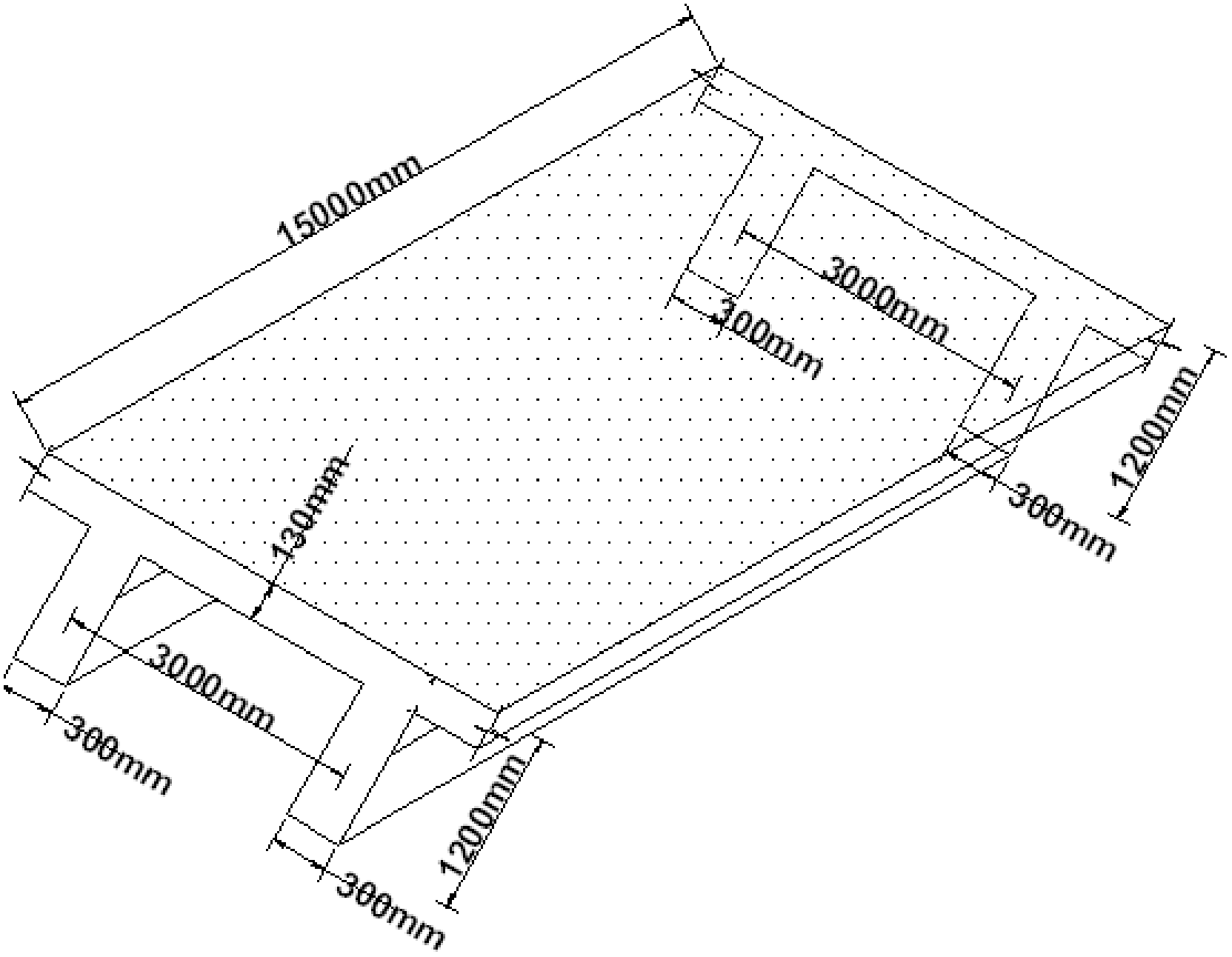
$$\therefore Smax_{c/c} = 260mm$$

$$S_{c/c} = \frac{685 - 2*57 - 2*\frac{25}{2}}{5-1} = 136mm < Smax_{c/c} = 260mm \rightarrow \therefore$$the beam meets the crack control criteria in the ACI code

EX3:

fy=400MPa, fc'=28MPa, continuous T-beam,span=15m, bw=300mm, hf=130mm, over all depth=1200mm, negative service moment[Md=350kN.m, Ml=950kN.m].

Select reinforcement for negative moment, then, check if beam meets the crack control criteria in the ACI code.


15000mm
3000mm
300mm
1200mm
300mm
130mm
3000mm
300mm
1200mm
300mm

Solution:

- $\frac{b-b_w}{2} \leq 8h_f \rightarrow \frac{b-300}{2} \leq 8 * 130 \rightarrow b = 2380mm$
- $b \leq \frac{l}{4} \rightarrow b \leq \frac{15000}{4} \rightarrow b = 3750mm$
- $\frac{b-b_w}{2} \leq \frac{l_{c1}+l_{c2}}{4} \rightarrow \frac{b-300}{2} \leq \frac{3000+300}{4} \rightarrow b = 3300mm$

Choose min. value of b=2380mm

$Mu^-$ =1.2Md+1.6Ml

=1.2*350+1.6*950=1940kN.m

$$Mu = \emptyset\rho bd^2 fy(1 - 0.59\rho\frac{fy}{fc'})$$

$$1.94 = 0.9 * \rho * 0.3 * 1.134^2 * 400(1 - 0.59\rho * \frac{400}{28})$$

$$1.94 = 138.88\rho - 1170.6\rho^2 \rightarrow \rho = 0.0162 > \rho_{min}\ O.K$$

As=0.0162*300*1134=5511mm$^2$

Use 7Ø32(5628mm$^2$)

Distribute the –ve reinf. Over the distance =

min(span/10=15000/10=1500mm, effective flange

width=2380mm)=1500mm

fs=0.6fy=0.6*400=240MPa

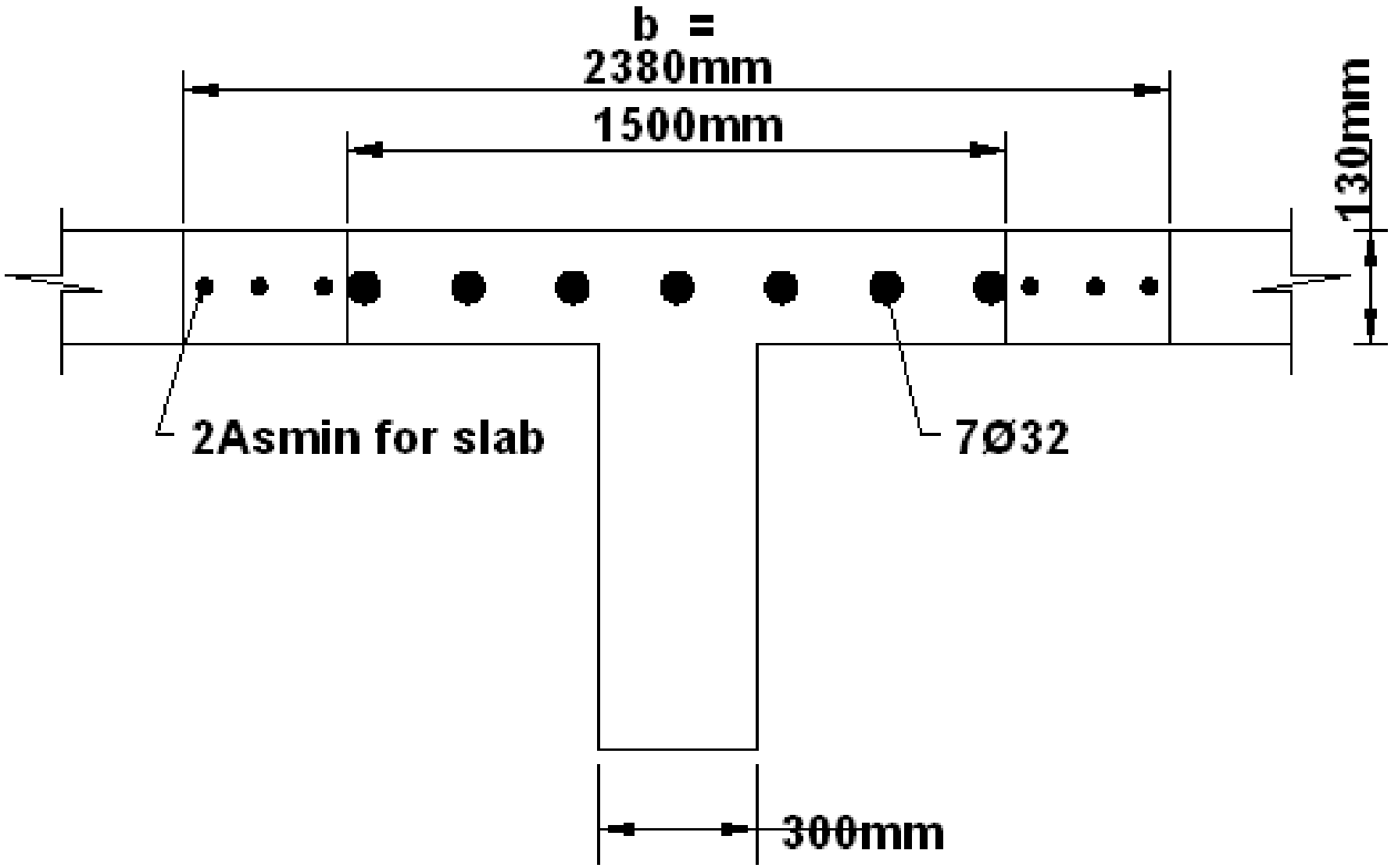
Cc=40+10=50mm

$$Smax_{c/c} = \frac{95000}{fs} - 2.5C_C = \frac{95000}{240} - 2.5 * 50 = 271mm$$

$$\leq 300\left(\frac{252}{fs}\right) = 300\left(\frac{252}{240}\right) = 315mm$$

$$\therefore Smax_{c/c} = 271mm$$

$S_{c/c} = \frac{1500-2*\frac{32}{2}}{7-1} = 245mm < Smax_{c/c} = 271mm \rightarrow$∴the beam meets the crack control criteria in the ACI code


b =
2380mm
1500mm
130mm
2Asmin for slab
7Ø32
300mm