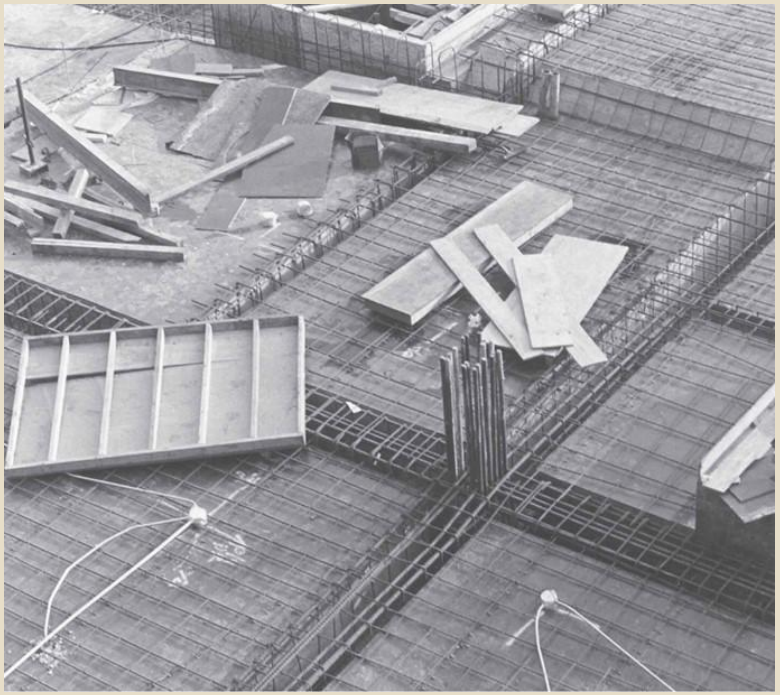
Design of Singly-Reinforced Beam Sections

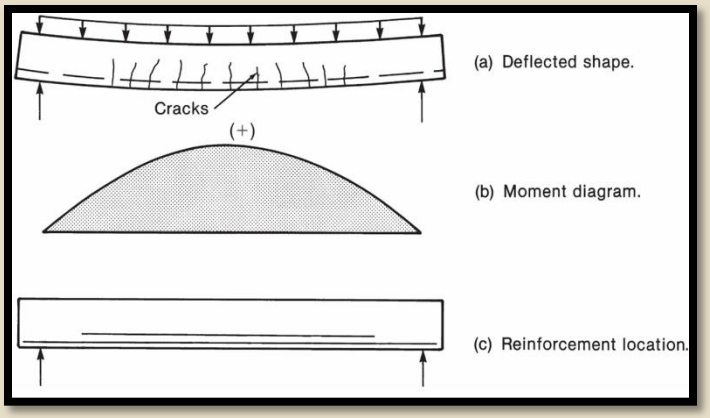
General Factors Affecting the Design of Rectangular Beams

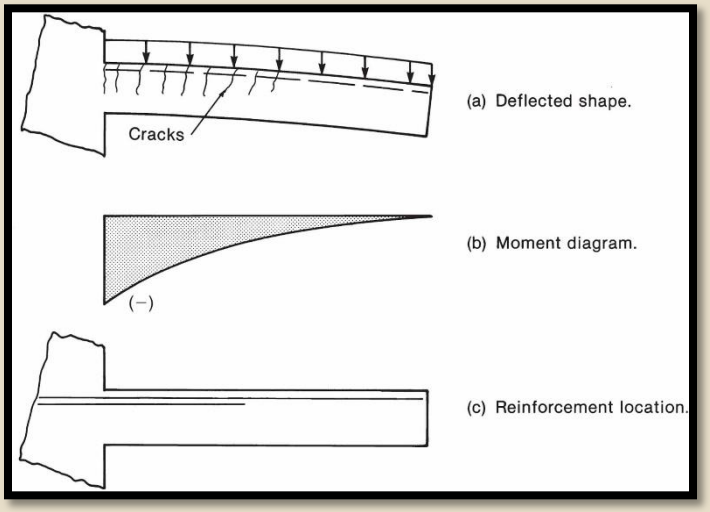
- Location of Reinforcement
- Construction of Reinforced Concrete Beams
- Preliminary Beam dimensions for Control of Deflections
- Concrete Cover and Bar Spacing



Location of Reinforcement

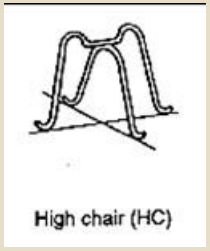
- Concrete cracks due to tensions and (as a result) reinforcement is required where flexure, axial loads, or shrinkage effects cause tensile stresses.
- The reinforcing bars for flexure are placed on the tensile faces of the member which corresponds to the convex side of the deflected shape.
- In addition to longitudinal reinforcement, transverse bars(referred to as *stirrups*) are provided to resist shear forces and to hold the various layers of bars in place during construction.

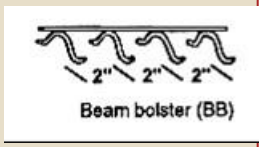




Construction of Reinforced Concrete Beams

- The beams are cast in the forms. Beam forms most often are built of plywood supported by scaffolding or by wooden supports.
- Whenever possible, the forms are constructed in such a way that they can be reused on several floors.
- The forms must be strong enough to support the weight of the concrete plus construction loads.
- The forms must be aligned correctly and cambered (arched upward), if necessary, so that the finished surface is flat after the forms are removed.
- The reinforcement is supported in the forms on wire or plastic supports referred to as *bolsters or chairs*.
- Bolsters or chairs hold the bars at the correct distance above the forms until the concrete has hardened.





Preliminary Beam Dimensions for Control of Deflections

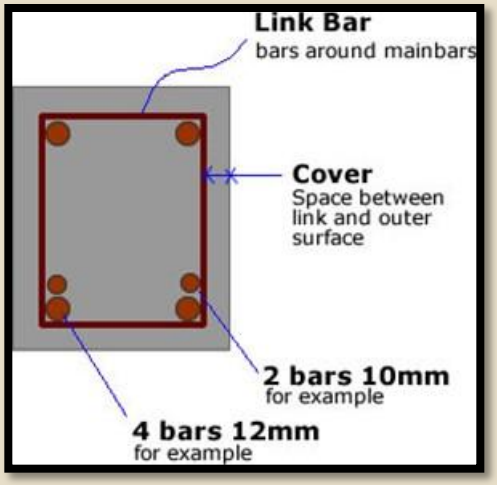
- The SBC/ACI code provides minimum thicknesses of beams (and one way slabs) for which deflections calculations are not required.

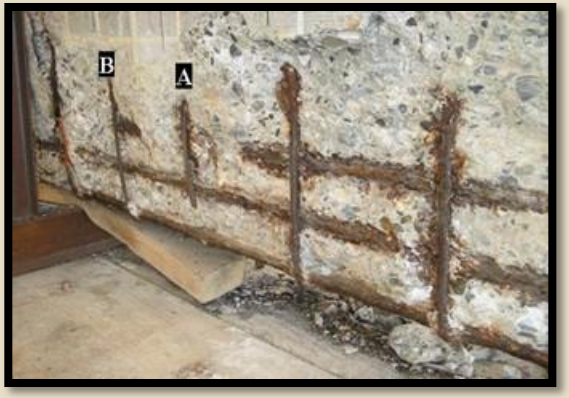
Minimum Thickness, *h*				
Member	Simply supported	One end continuous	Both ends continuous	Cantilever
Solid one-way slabs	$\ell / 20$	$\ell / 24$	$\ell / 28$	$\ell / 10$
Beams or ribbed one-way slabs	$\ell / 16$	$\ell / 18.5$	$\ell / 21$	$\ell / 8$

Concrete Cover and Bar Spacing

Concrete between the surface of the beam and the reinforcing bars is defined as Cover. Beams require cover for three primary reasons:

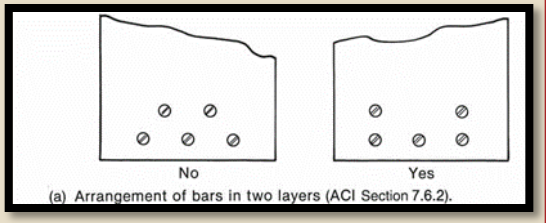
1. To bond the reinforcement to the concrete so that the two elements act together. The efficiency of the bond increases as the cover increases. A cover of at least one bar diameter is required for this purpose.
2. To protect the reinforcement against corrosion.
3. To protect the reinforcement from strength loss due to overheating in the case of fire. A 40 mm cover to the stirrups or ties of beams corresponds to a 2-hour fire rating.



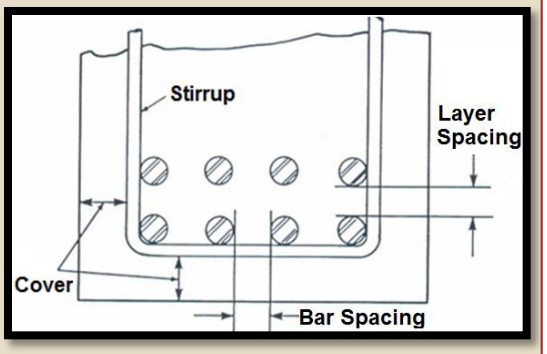


SBC 304 Provisions

- **LAYER SPACING**
  - Where parallel reinforcement is placed in two or more layers, bars in the upper layers shall be placed directly above bars in the bottom layer with clear distance between layers larger of 1.33 diameter of coarse aggregate and 25 mm (SBC 304).This is necessary to allow the concrete and vibrators to pass through the layers.



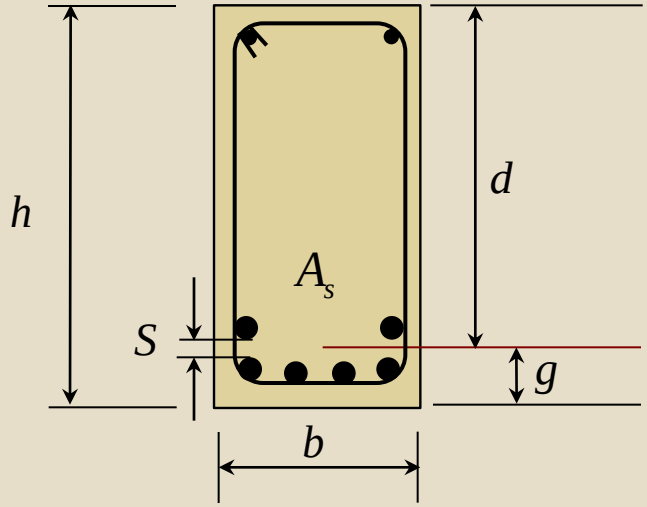
- **BAR SPACING**
  - The minimum clear spacing between parallel bars in a layer shall be larger of d_b,, 25 mm and 1.33 diameter of coarse aggregate (SBC 304)



- **CONCRETE COVER**
  - The minimum concrete cover for primary reinforcement, ties and stirrups, spirals shall be 40 mm (SBC 304 Section 7.7.1)
- **AGGREGATES**
  - Nominal maximum size of coarse aggregate shall be not larger than 3/4 the minimum clear spacing between individual reinforcing bars (SBC 304 Section 3.3.2)

Calculation of Effective Depth for a given bar arrangement

- The effective depth, d, of a beam is defined as the distance from the extreme compression fiber to the centroid of the longitudinal tensile reinforcement.



Distance of tension reinforcement centroid from the bottom of the beam (g):

$$g = \frac{\sum A_{si} y_i}{\sum A_{si}}$$

$$\therefore d = h - g$$

Estimating the Effective Depth of a Beam

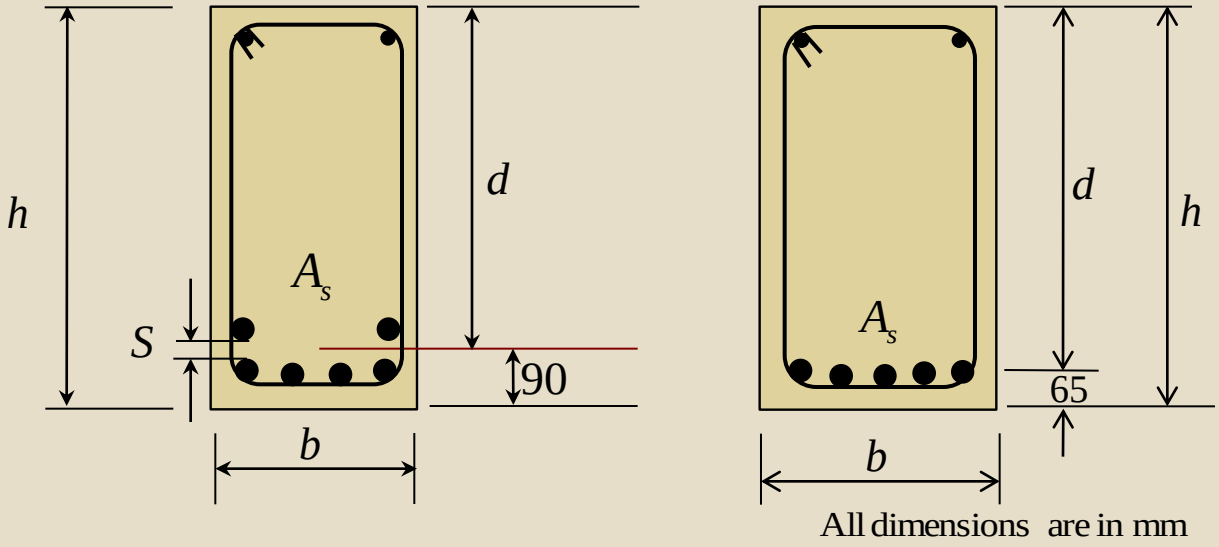
- It is generally satisfactory to estimate the effective depth of a beam using the following approximations:

For beams with one layer of tension reinforcement

$$d \cong h - 65 \text{ mm}$$

For beams with two layers of tension reinforcement

$$d \cong h - 90 \text{ mm}$$



Note: Generally speaking, beam width *b* should not be less than 250 mm

Calculation of Minimum Web Width for a given bar arrangement

Diameter of the bar $= d_b$

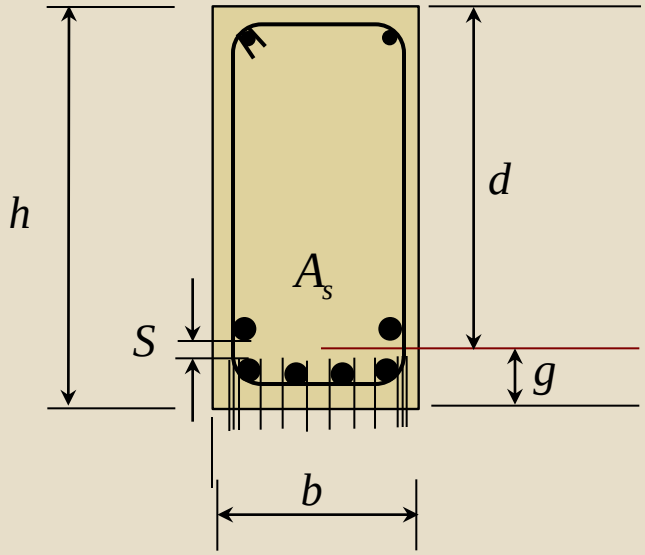
Diameter of the stirrup $= d_s$

Distance between the bar and tie(stirrup) $= 2d_s - 0.5d_b$

Spacing between the bars $= S_b$

$\therefore b = 2[\text{Clear Cover} + d_s + (2d_s - 0.5d_b)] + nd_b + (n-1)S_b$

$\Rightarrow b = nd_b + (n\text{-}1)\,S_b + 6d_s - d_b + 2\text{Clear Cover}$



Minimum Web Width:

S_b = larger of $(d_b$, 25 mm, and 1.33 diameter of coarse aggregate $)$

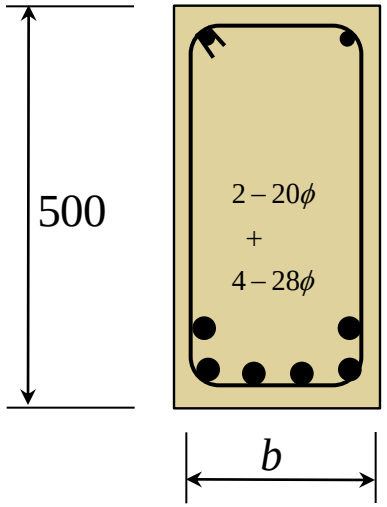
Minimum Clear Cover = 40 mm

The substitution of above values will yield minimum web width $(b_{\min})$

$$b_{\min} = nd_b + (n\text{-}1)\,S_b + 6d_s - d_b + 2\text{Clear Cover}$$

Problem-1

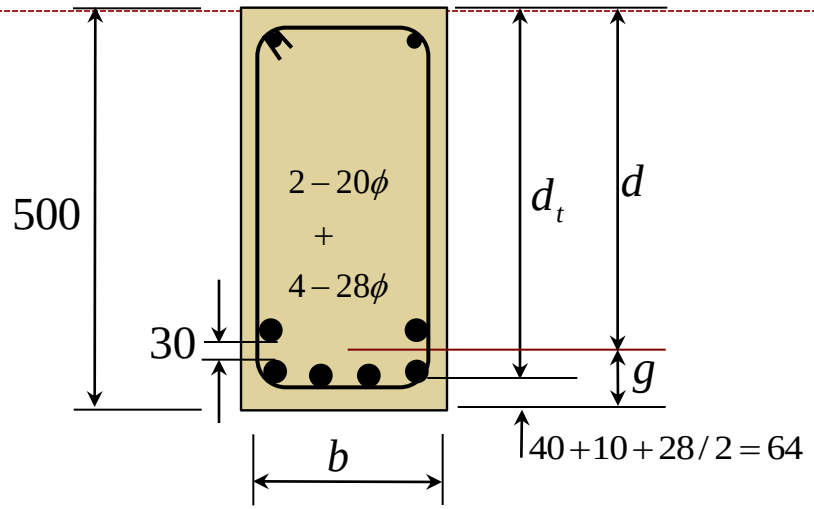
Compute d and the minimum value of b for a beam having bar arranged as shown in the figure. The clear distance between the bar layers = 30 mm and the size of stirrups = 10 mm. Asume maximum size of aggregate = 19 mm and minimum cover = 40 mm.



All dimensions are in mm

Solution: Calculation of *d*

Calculation of *d*



All dimensions are in mm

Distance of tension reinforcement centroid from the bottom of the beam (g):

$$g = \frac{\sum A_{si} y_i}{\sum A_{si}} = \frac{A_{s1} y_1 + A_{s2} y_2}{A_{s1} + A_{s2}}$$

$$\Rightarrow g = \frac{\left(4 \times \pi / 4 \times 28^2\right)(40 + 10 + 14) + \left(2 \times \pi / 4 \times 20^2\right)(10 + 30 + 14 + 64)}{\left(4 \times \pi / 4 \times 28^2\right) + \left(2 \times \pi / 4 \times 20^2\right)}$$

$$\Rightarrow g = \frac{12461.8 \times 64 + 628 \times 118}{12461.8 + 628} = 66.6 \text{ mm}$$

$$\therefore d = h - g = 500 - 66.6 = \underline{\underline{433.4 \text{ mm}}} \qquad \textit{Ans.}$$

Solution: Calculation of b_{min}

Calculation of b_{min}

Given :

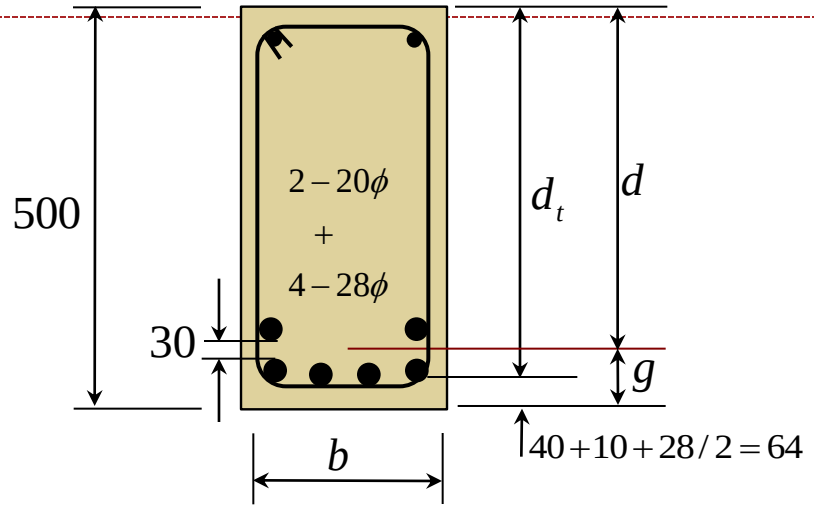
$n = 4$ (in the bottom layer)

$d_b = 28\,\text{mm}$

$S_b = \max\left[1.33\times 19,\ 25\,\text{mm},\ d_b (= 28\,\text{mm})\right] = 28\,\text{mm}$

$d_s = 10\,\text{mm}$

Clear Cover $= 40\,\text{mm}$



All dimensions are in mm

$$b_{\min} = nd_b + (n\text{-}1)\,S_b + 6d_s - d_b + 2\text{Clear Cover}$$

$$\Rightarrow b_{\min} = 4\times 28 + (4-1)\times 28 + 6\times 10 - 28 + 2\times 40 = 308\,\text{mm} \approx 325\,\text{mm}$$

$$\therefore b_{\min} = \underline{\underline{325\,\text{mm}}} \quad Ans.$$

Thus, the minimum width is 325 mm, and design should be based on d = 433.4 mm