The cross-section of a beam, for a given bending moment M, is found from $bd^2 = \frac{M}{R}$ and when R_c and R_s are not equal then the smaller value governs. The graphic diagrams furnish values of d, A_s and bar sizes for all values of M and R, when $n = 15$. The points where horizontal reinforcement may be turned up can be found as for plate girder flanges.

For floor slabs, the maximum bar spacing should never exceed d.

Shear reinforcement. Let V = total shear on any vertical section of width b and net depth d. Also let a = the required stirrup area for this section, when stirrups are spaced s lengthwise of the beam.

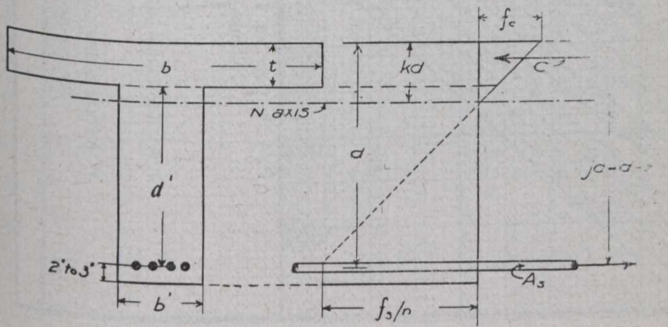
The average vertical shear per sq. in. of section is $v = V/bd$, of which $0.7\,v$ is assumed to be carried by the stirrups and $0.3\,v$ by the concrete. The stress in stirrup rods at one section is $Q = 0.7\,vbs$ for vertical stirrups, giving the required stirrup area for a single section as

$$\left.\begin{aligned} a &= \frac{Q}{f_s} = \frac{0.7\,vbs}{10{,}000} = \frac{0.7\,Vs}{10{,}000\,d} \text{ for vertical stirrups} \\ a &= \frac{0.7\,Q}{f_s} = \frac{0.5\,vbs}{10{,}000} = \frac{0.5\,Vs}{10{,}000\,d} \text{ for stirrups at } 45^\circ \end{aligned}\right\} \text{assuming that the stirrups carry 0.7 of the shear and that none of the horizontal reinforcement is bent up to carry shear.}$$

The horizontal stirrup spacing s should not exceed $0.6\,d$.

It is preferable to turn up a portion of the horizontal reinforcement near the ends to carry the shear, rather than to employ stirrups for this purpose.

T-Beams in Simple Flexure.



l = span of beam; l' = span of floor slab.

Limits in design:

$$b = \frac{f_s A_s}{f_c t\,(1 - t/2kd)} \text{ or} < 8t \text{ and } t > l'/30.$$

$$d = l/12 \text{ to } l/10 \text{ and } d' = \sqrt{\frac{60\,M}{f_s b'}} - \frac{t}{2} \text{ for min. cost.}$$

b' must be chosen to suit the rod spacing, allowing 2.5 diam. for round and 3 diam. for square rods.

The min. web area $= b'd = \frac{V_{\max}}{100}$, allowing 100 lbs. per sq. in. shear on the gross area.

Find $k = \sqrt{2pn + (pn)^2} - pn$, noting that $p = \frac{A_s}{bd}$, not $\frac{A_s}{b'd}$. When $k < \frac{t}{d}$ we have Case I

Case I.—When the neutral axis falls inside the slab or flange, making k < t/d.

The formulæ for rectangular beams apply here and the steel usually governs, while f_c will be small. Hence approximately $M_s = f_s A_s (d - \frac{t}{3})$ and $M_c = \frac{1}{2} f_c kjbd^2$, giving $A_s = \frac{M}{f_s (d - t/3)}$ or $f_s = \frac{M}{A_s (d - t/3)}$ and $f_c = \frac{2\,M}{kjbd^2} = \frac{2\,R_c}{kj}$ where M = moment of external forces, k as above and $j = 1 - k/3$.

Case II.—When the neutral axis falls in the web, neglecting compression in the web.

$$k = \frac{nA_s + \frac{bt^2}{2d}}{nA_s + bt} = \frac{pn + \frac{1}{2}(\frac{t}{d})^2}{pn + t/d} \text{ and } z = \frac{(3\,k - 2\frac{t}{d})\frac{t}{3}}{2k - t/d} \text{ also } j = 1 - \frac{z}{d} = \frac{1 - \frac{t}{d} + \frac{1}{3}(\frac{t}{d})^2 + \frac{(t/d)^3}{12\,pn}}{1 - t/2d}$$

$M_s = f_s A_s(d - z)$ and $M_c = f_c (1 - \frac{t}{2kd}) (d - z)\,bt$, the smaller value governing.

Finally $A_s = \frac{M}{f_s(d - z)}$; $f_s = \frac{T}{A_s} = \frac{M}{A_s(d - z)}$; and $f_c = \frac{f_s k}{n(1 - k)} = \frac{pf_s}{(1 - \frac{t}{2kd})\frac{t}{d}} = \frac{M}{(1 - \frac{t}{2kd})(d - z)bt}$.

For designing curves $R = \frac{M}{bd^2} = f_c (1 - \frac{t}{2kd}) \frac{t}{d} \cdot j$.

Approximately, $M_s = f_s A_s(d - \frac{t}{2})$; $M_c = \frac{1}{2} f_c bt\,(d - \frac{t}{2})$; $C = T = \frac{M}{d - t/2}$.

$f_c = \frac{2C}{bt}$ and $f_s = \frac{T}{A_s}$. Assume $jd = d - z = \frac{7}{8}d$.

Shear Reinforcement.—The required stirrup area at a single section becomes $a = \frac{0.7\,Vs}{10{,}000\,(d - t/2)}$ for vertical stirrups and $a = \frac{0.5\,Vs}{10{,}000\,(d - t/2)}$ for stirrups at 45°.

Slab Reinforcement in Two Directions.—

$r = \frac{l^4}{l^4 + l_1^4}$ = proportion of load carried by the short span l_1 for rectangular slabs.

for l/l_1 =	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
r =	0.5	0.6	0.67	0.74	0.79	0.83	0.87	0.89	0.91	0.93	0.94