4. Reinforced Concrete

4.1 Classes of Reinforced Concrete. The class of concrete to be used in any specific job should be based on a study of the job requirements as to strength and durability. Many factors affect the quality of concrete; the best materials and design do not produce excellent concrete without high quality methods of construction.

Nine classes of concrete are presently established. They cover the various conditions of design and construction encountered by the Soil Conservation Service. For Class 5000, Class 4000, Class 3000, and Class 2500 concrete the Contractor is responsible for the design of the concrete mix. For Class 5000X, Class 4000X, Class 3000X, Class 3000M, and Class 2500X concrete the Engineer is responsible for the design of the concrete mix. The following is a general guide to these concrete classes and their use.

Class 5000 or 5000X concrete -- for special structures, for precast or prestressed construction, for extreme exposure conditions.

Class 4000 or 4000X concrete -- for standard types and sizes of structures, for moderate exposure conditions.

Class 3000 or 3000X concrete -- for small simple structures, for mass foundations.

Class 3000M -- for minor concrete structures in which the quantity of concrete is less than 5 yards and where the location of the concrete will permit easy maintenance or replacement.

Class 2500 or 2500X concrete -- for small structures built by the farmer or unskilled labor, for plain concrete construction.

Guide Construction Specifications 31. Concrete, 32. Concrete for Minor Structures, and 34. Steel Reinforcement (NEH Section 20) state the technical and workmanship requirements for the operations required in reinforced concrete construction. These specifications include such items as:

Air Content and Consistency
Design of Concrete Mix
Inspection and Testing
Mixing, Conveying, Placing, Consolidating and Curing Concrete
Preparation and Removal of Forms
Fabrication and Placing of Reinforcement.

Guide Material Specifications 531. Portland Cement, 522. Aggregate for Portland Cement Concrete, and 539. Steel Reinforcement (NEH Section 20) state the quality of materials to be incorporated in the construction.

4.2 Design Codes and Criteria:

4.2.1 General Code to be Used. The American Concrete Institute Standard "Building Code Requirements for Reinforced Concrete" (ACI 318-77), Appendix B - Alternate Design Method is used as the design code for working stress design except as modified in 4.2.2.

4.2.2 Other Design Criteria

(a) The allowable extreme fiber unit stress in compression in flexural members is: $f_c = 0.40\ f'_c$.

(b) The allowable tensile unit stress in reinforcement is: $f_s = 20000$ psi. The design yield strength is: $f_y = 40000$ psi.

(c) Members subjected to bending and direct compressive force, in which the eccentricity ($e = M/N$) is not less than that causing balanced working stresses, are designed on the basis of recognized theory of cracked sections. The tensile steel may be stressed to its allowable value; the concrete stress may not exceed its allowable value.

(d) In doubly reinforced flexural members, the modular ratio, E_s/E_c is used to transform compression reinforcement for stress computations.

(e) The minimum clear concrete cover over reinforcement is two inches, except when concrete is deposited on or against earth, the minimum clear concrete cover is three inches. However, in structural design of slabs or beams without web reinforcement, the distance from the surface of the concrete to the centerline of the nearest reinforcing steel may be taken as 2-1/2 or 3-1/2 inches, as the case may be, to simplify the determination of the effective depth, for all bars one inch or less in diameter.

Consideration should be given to increasing the cover when a concrete surface is exposed to high velocities and the water carries abrasive materials.

(f) Reinforcing steel is required in both faces and in both (orthogonal) directions in all concrete slabs and walls, except that only one grid of reinforcing is required in concrete linings of trapezoidal channels. This steel serves either as principal reinforcement or as temperature and shrinkage reinforcement. The minimum steel areas for slabs and walls having thickness equal to or less than 32 inches, in each face and in each direction, expressed as the ratio, ρ_t, of reinforcement area, A_s, to gross concrete area, bt, are as follows:

1. The steel in the direction in which the distance between expansion or contraction joints does not exceed thirty feet,

   $\rho_t = 0.002$ in an exposed face

   $\rho_t = 0.001$ in an unexposed face.

2. The steel in the direction in which the distance between expansion or contraction joints exceeds thirty feet,

$$\rho_t = 0.003 \text{ in an exposed face}$$

$$\rho_t = 0.002 \text{ in an unexposed face.}$$

The minimum steel areas for slabs and walls having thicknesses greater than 32 inches are computed as though the thickness were 32 inches.

When expansion or contraction in a member is restrained along any line, the concept of equivalent distance between expansion or contraction joints should be used to determine the required steel ratio, ρ_t. The equivalent distance is taken as double the perpendicular distance from the line of restraint to the far edge or line of support of the member.

When the surface of a wall or slab will be exposed for a considerable period during construction, the steel provided should satisfy requirements for an exposed face.

(g) Where a single grid of reinforcement is used, as permitted above, the steel ratio, ρ_t, is the sum of that listed for both faces.

(h) Splices and development lengths for temperature and shrinkage reinforcement are designed for the design yield strength, f_y.

(i) The maximum spacing of principal steel is twice the thickness of the wall or slab, but not more than 18 inches. The maximum spacing of temperature steel is three times the thickness of the wall or slab, but not more than 18 inches.

(j) Where principal steel is required in only one direction, it is ordinarily placed nearer the concrete surface than the temperature steel. Where principal steel is required in both directions, the steel which carries the larger moment is, ordinarily placed nearer the concrete surface. Where principal steel is required in neither direction, the temperature steel parallel to the longer dimension of the slab or wall is ordinarily placed nearer the concrete surface.

(k) The clear distance between parallel bars in a layer is not less than the bar diameter, 1-1/3 times the maximum size of the coarse aggregate, nor 1 inch. Where parallel reinforcement is placed in two or more layers, bars in the upper layers are placed directly above bars in the bottom layer. The clear distance between layers is not less than 1 inch. The clear distance between bars also applies to the clear distance between a contact lap splice and adjacent splices or bars.

(ℓ) The calculated tension or compression in any bar at any section must be developed on each side of that section by proper embedment length, end anchorage, or hooks. Hooks may be used in developing bars in tension. Hooks are not effective in developing bars in compression.

(m) The development lengths, for design yield strength f_y = 40 ksi, for bars #11 and smaller, are given as follows.

For tension top bars, the development length, ℓ_d, is the larger of $1.4(1600\ A_b/\ \sqrt{f'_c})$ or $1.4(16\ d_b)$ but not less than 12 inches.

For all other tension bars, the development length, ℓ_d, is the larger of $(1600\ A_b/\ \sqrt{f'_c})$ or $(16\ d_b)$ but not less than 12 inches.

Top bars are defined as horizontal bars so placed that more than 12 inches of concrete is cast in the member below the bars. Tension bars spaced laterally not less than 6 inches on centers, and bars with at least 3 inches clear from face of member to first bar, may use 0.8 the development length given above but not less than 12 inches.

For compression bars, the development length, ℓ_d, is the larger of $(800\ d_b/\ \sqrt{f'_c})$ or $(12\ d_b)$ but not less than 8 inches.

In the above relations: A_b is the area of an individual bar in square inches, and d_b is the nominal diameter of a bar in inches.

(n) Splices should be made at or close to points of inflection if it is practical to do so. Lap splices shall not be used for bars larger than #11. Bars in a noncontact splice shall not be farther apart than 1/5 the required length of lap nor 6 inches. Lap splices are designed for the design yield strength f_y = 40 ksi.

(o) Three classes of tension lap splices are established. The minimum length of lap is determined as a multiplier for the class times the development length, ℓ_d, but not less than 30 bar diameters. The classes and minimum lengths are:

Class A splice . . . . . 1.0 ℓ_d

Class B splice . . . . . 1.3 ℓ_d

Class C splice . . . . . 1.7 ℓ_d.

The splice class required depends upon the stress level in the reinforcement to be spliced and the portion of the total reinforcement to be spliced at the cross section.

If the area of tensile steel provided at the splice location is equal to or more than twice that required by analysis (low tensile stress in the reinforcement) and not more than 75 percent of the bars are to be lap spliced within the required lap splice length, a Class A splice may be used. If more than 75 percent of the bars are to be lap spliced within the required lap splice length, a Class B splice is required.

If the area of tensile steel provided at the splice location is less than twice that required by analysis (high tensile stress in reinforcement) and not more than 50 percent of the bars are to be lap spliced within the required lap splice length, a Class B splice may be used. If more than 50 percent of the bars are to be lap spliced within the required lap splice length, a Class C splice is required.

(p) The minimum length for compressive lap splices is the larger of 24 bar diameters or 12 inches. For $f'_c < 3000$ psi, the lap length is increased by 1/3.

(q) Critical sections for development of reinforcement are at points of maximum stress and at points where adjacent reinforcement terminates.

Except at supports of simple spans and at the free end of cantilevers, every reinforcing bar is extended beyond the point at which it is no longer needed to resist flexural stress, for a distance equal to the effective depth of the member or 12 bar diameters, whichever is greater.

Continuing reinforcement has an embedment length not less than the development length, ℓ_d, beyond the point where bent or terminated tension reinforcement is no longer needed to resist flexural stress.

At least 1/3 the positive moment reinforcement in simple spans and 1/4 the positive moment reinforcement in continuous spans extends along the same face of the span into the support at least 6 inches.

At least 1/3 the negative moment reinforcement at a support extends beyond the extreme position of the point of inflection a distance not less than the effective depth of the member, 12 bar diameters, or 1/16 the clear span, whichever is greater.

(r) Sufficient longitudinal tension steel perimeter is provided at every section so that flexural bond stresses do not exceed allowable values. Critical sections for flexural bond stresses occur where the rate of change of moment is greatest or where the steel perimeter is least, or both. For simple spans, critical sections are at the faces of supports. For continuous spans: for negative steel, critical sections are located at faces of supports and at locations where bars terminate; for positive steel, critical sections are at points of inflection.

(s) To aid in the control of flexural cracking in beams and one-way slabs, cross sections at both maximum positive and maximum negative moment locations are proportioned so that the quantity, Z, given by

$$Z = f_s \sqrt[3]{d_c A}$$

does not exceed 130. In the relation: f_s is the calculated stress in the reinforcement in ksi (in lieu of calculations, the value of f_s may be taken as the allowable stress), d_c is the thickness of concrete cover in inches measured from the extreme tension fiber to the center of the longitudinal bar located closest to the extreme fiber, and A is the effective tension area of concrete per bar in square inches. A is determined as the tension area of concrete surrounding the flexural tension reinforcement and having the same centroid as the reinforcement, divided by the number of bars.

4.2.3 State and other Local Codes. State and local codes may not be satisfied by the above mentioned code or design criteria. The local design engineer should be familiar with the state and local codes and it should be his responsibility to see that these codes are met.

4.3 Design Procedures

4.3.1 Reference Materials. Procedures for design may be found in several manuals and textbooks, among which are:

"Reinforced Concrete Design" by Sutherland and Reese

"Reinforced Concrete Structures" by Peabody

"Reinforced Concrete Fundamentals" by Ferguson

"Theory and Practice of Reinforced Concrete" by Dunham

"Design of Concrete Structures" by Winter, et al

"Reinforced Concrete Design" by Wang and Salmon

Various design handbooks by ACI

Various publications of the Portland Cement Association

"CRSI handbook" by Concrete Reinforcing Steel Institute.

Numerous computation aids have been developed to simplify and speed up design work by eliminating the need of solving various design formulas. These aids follow, and their use is illustrated by 4.3.2.

4.3.2 Example Problems. Example problems for:

(a) Simple Bending
(b) Bending and Direct Compressive Force
(c) Bending and Direct Tensile Force
(d) Beam Shear (as a Measure of Diagonal Tension)
(e) Flexural Bond
(f) Temperature and Shrinkage Steel

are solved below. All problems use $f'_c = 4000$ psi, $n = 8.0$, $f_s = 20$ ksi, and concrete cover from center of steel = 2.5 in.

(a) Simple Bending

1. Problem: Find the effective depth and steel area which produces balanced stresses at a slab section where the moment is 14.0 ft kips per ft of width.

   Solution: On ES-164, sheet 1 at moment $M_s = M = 14.0$ ft kips and the balanced stress line, read $d = 7.20$ in. and $A = A_s = 1.34$ sq in. A practical solution is $d = 7.5$ in., $t = 7.5 + 2.5 = 10.0$ in. and #8 bars at 7 in. on centers.

2. Problem: Determine the allowable moment for a slab 8 in. thick, reinforced with #4 @ 12 in. on centers.

   Solution: $d = 8 - 2.5 = 5.5$ in.; from ES-46 $A_s = 0.20$ sq in per ft

   On ES-164, sheet 1 at effective depth $d = 5.5$ in. and $A = A_s = 0.20$ sq in., read $M = M_s = 1.70$ ft kips per ft of width.

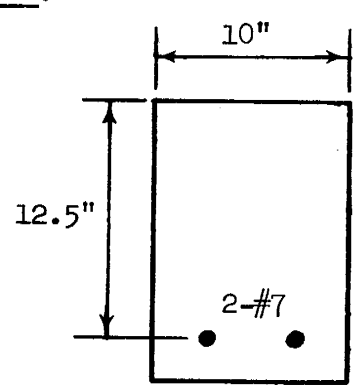
3. Problem: Find the steel area required for a beam having a width of 10 in., an effective depth of 12.5 in., and a moment of 22 ft kips.

   Solution: Moment per ft of width = 22(12/10) = 26.4 ft kips

   On ES-164, sheet 1 at moment $M_s = M = 26.4$ ft kips and $d = 12.5$ in., read $A = A_s = 1.42$ sq in. Steel area required for given beam = 1.42(10/12) = 1.18 sq in.
   Select 2 – #7 bars, $A_s = 1.20$ sq in.

4. Problem: Check the solution of problem (a)3 by using the transformed section and the common flexure formula.

   Solution:



$M = 22$ ft kips

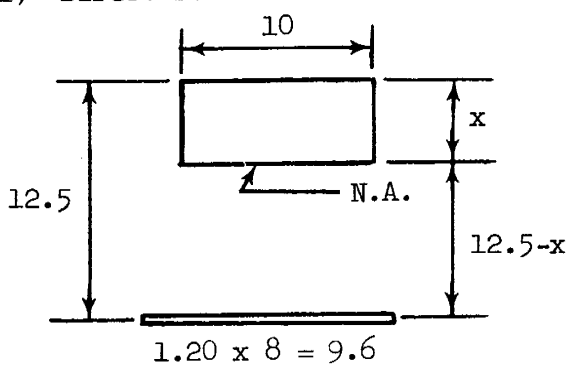
$A_s = 1.20$ sq in

Determine the location of the neutral axis. For simple bending, the neutral axis is the same as the center of gravity axis. This may be located in several ways, but two are shown.

(1) Trial and error solution for the location of the neutral axis. Assume the neutral axis is 3.8 in. below the top of the beam, take moments about the top of the beam to obtain a new estimate of the distance to the neutral axis.

		Area	Arm	Moment
Compression	10.00 x 3.8	= 38.0	1.9	72.2
Transformed Tension	1.20 x 8	= 9.6	12.5	120.0
		47.6		192.2/47.6 = 4.04
Corrective Area	10.00 x 0.24	= 2.4	3.92	9.4
		50.0		201.6/50.0 = 4.03"

(2) Direct solution for location of neutral axis. Balance the moment of the compressive area and the moment of the transformed steel area about the unknown location of the neutral axis.



$$(10x)\left(\frac{x}{2}\right) = 9.6(12.5 - x)$$

$$5x^2 + 9.6x = 120$$

$$x = 4.03"$$

Compute the Moment of Inertia about the neutral axis.

$$\frac{1}{3}(10)(4.03)^3 = 218$$

$$9.6(8.47)^2 = 688$$

$$I = 906 \text{ in}^4$$

Compute the unit stresses.

$$f_c = \frac{Mx}{I} = \frac{(22 \times 12 \times 1000)(4.03)}{906} = 1170 \text{ psi} < 1600 \text{ psi OK}$$

$$f_s = \frac{nM(d - x)}{I} = \frac{8(22 \times 12)(8.47)}{906} = 19.7 \text{ ksi} < 20 \text{ ksi OK}$$

5. Problem: Find the steel areas required at a slab section having an effective depth of 15 in. and a moment of 65 ft kips per ft of width.

Solution: On ES-164, sheet 1 at moment $M_s = M = 65.0$ ft kips and $d = 15.0$ in., read required steel areas $A = A_s = 3.0$ sq in. and $A_s' = 0.70$ sq in.

From ES-46 select:

#9 @ 4" on centers for tensile steel.
#8 @ 12" on centers for compressive steel.

(b) Bending and Direct Compressive Force

1. Problem: Find the steel area required at a slab section having a total depth of 12 in., a moment of 15.5 ft kips per ft of width and a direct compressive force of 13.7 kips per ft of width.

Solution: $d = 12 - 2.5 = 9.5$ in.; $d'' = (12/2) - 2.5 = 3.5$ in.

$$M_s = M + \frac{Nd''}{12} = 15.5 + \frac{13.7 \times 3.5}{12} = 19.5 \text{ ft kips}$$

On ES-164, sheet 1 at moment $M_s = 19.5$ ft kips and $d = 9.5$ in., read $A = 1.40$ sq in.

$$A_s = A - \frac{N}{20} = 1.40 - \frac{13.7}{20} = 0.72 \text{ sq in.}$$

From ES-46 select:

#7 @ 10" on centers.

2. Problem: Same as problem (b)1 except moment is 22.0 ft kips per ft of width.

Solution: $M_s = M + \frac{Nd''}{12} = 22.0 + \frac{13.7 \times 3.5}{12} = 26.0$ ft kips

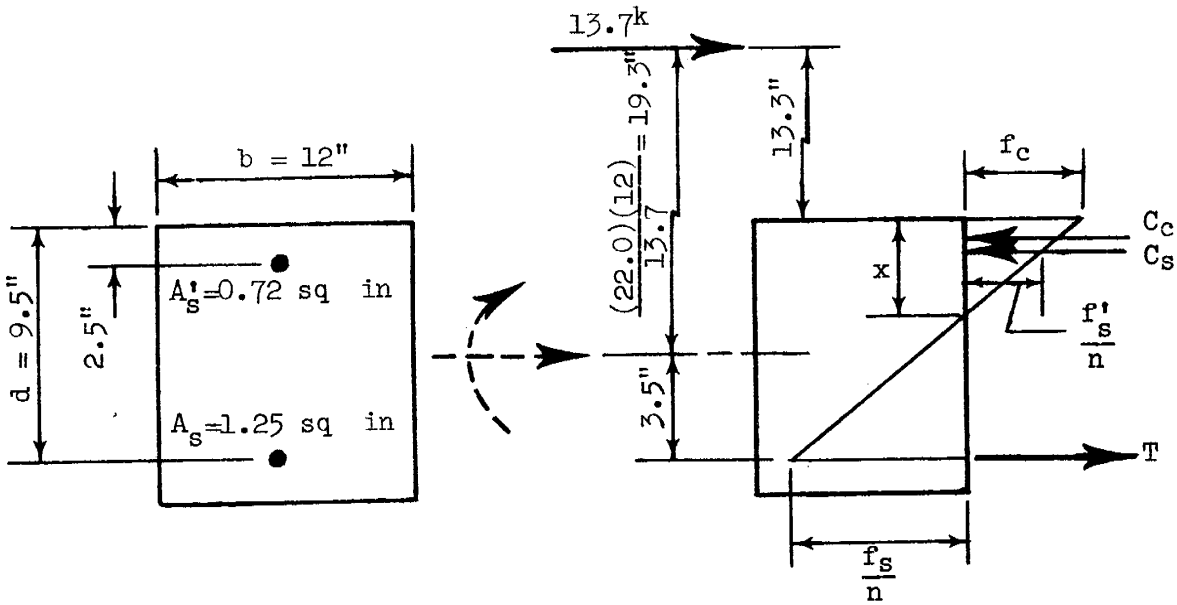
On ES-164, sheet 1 at moment $M_s = 26.0$ ft kips and $d = 9.5$ in., read required areas $A = 1.90$ sq in and

$A_s' = 0.70$ sq in. Thus $A_s = A - \frac{N}{20} = 1.90 - \frac{13.7}{20} = 1.22$ sq in.

From ES-46 select #7 @ 10" on centers staggered with #6 @ 10" on centers for tensile steel, $A_s = 0.72 + 0.53 = 1.25$ sq in. Select #7 @ 10" on centers for compressive steel, $A_s' = 0.72$ sq in.

3. Problem: Check the solution of problem (b)2 by computing the unit stresses.

Solution: Replace the moment, M = 22.0 ft kips and direct compressive force N = 13.7 kips, by an equivalent eccentric compressive force as shown.



The force relations in terms of concrete stress are:

$$C_c = \frac{1}{2} f_c bx = 6\ f_c x$$

$$C_s = \frac{f'_s}{n}(n-1)A'_s = f_c\left(\frac{x-2.5}{x}\right)(n-1)A'_s = 5.04 f_c\left(\frac{x-2.5}{x}\right)$$

$$T = \frac{f_s}{n}(n)A_s = f_c\left(\frac{9.5-x}{x}\right)nA_s = 10.0 f_c\left(\frac{9.5-x}{x}\right)$$

Moments about a point on the line of action of the eccentric force yield:

$$T(19.3 + 3.5) = C_c(13.3 + \tfrac{x}{3}) + C_s(13.3 + 2.5)$$

$$228\ f_c\left(\frac{9.5-x}{x}\right) = 6\ f_c x(13.3 + \tfrac{x}{3}) + 79.6\ f_c\left(\frac{x-2.5}{x}\right)$$

$$x^3 + 39.9x^2 + 153.8x = 1188$$

therefore, by trial, x = 3.75 in.

Summation of forces yields:

$$C_c + C_s - T = 13700$$

$$6\ f_c(3.75) + 5.04\ f_c\left(\frac{3.75 - 2.5}{3.75}\right) - 10\ f_c\left(\frac{9.5 - 3.75}{3.75}\right) = 13700$$

therefore, $f_c = 1550$ psi < 1600 psi OK

$$f_s = 8(1.550)\left(\frac{9.5 - 3.75}{3.75}\right)$$

$$= 19.0 \text{ ksi} < 20 \text{ ksi} \qquad \text{OK}$$

(c) Bending and Direct Tensile Force

1. Problem: Find the steel area required at a slab section having a total depth of 12 in., a moment of 22.0 ft kips per ft of width, and a direct tensile force of 13.7 kips per ft of width.

Solution:

$$d = 12 - 2.5 = 9.5 \text{ in.};\ d'' = (12/2) - 2.5 = 3.5 \text{ in.}$$

$$M_s = M - \frac{Nd''}{12} = 22.0 - \frac{13.7 \times 3.5}{12} = 18.0 \text{ ft kips}$$

On ES-164, sheet 1 at moment $M_s = 18.0$ ft kips and $d = 9.5$ in., read $A = 1.28$ sq in.

$$A_s = A + \frac{N}{20} = 1.28 + \frac{13.7}{20} = 1.97 \text{ sq in}$$

From ES-46 select #9 @ 6" on centers.

(d) Beam Shear (as a Measure of Diagonal Tension)

1. Problem: Determine the allowable total shear at the face of the support of a uniformly loaded beam having no web reinforcement if $b = 12$ in., $t = 13$ in., and the live plus dead loading is $q = 1.2$ kips per lineal ft.

Solution: $d = 13 - 2.5 = 10.5$ in.

On ES-164, sheet 2 at $d = 10.5$ in. and $q = 1.2$ kips per lineal ft, read $V_s = 9.88$ kips.

2. Problem: Same as problem (d)1 except b = 8 in.

Solution: Compute q for b = 12 in., $q = 1.2(\frac{12}{8}) = 1.8$ kips per lineal ft.

On ES-164, sheet 2 at d = 10.5 in. and q = 1.8 kips per lineal ft, read $V_s = 10.4$ kips. Compute V_s for b = 8 in.,

$V_s = 10.4(\frac{8}{12}) = 6.93$ kips.

3. Problem: Determine the depth required by shear, if no web reinforcement is used, when a uniformly loaded one-way slab having a clear span of 12.0 ft carries a live load of 2.0 kips per sq ft.

Solution: For the first trial neglect dead weight; then q = 2.0 kips per lineal ft and $V_s = \frac{1}{2}\,qL = \frac{1}{2} \times 2.0 \times 12 = 12.0$ kips. On ES-164, sheet 2 at $V_s = 12.0$ kips and q = 2.0 kips per lineal ft, read d = 11.9 in. Including the dead weight, d must be greater than 11.9 in.; therefore try d = 13.0 in., t = 13.0 + 2.5 = 15.5 in.,

and $q = 2.0 + 0.150(\frac{12 \times 15.5}{144}) = 2.19$ kips per lineal ft, so that

$V_s = \frac{1}{2} \times 2.19 \times 12 = 13.1$ kips. On ES-164, sheet 2 at $V_s = 13.1$ kips and q = 2.19 kips per lineal ft, read d = 12.8 in. Since $12.8 \leq 13.0$ use d = 13.0 in. and t = 15.5 in.

(e) Flexural Bond

"Top bars" are defined as horizontal bars so placed that more than 12 in. of concrete is cast in the member below the bars.

1. Problem: Determine the allowable total shear at the face of the support of a one-way simple slab having t = 13 in. and reinforced with #5 @ 12" on centers.

Solution: d = 13 − 2.5 = 10.5 in.; from ES-46 $\Sigma o = 1.96$ in. per ft of width. On ES-164, sheet 3, the chart for "Tension Bars Other Than Top Bars" at $\Sigma o = 1.96$ in. and the line for #5 bars, read V/d = 0.83 kips per in. Thus V = 0.83 x 10.5 = 8.72 kips per ft of width.

2. Problem: Determine the maximum spacing permitted by bond if #6 bars are used to reinforce a one-way cantilever slab having t = 15 in. and V = 11.9 kips per ft of width.

Solution: d = 15 − 2.5 = 12.5 in.; $V/d = \frac{11.9}{12.5} = 0.95$ kips per in.

On ES-164, sheet 3, the chart for "Tension Top Bars" V/d = 0.95 kips per in. and the line for #6 bars, read $\Sigma o = 3.80$ in.

The maximum allowable spacing is $s = 12(\frac{2.36}{3.80}) = 7.45$ in.

(f) Temperature and Shrinkage Steel

1. Problem: Determine the temperature and shrinkage steel required in the exposed face and the T and S steel required in the unexposed face of a 16 in. thick slab. The distance between joints in each face is less than 30 ft.

   Solution: For the exposed face, the minimum value of p_t is 0.002. Thus from ES-47 for t = 16 any of the following combinations of bar size and spacing might be selected: #4 @ 6", #5 @ 9", #6 @ 13", or #7 @ 18". For the unexposed face, the minimum value of p_t is 0.001. Thus from ES-47 any of the following might be selected: #3 @ 6", #4 @ 12", or #5 @ 18". Note that ES-164, sheet 1 can be used to determine the required areas of T and S steel; i.e., for d = 16 − 2.5 = 13.5 in. and p_t = 0.002 read A_s = 0.38 sq in. per ft, similarly for p_t = 0.001 read A_s = 0.19 sq in. per ft.

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN
WORKING STRESS DESIGN
ALLOWABLE STRESSES

ALLOWABLE WORKING STRESSES IN CONCRETE						
Description (Stresses in psi)		Class of Concrete				
		Any	5000	4000	3000	2500
Compressive strength	f_c'	f_c'	5000	4000	3000	2500
Modular ratio, for concrete weighing 145 pcf *	n	$\frac{503.3}{\sqrt{f_c'}}$	7	8	9	10
Flexure:						
Extreme fiber stress in compression	f_c	$0.40f_c'$	2000	1600	1200	1000
Extreme fiber stress in tension in plain concrete	f_t	$1.6\sqrt{f_c'}$	113	102	88	80
Shear (computed as V/bd as a measure of diagonal tension):						
Beams - shear at a distance [d] from the face of the support:						
Beams with no web reinforcement	v_c	$1.1\sqrt{f_c'}$	78	70	60	55
Beams with properly designed web reinforcement	v	$5.0\sqrt{f_c'}$	354	316	274	250
Slabs and Footings - peripheral shear at a distance [d/2] from the periphery of the area of the concentrated load or reaction with no web reinforcement	v_c	$2.0\sqrt{f_c'}$	141	126	110	100
Flexural Bond (deformed bars, sizes ≤ #11):						
Tension top bars	$\bar{u}$	$3.4\sqrt{f_c'}/D \leq 350$				
All other tension bars	u	$4.8\sqrt{f_c'}/D \leq 500$				
		(D = nominal diameter of bar, inches)				

* n is taken to nearest whole number

ALLOWABLE WORKING STRESSES IN REINFORCEMENT		
Description (Stresses in psi)		Grade of Steel
		40, 50, or 60
In tension:	f_s	20000
In compression:		
flexural members	f_s'	20000
columns	f_s	16000

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES-160 SHEET 1 OF 3 DATE 7-64

Revised 8-80

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN
WORKING STRESS DESIGN
ALLOWABLE BOND STRESSES

Allowable Flexural Bond Stress, psi										
Description	Class of Concrete	Bar Size								
		#3	#4	#5	#6	#7	#8	#9	#10	#11
Tension Top Bars	5000	350	350	350	321	275	241	214	192	175
	4000	350	350	342	287	246	215	191	172	156
	3000	350	350	298	248	213	186	165	149	135
	2500	350	340	272	227	194	170	151	136	124
All Other Tension Bars	5000	500	500	500	454	389	340	302	272	247
	4000	500	500	487	405	347	304	270	243	221
	3000	500	500	422	351	301	263	234	211	192
	2500	500	480	384	320	274	240	213	192	174

Flexural Bond Stress

$$u = \frac{V}{\Sigma o j d}$$

V = total shear at the section under investigation, lbs.

Σo = sum of perimeters of the longitudinal tension bars at the section, inches, if all bars are the same size; for mixed sizes, substitute $4\ A_s/D$, where A_s is total longitudinal tension steel area and D is the largest bar diameter.

j = ratio of distance between resultant compression and tension forces to the depth, d. Usually taken as 7/8 for these computations.

d = effective depth, inches.

Flexural bond stress is not considered in compression.

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN
WORKING STRESS DESIGN
DEVELOPMENT LENGTHS

Development Length, inches										
Description	Class of Concrete	Bar Size								
		#3	#4	#5	#6	#7	#8	#9	#10	#11
Tension Top Bars	5000	12	12	14	17	20	25	32	40	49
	4000	12	12	14	17	21	28	35	45	55
	3000	12	12	14	18	25	32	41	52	64
	2500	12	12	14	20	27	36	45	57	70
All Other Tension Bars	5000	12	12	12	12	14	18	23	29	35
	4000	12	12	12	12	15	20	25	32	40
	3000	12	12	12	13	18	23	29	37	46
	2500	12	12	12	14	19	25	32	41	50
All Compression Bars	5000	8	8	8	9	11	12	14	16	17
	4000	8	8	8	10	11	13	15	16	18
	3000	8	8	9	11	13	15	16	18	20
	2500	8	8	10	12	14	16	18	20	22

Notes:

(a) Development lengths are given for design yield strength. $f_y = 40$ ksi

(b) Tension bars spaced laterally not less than 6 inches on center, and bars with at least 3 inches clear from face of member to first bar may use 0.8 development lengths shown but not less than 12 inches.

(c) See ES-227, sheet 3 of 3 for lapped splice lengths.

STRUCTURAL DESIGN: Reinforced Concrete Design
Strength Design
Lap Splices in Reinforcement

Lapped Splice Lengths, inches												
Grade of Steel	Description	Class of Concrete	Class of Splice	Bar Size								
				#3	#4	#5	#6	#7	#8	#9	#10	#11
40	Tension Top Bars	6000	A	12	15	19	23	27	30	34	38	46
			B	16	16	19	23	27	30	38	48	59
			C	21	21	24	29	34	39	50	63	77
		5000	A	12	15	19	23	27	30	34	41	50
			B	16	16	19	23	27	33	42	53	65
			C	21	21	24	29	34	43	54	69	85
		4000	A	12	15	19	23	27	30	36	45	56
			B	16	16	19	23	28	37	47	59	72
			C	21	21	24	29	37	48	61	77	95
		3000	A	12	15	19	23	27	33	41	52	64
			B	16	16	19	24	32	43	54	68	83
			C	21	21	24	31	42	55	70	89	109
		2500	A	12	15	19	23	27	36	45	57	70
			B	16	16	19	26	35	47	59	74	91
			C	21	21	24	34	46	61	77	97	119
	All Other Tension Bars	6000	A	12	15	19	23	27	30	34	38	42
			B	16	16	19	23	27	30	34	38	42
			C	21	21	21	23	27	30	36	45	55
		5000	A	12	15	19	23	27	30	34	38	42
			B	16	16	19	23	27	30	34	38	46
			C	21	21	21	23	27	31	39	49	61
		4000	A	12	15	19	23	27	30	34	38	42
			B	16	16	19	23	27	30	34	42	52
			C	21	21	21	23	27	34	44	55	68
		3000	A	12	15	19	23	27	30	34	38	46
			B	16	16	19	23	27	31	38	49	60
			C	21	21	21	23	30	40	50	64	78
		2500	A	12	15	19	23	27	30	34	41	50
			B	16	16	19	23	27	33	42	53	65
			C	21	21	21	24	33	44	55	70	85
	All Compression Bars	6000		12	12	15	18	21	24	27	30	33
		5000		12	12	15	18	21	24	27	30	33
		4000		12	12	15	18	21	24	27	30	33
		3000		12	12	15	18	21	24	27	30	33
		2500		16	16	20	24	28	32	36	40	44

Tension bars spaced laterally not less than 6 inches on center, and bars with at least 3 inches clear from face of member to first bar may use 0.8 lap lengths shown but not less than 12 inches.

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN
BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE.
FOR 12 INCH WIDTH

$f'_c = 2500$ psi

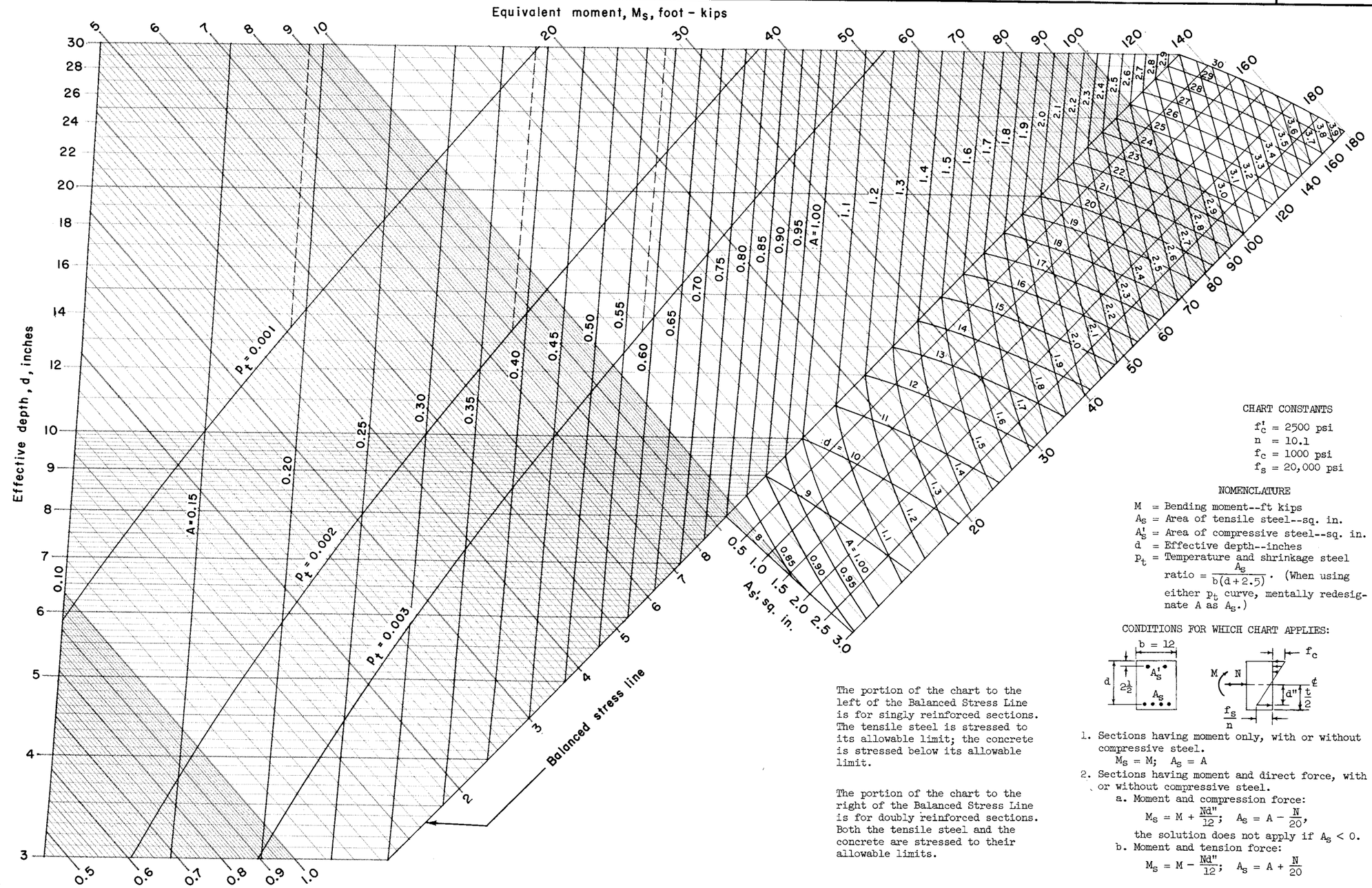


CHART CONSTANTS

$f'_c = 2500$ psi
$n = 10.1$
$f_c = 1000$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

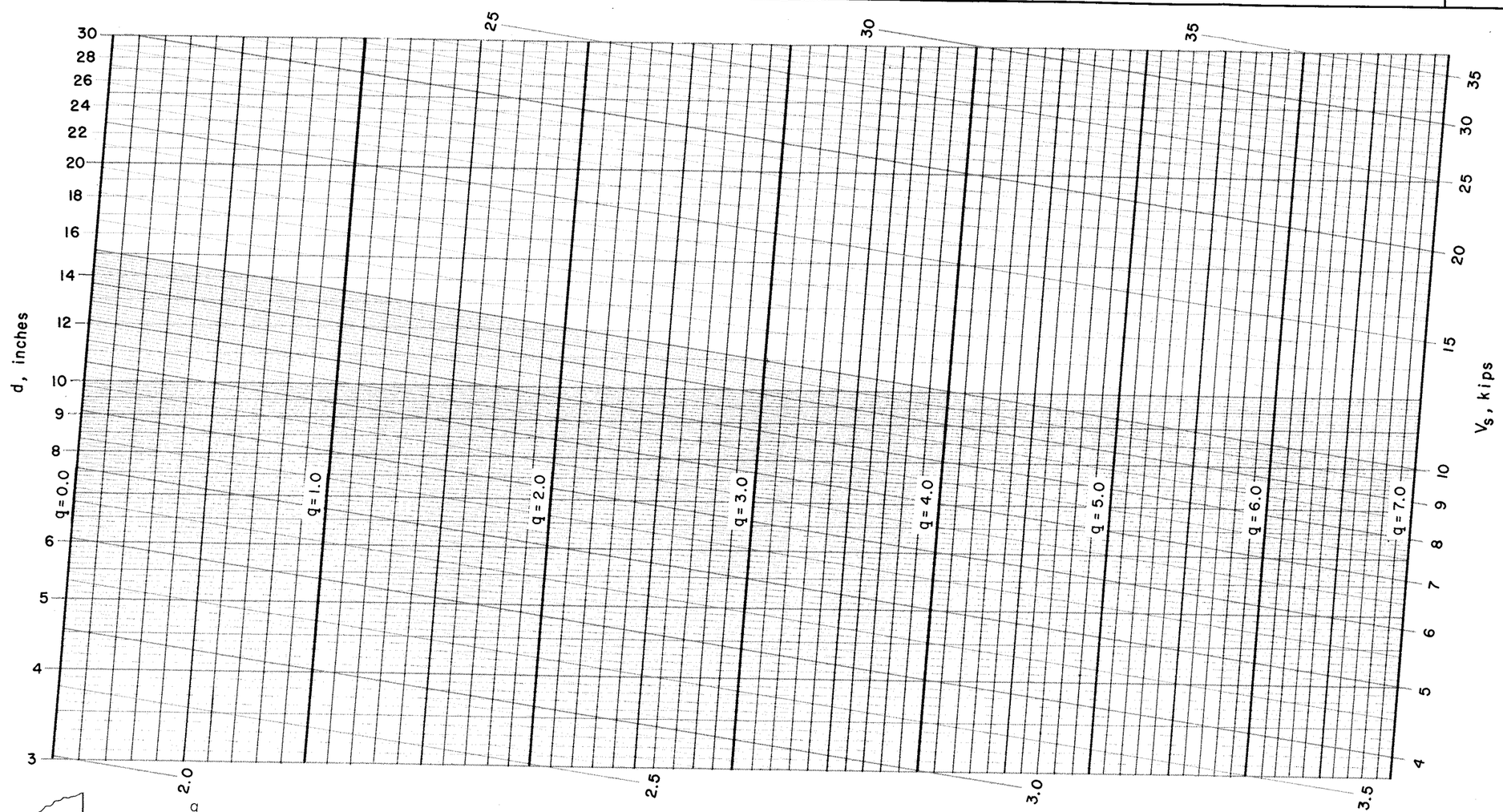
REFERENCE

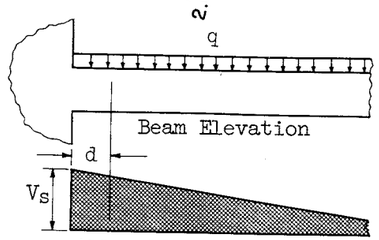
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 161
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 2500$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1. + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

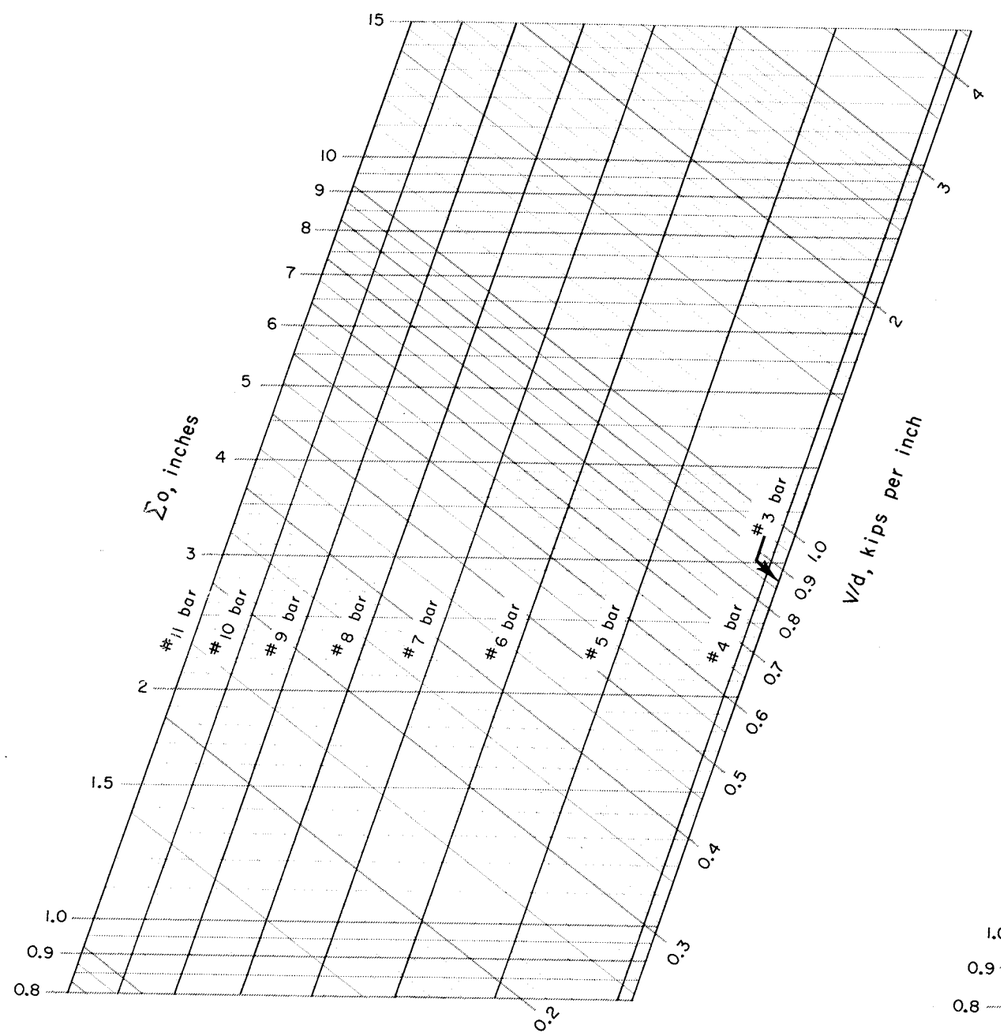
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 161
SHEET 2 OF 3
DATE 7-64

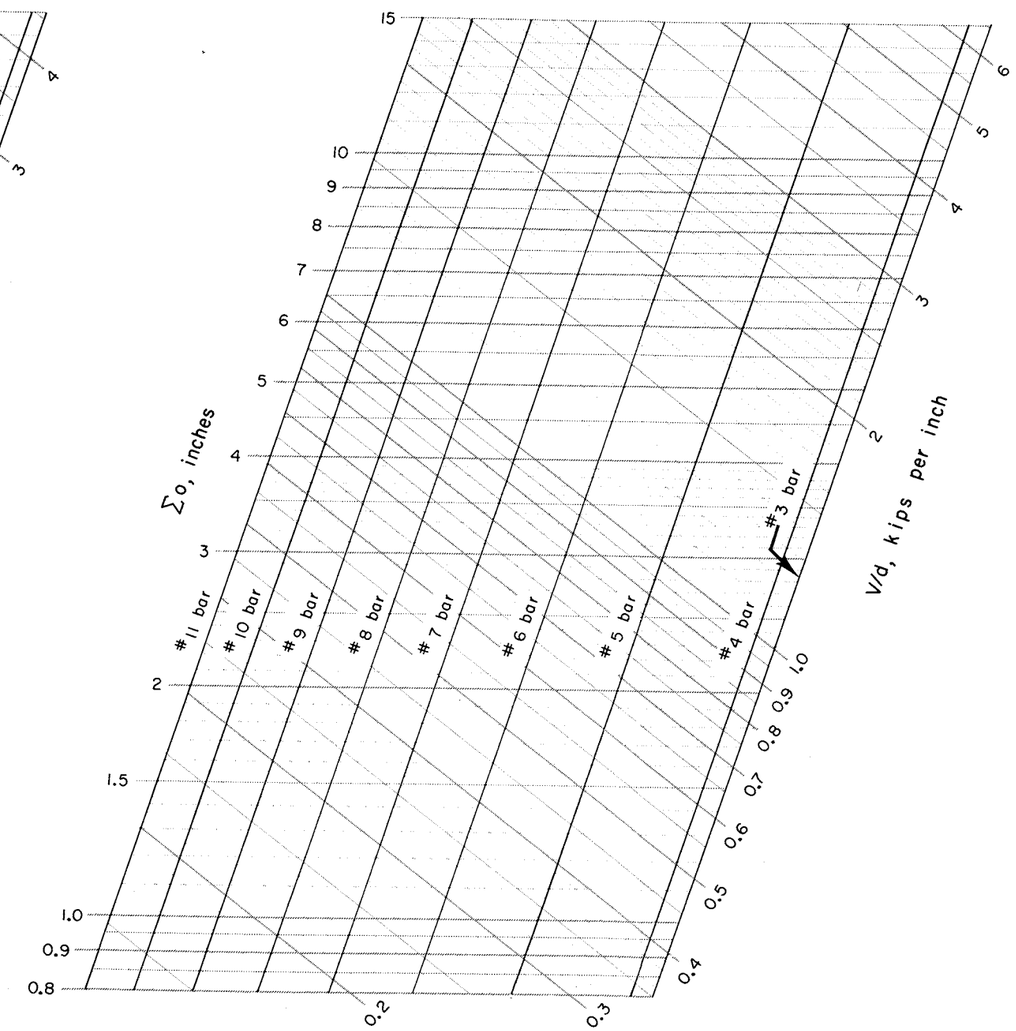
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 2500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leqq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leqq 500$

REFERENCE

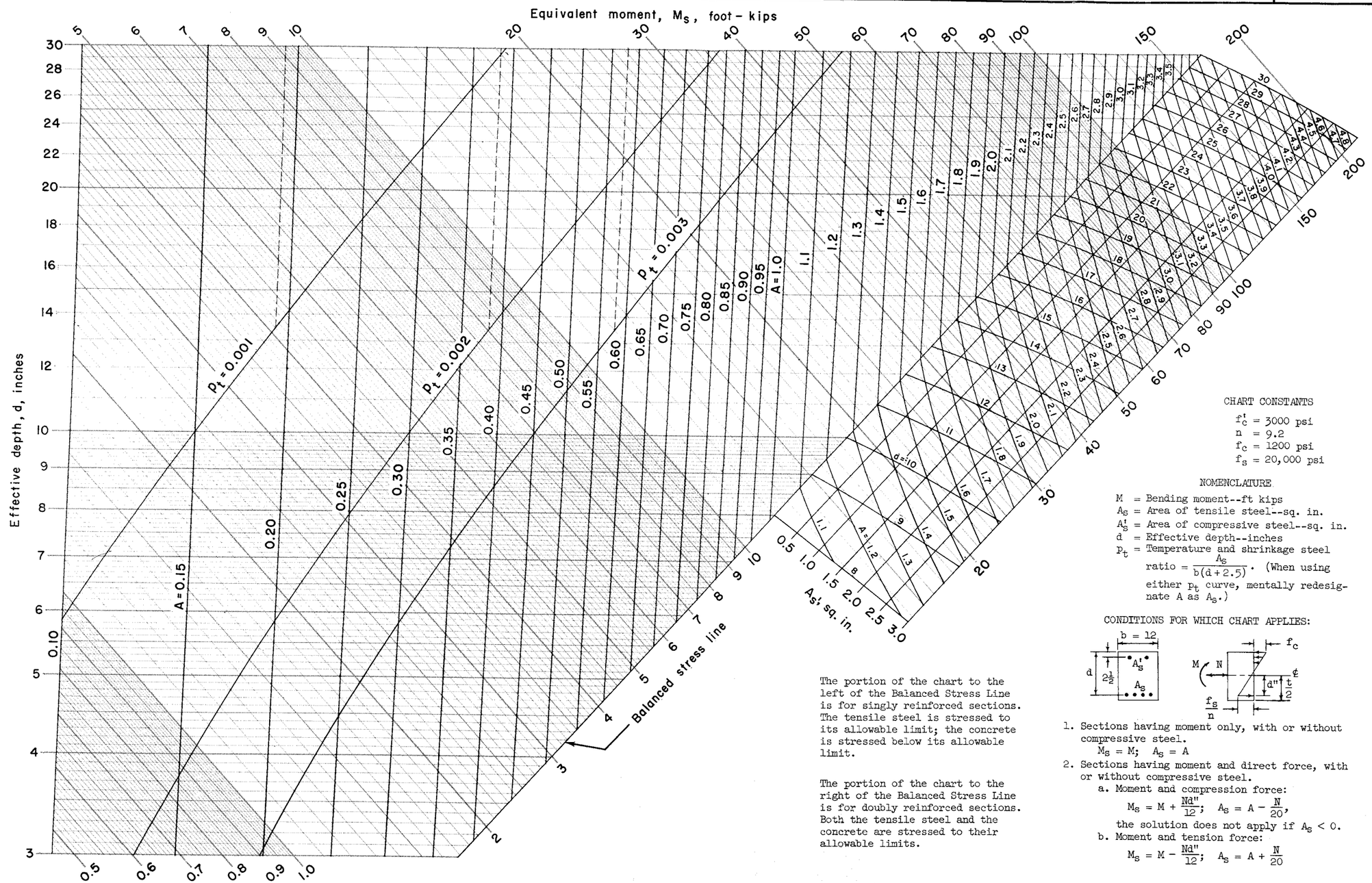
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 161
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 3000$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

$f'_c = 3000$ psi
$n = 9.2$
$f_c = 1200$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

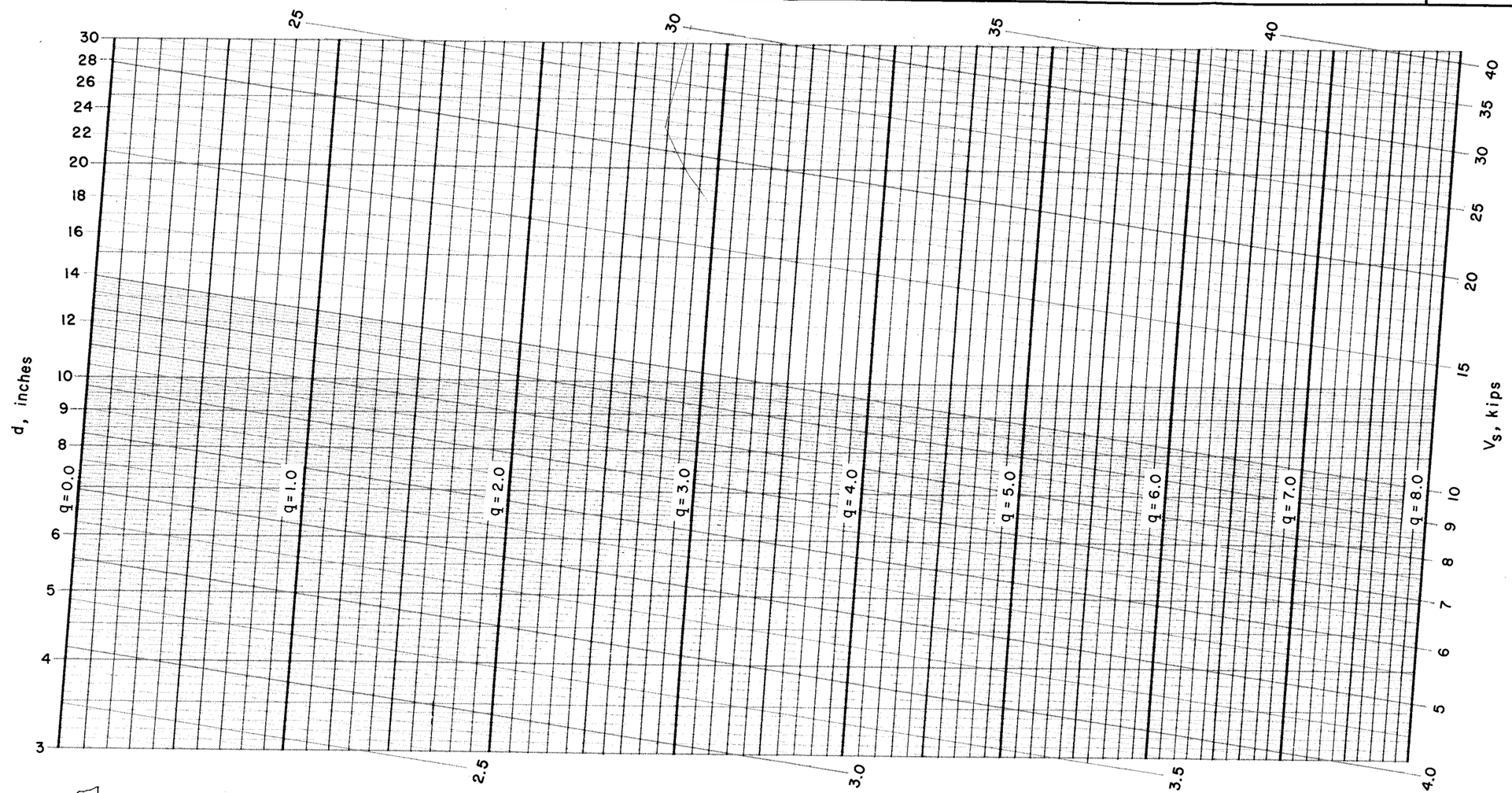
REFERENCE

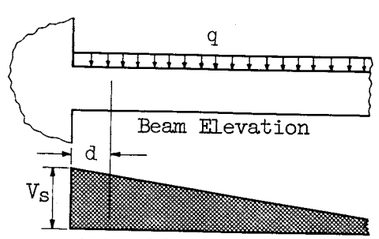
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 162
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 3000$ psi





Allowable Shear Diagram

$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

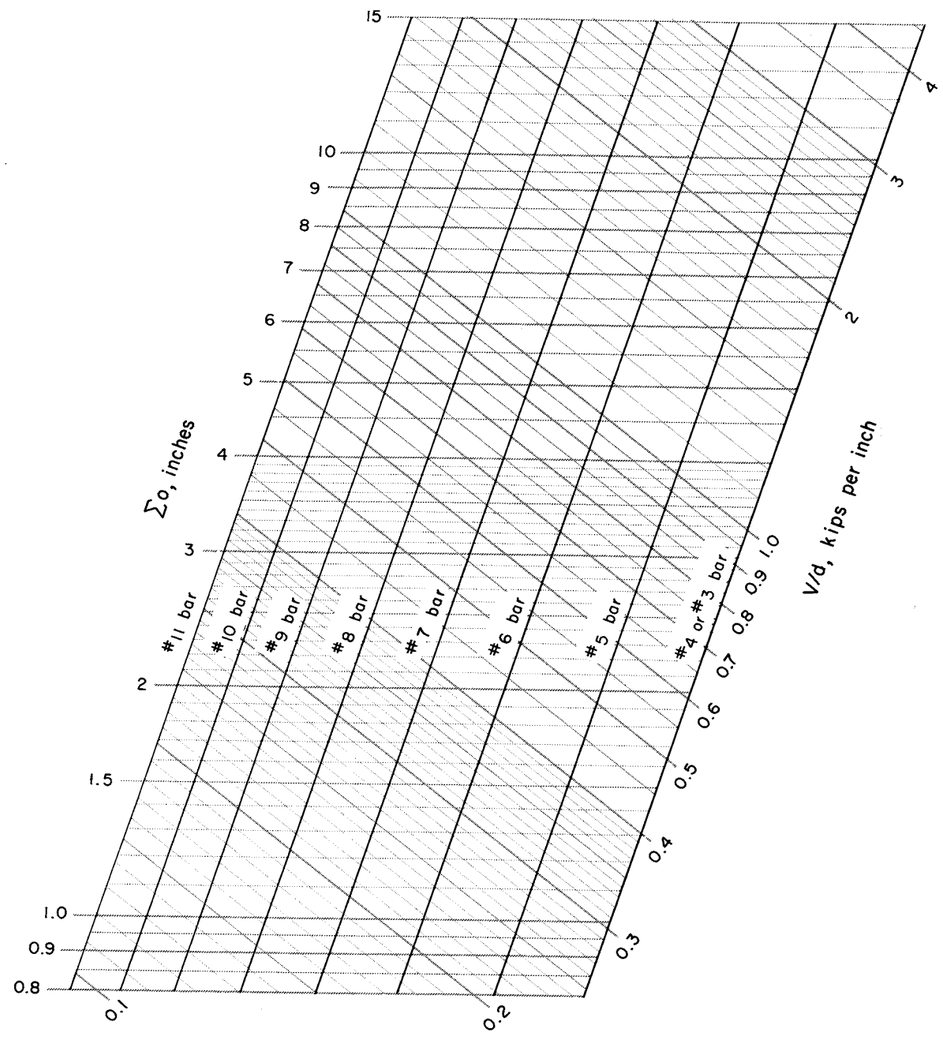
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 162
SHEET 2 OF 3
DATE 7-64

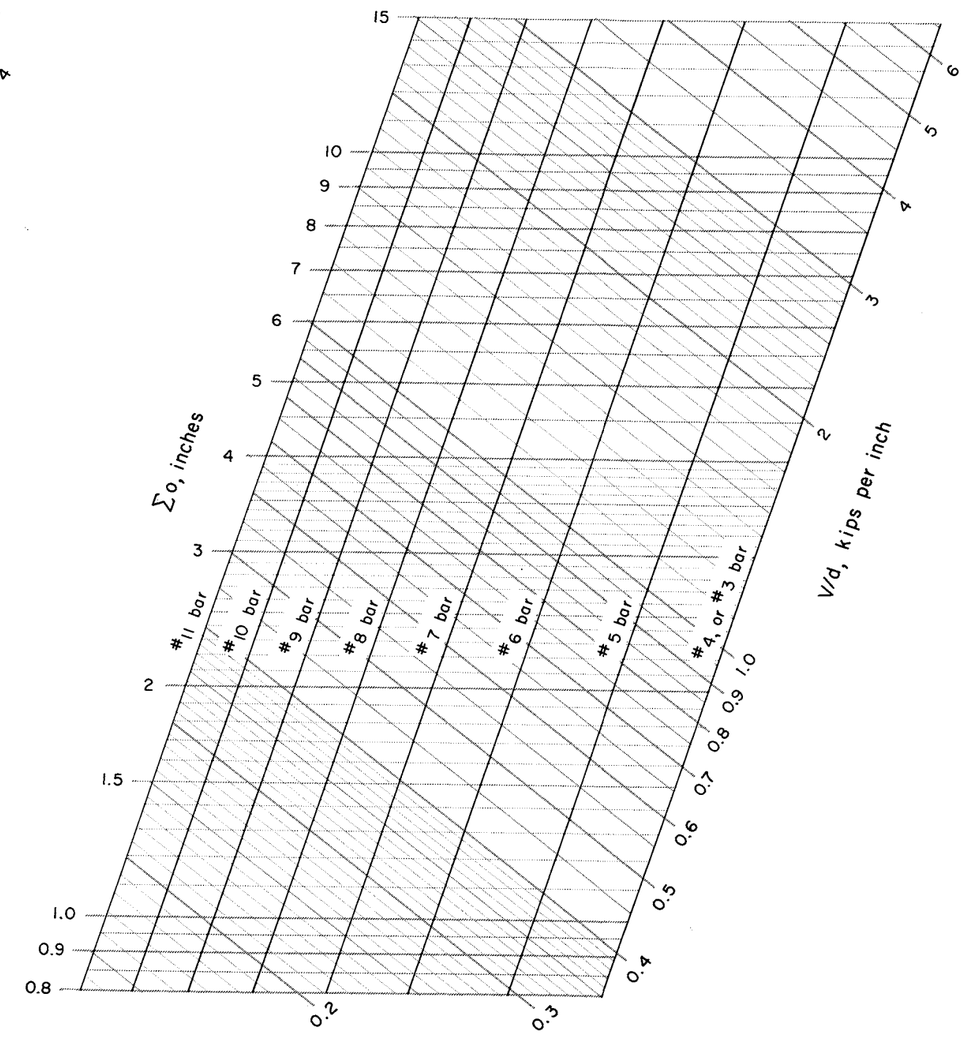
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 3000$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi

For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$

For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

ACI Building Code (ACI 318 – 63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-162
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 3500$ psi

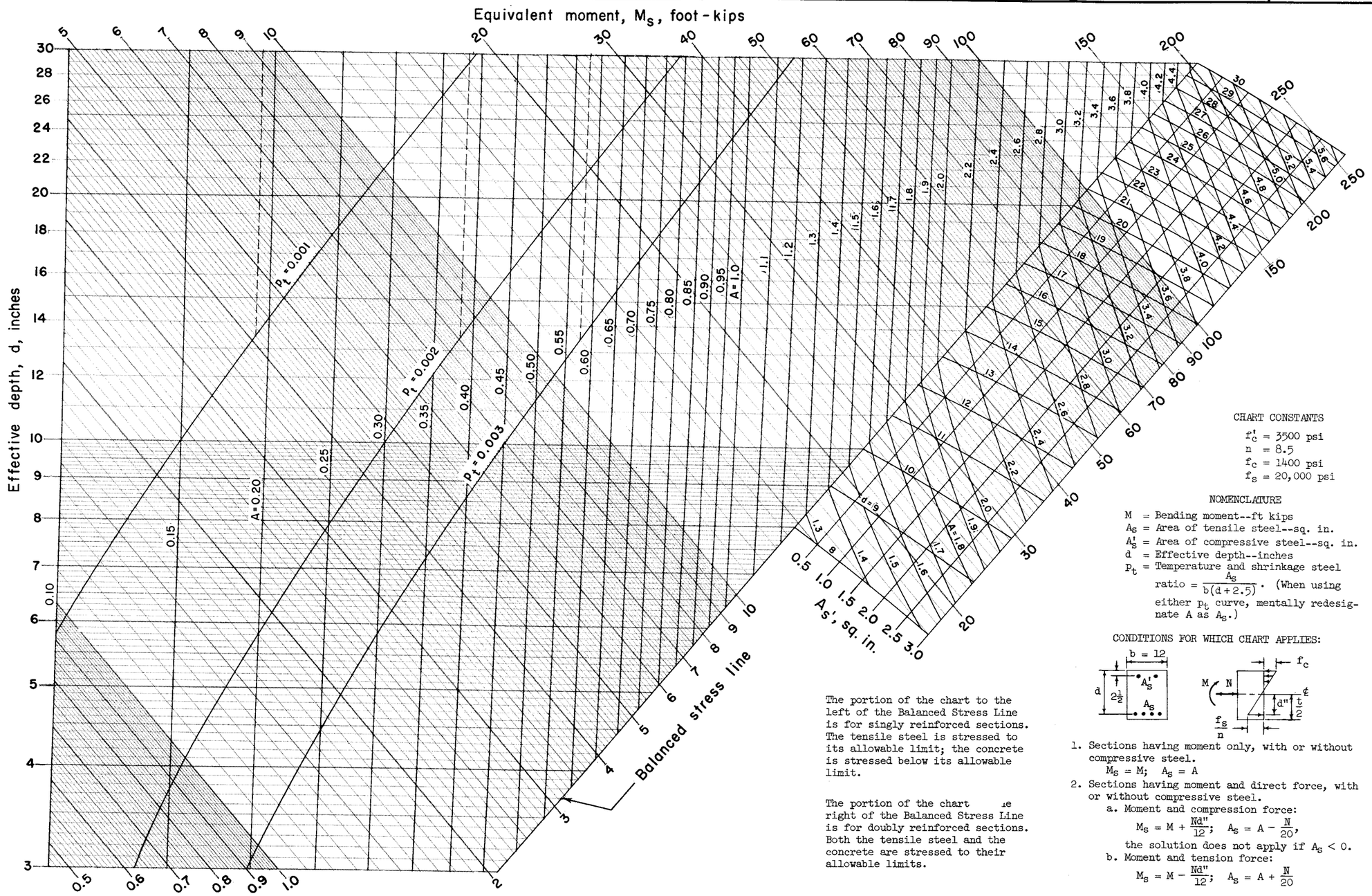


CHART CONSTANTS

$f'_c = 3500$ psi
$n = 8.5$
$f_c = 1400$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart [illegible] right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

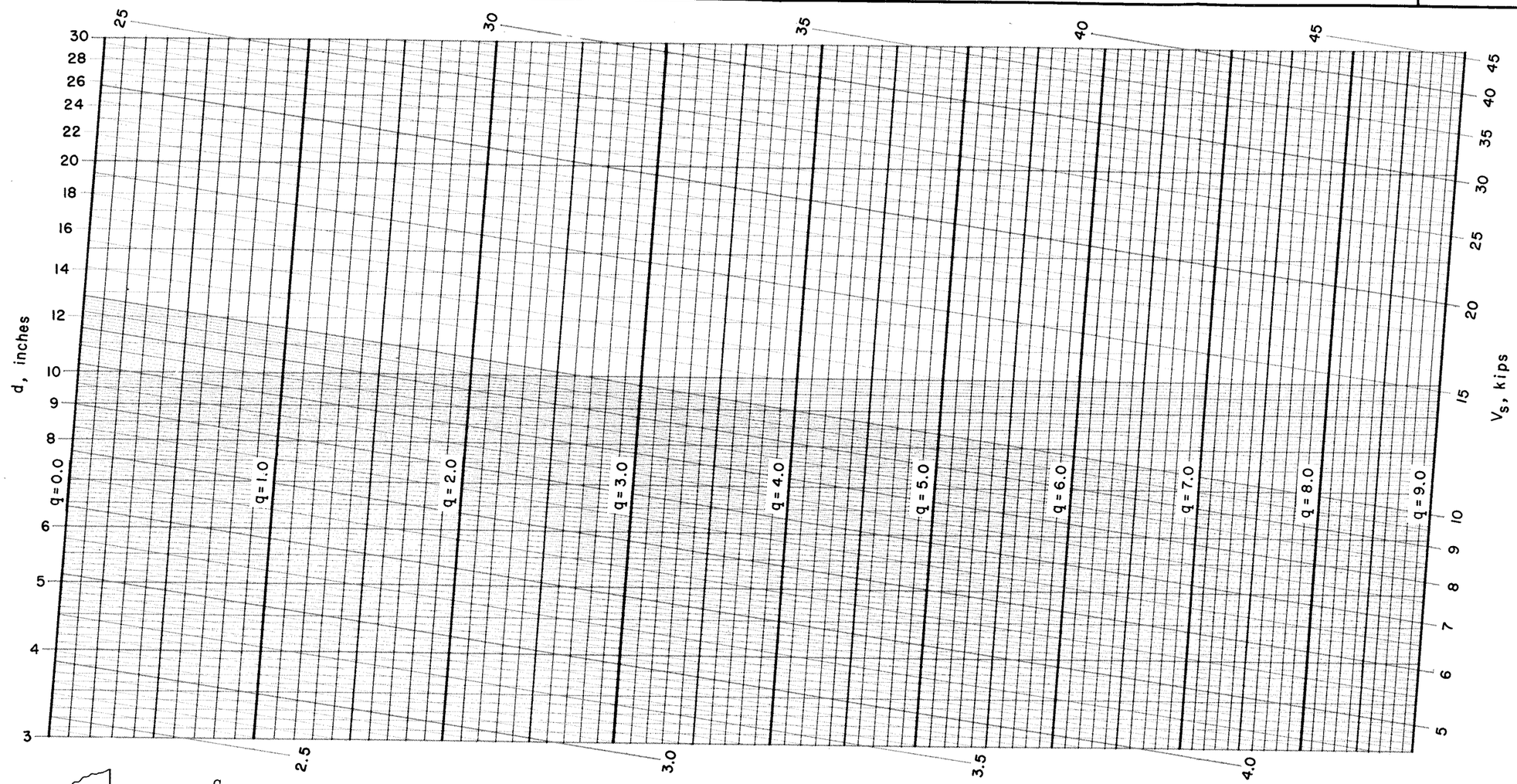
REFERENCE

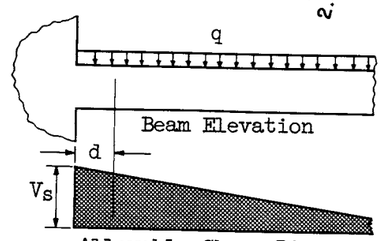
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO. ES- 163
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED
BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 3500$ psi





Allowable Shear Diagram

$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

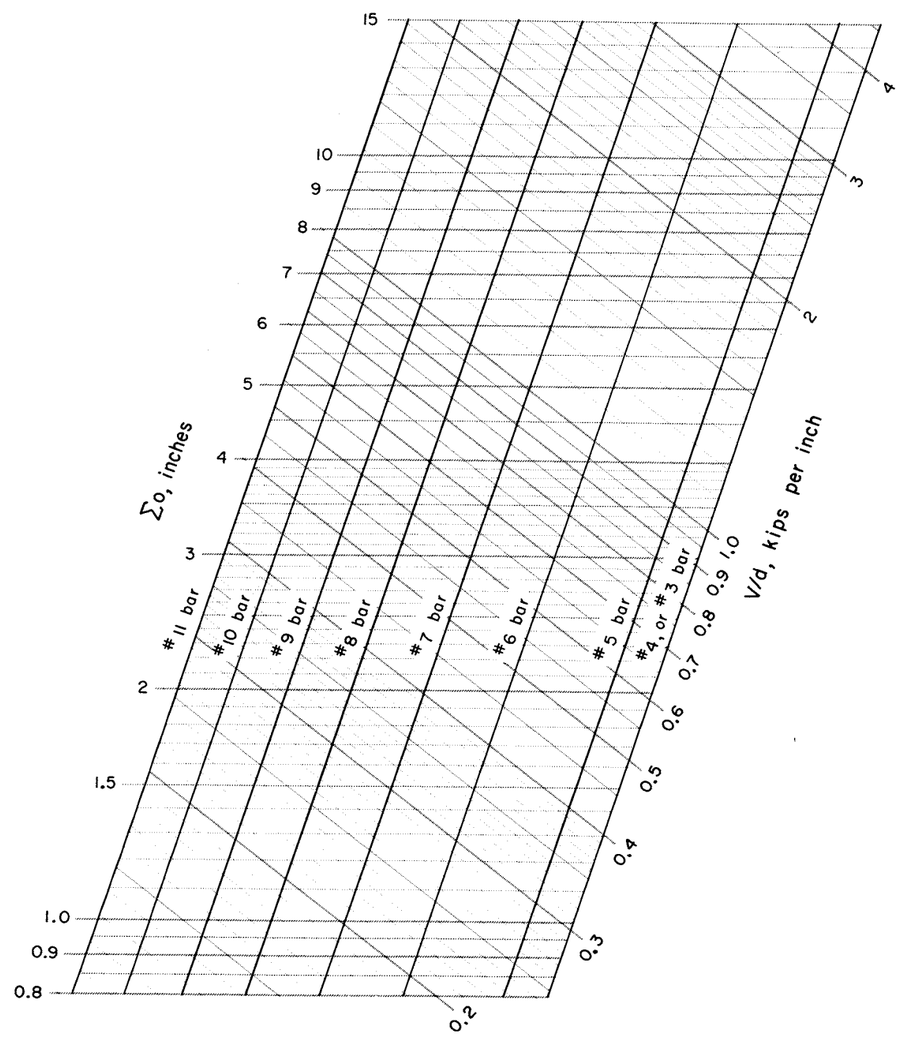
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 163
SHEET 2 OF 3
DATE 7 - 64

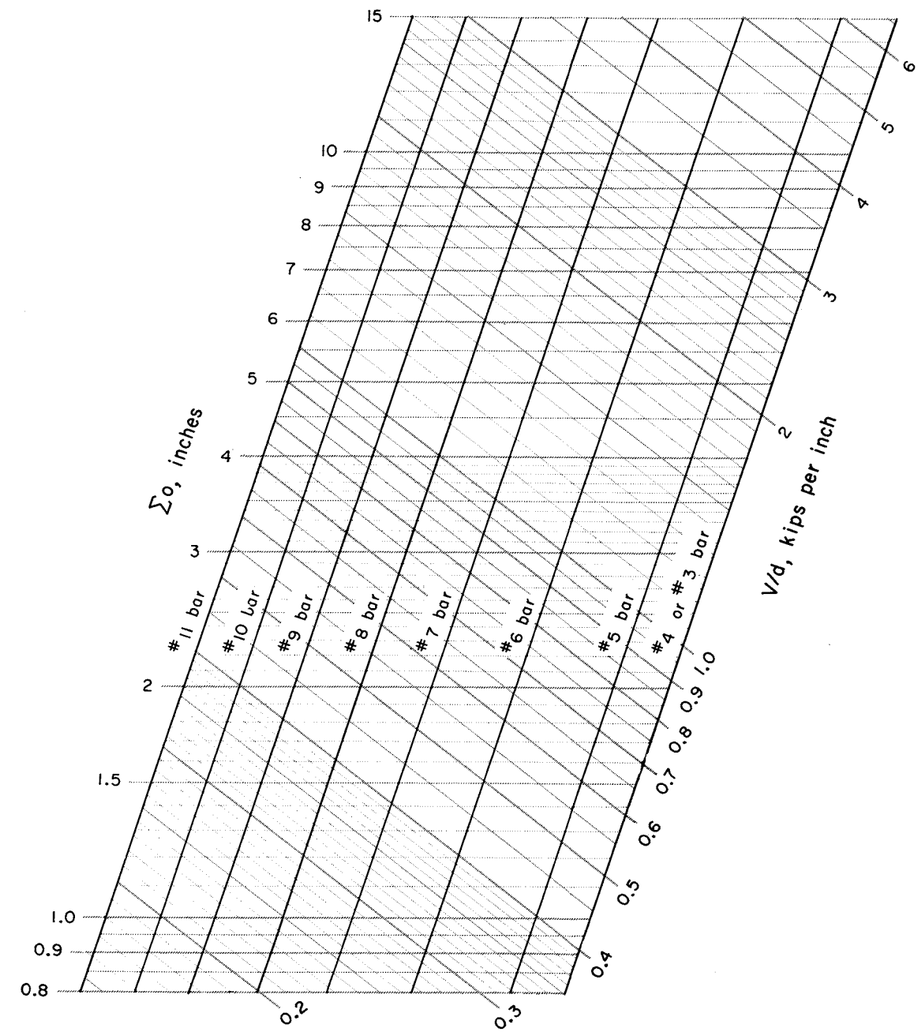
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 3500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

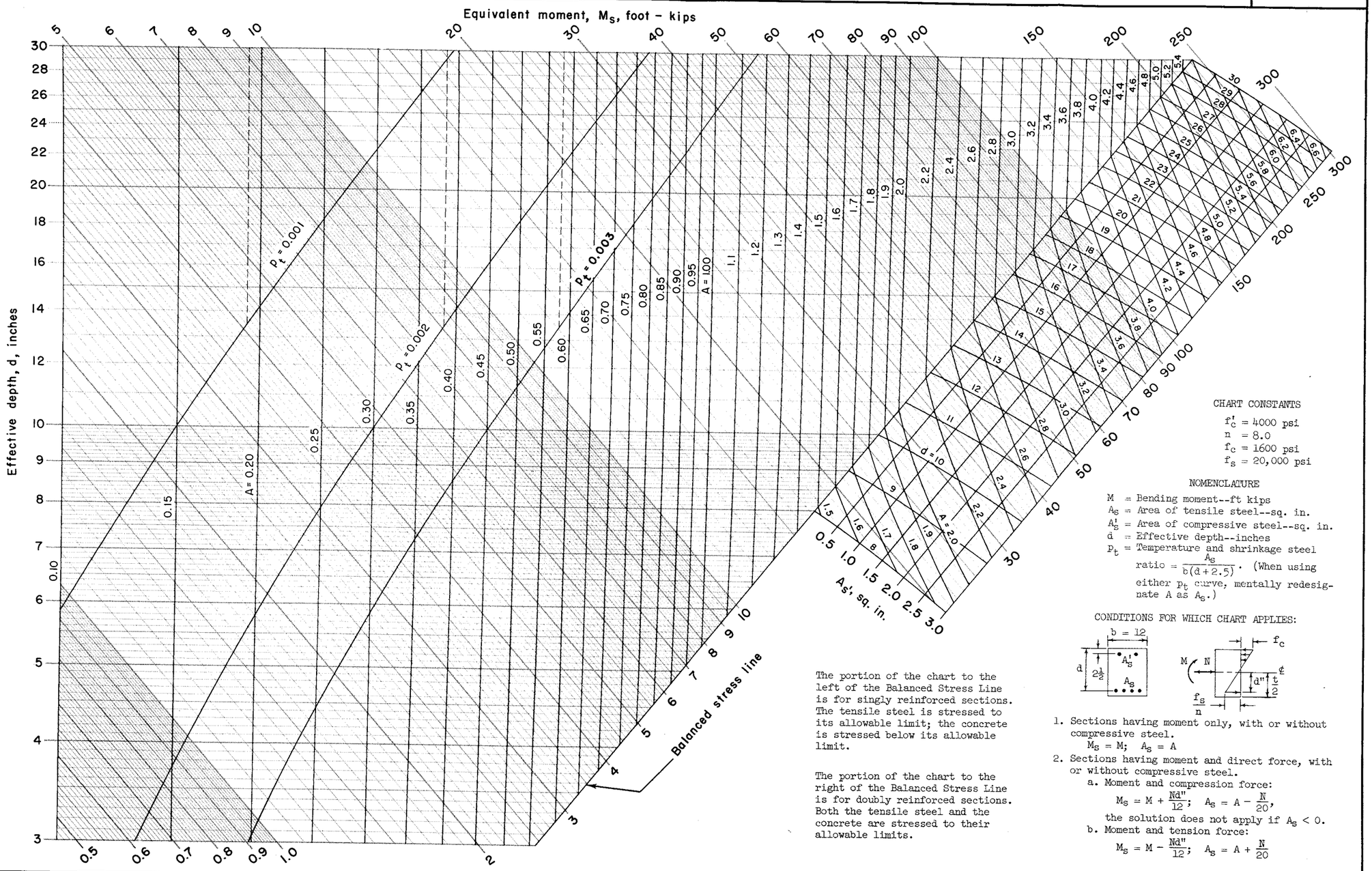
ACI Building Code (ACI 318 - 63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-163
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN
BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE.
FOR 12 INCH WIDTH

f'_c = 4000 psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

f'_c = 4000 psi
n = 8.0
f_c = 1600 psi
f_s = 20,000 psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio = $\frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

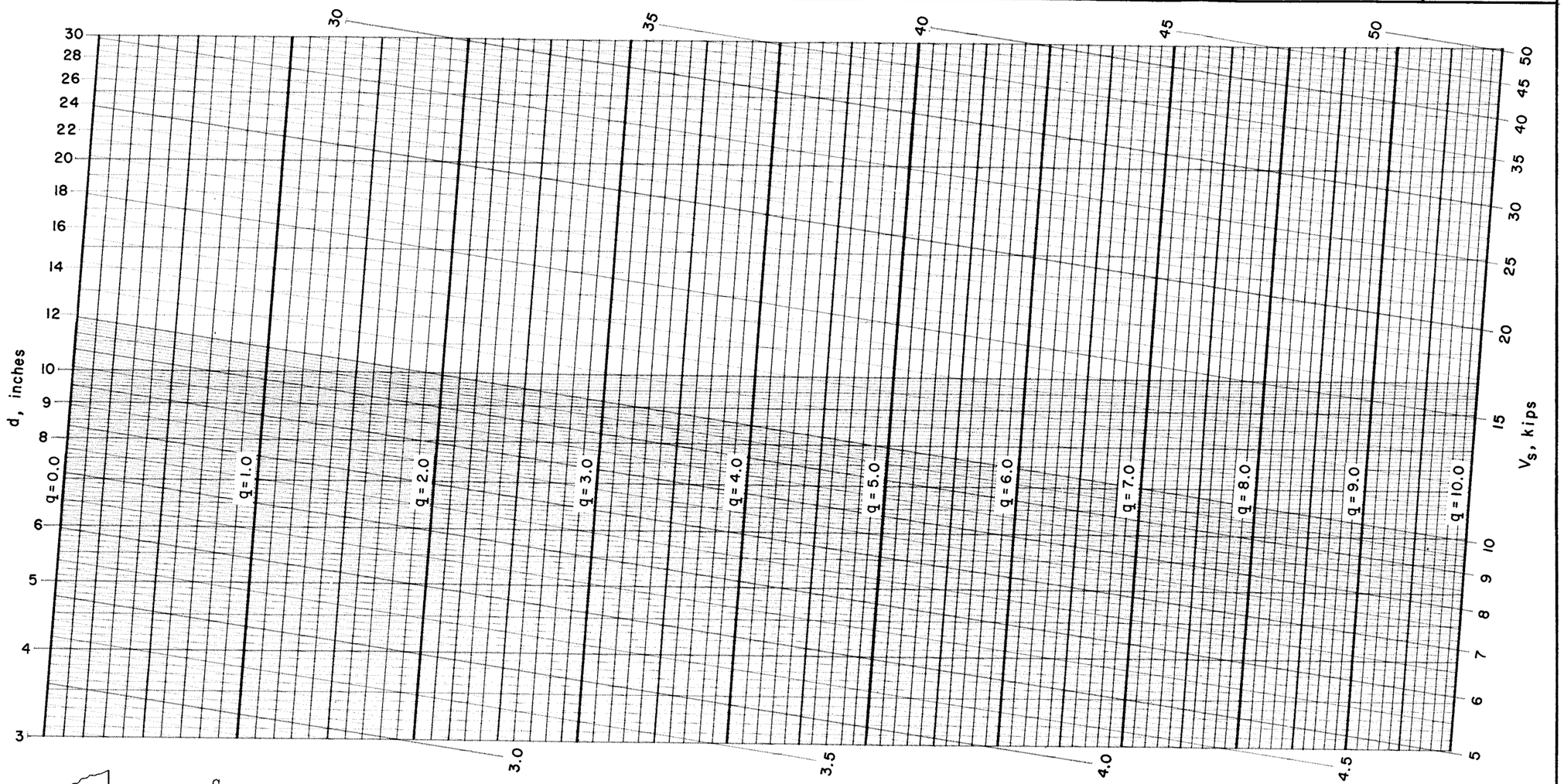
REFERENCE

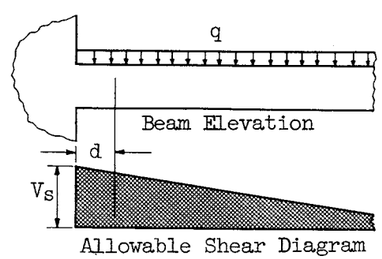
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 164
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 4000$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

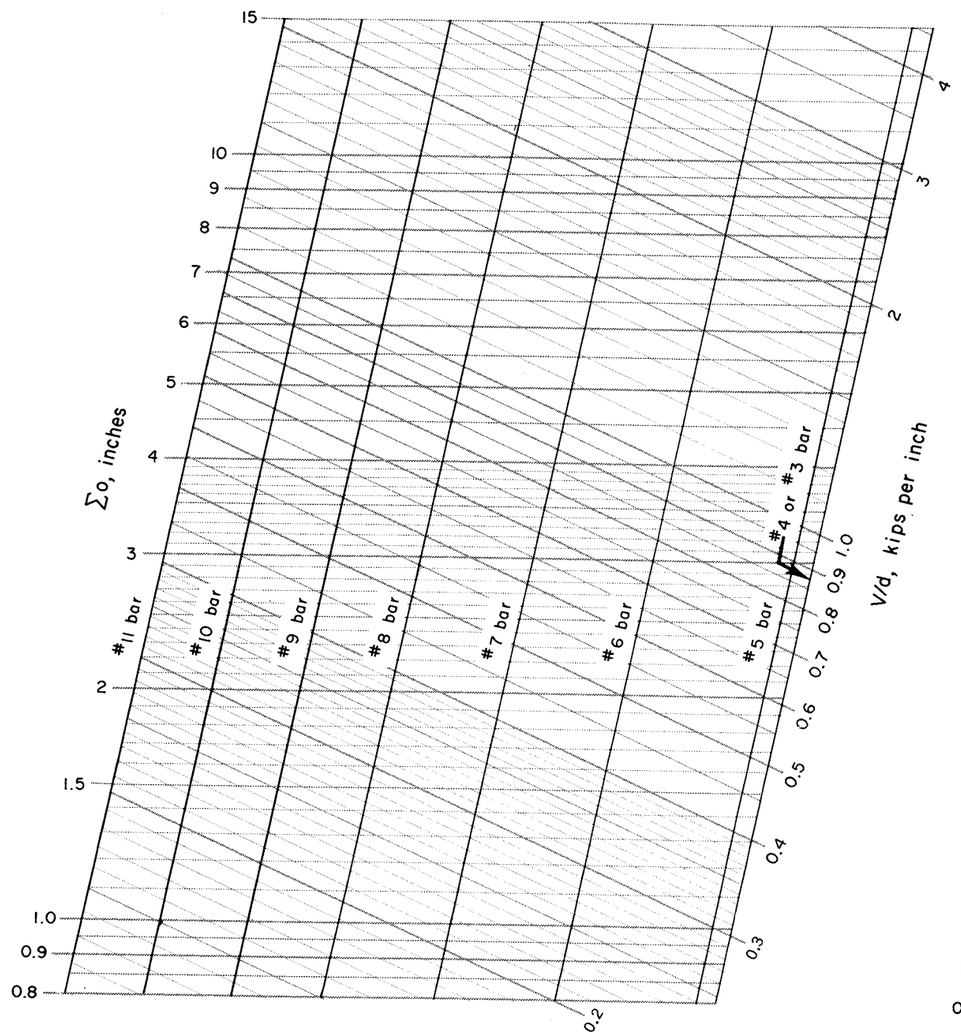
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 164
SHEET 2 OF 3
DATE 7-64

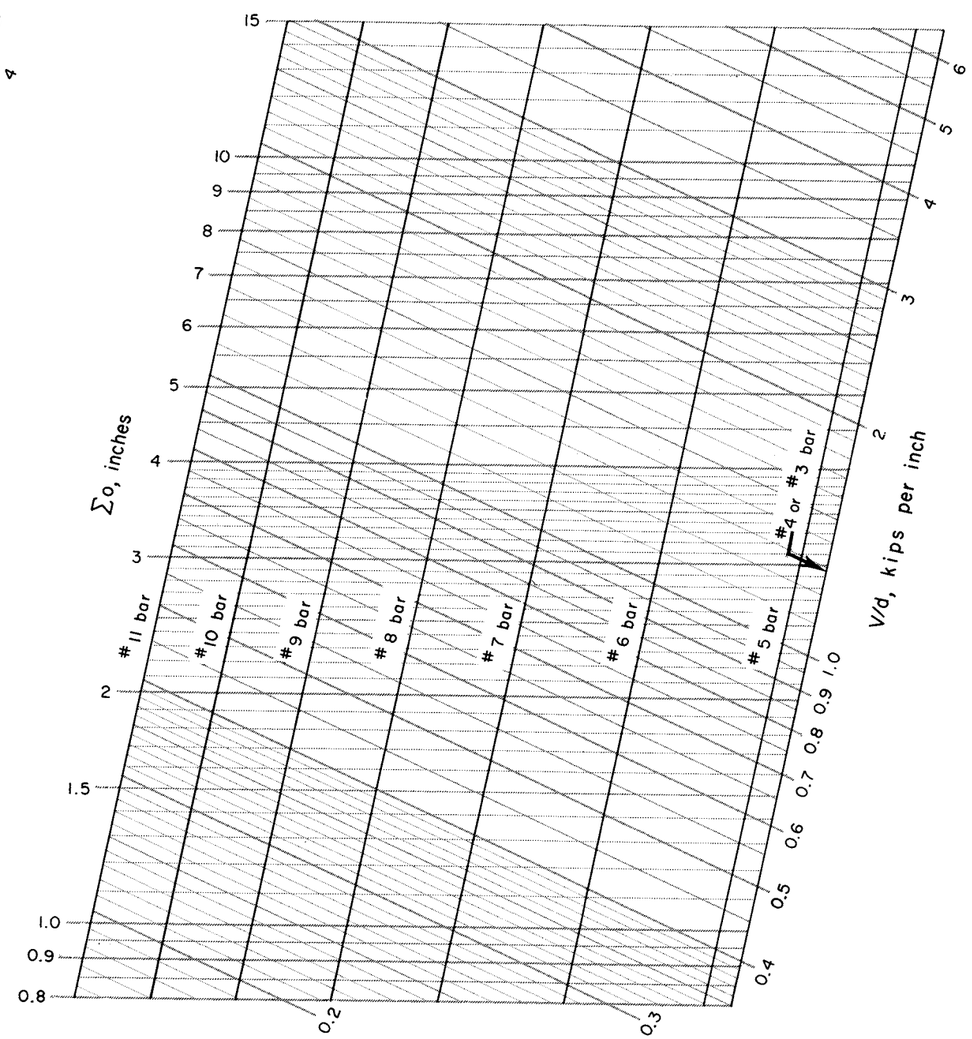
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 4000$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

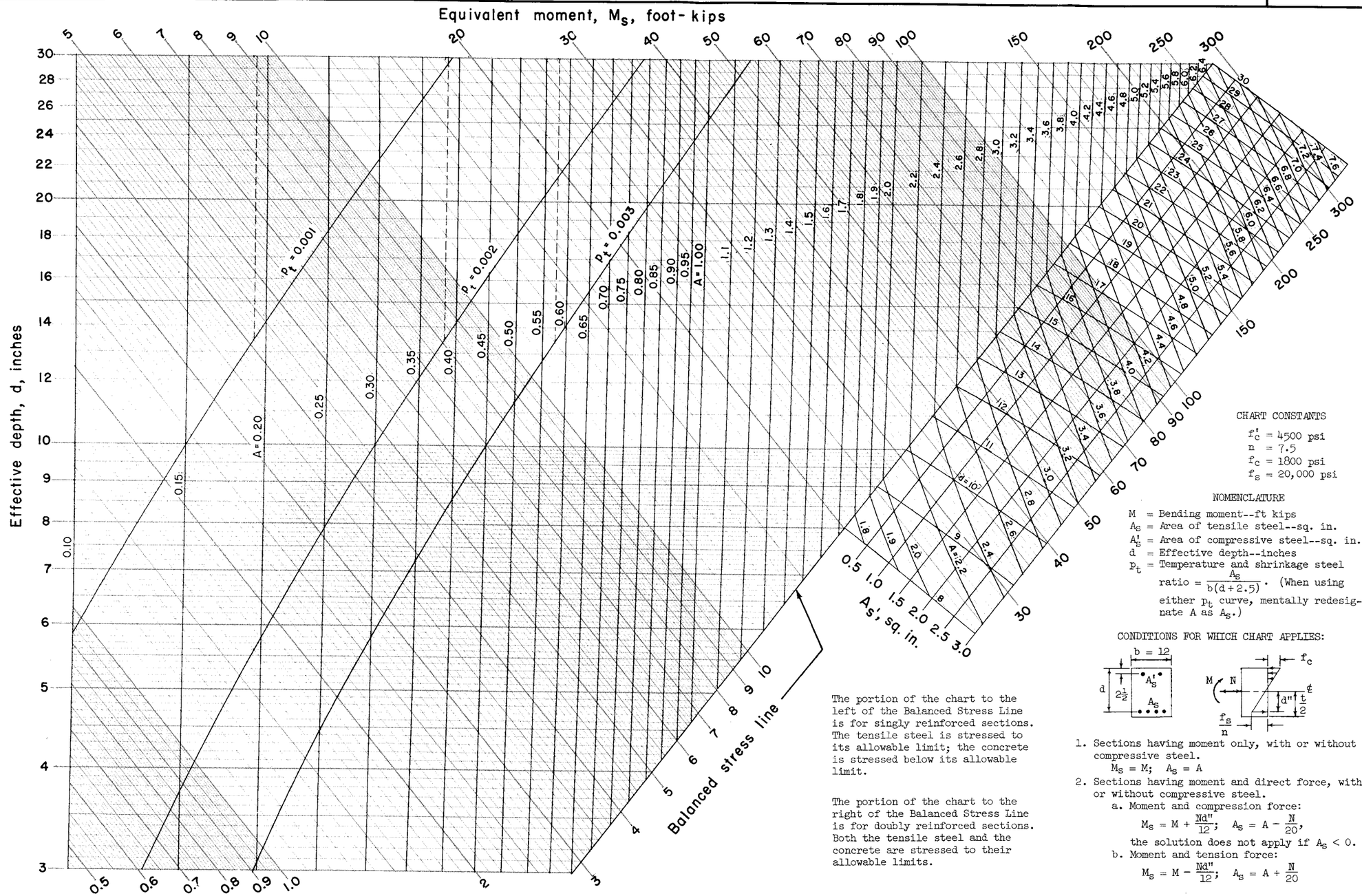
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 164
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN
BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE.
FOR 12 INCH WIDTH

$f'_c = 4500$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

$f'_c = 4500$ psi
$n = 7.5$
$f_c = 1800$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

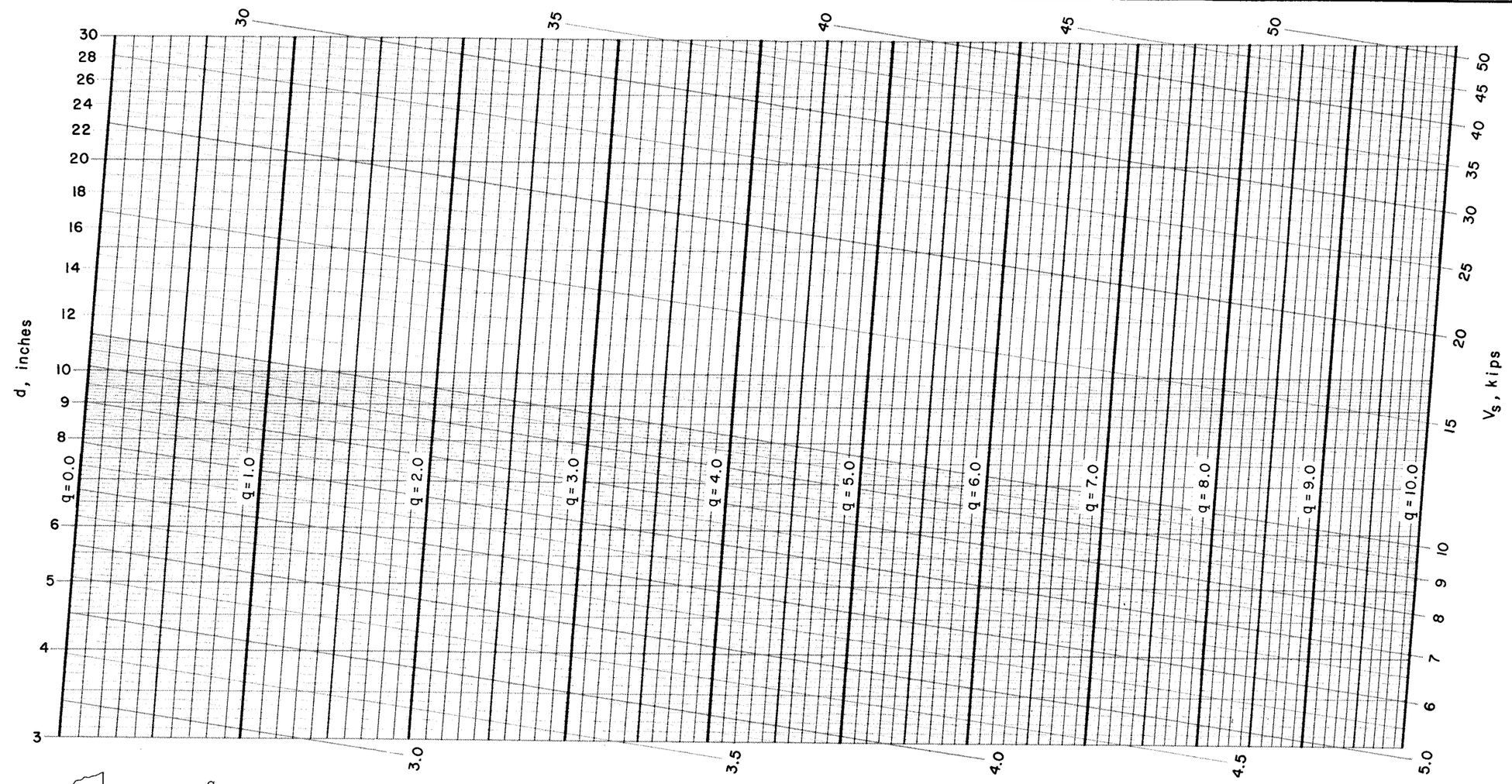
REFERENCE

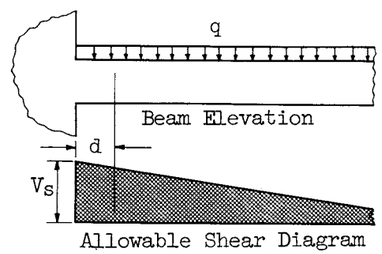
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 165
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 4500$ psi





Allowable Shear Diagram

$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$. psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

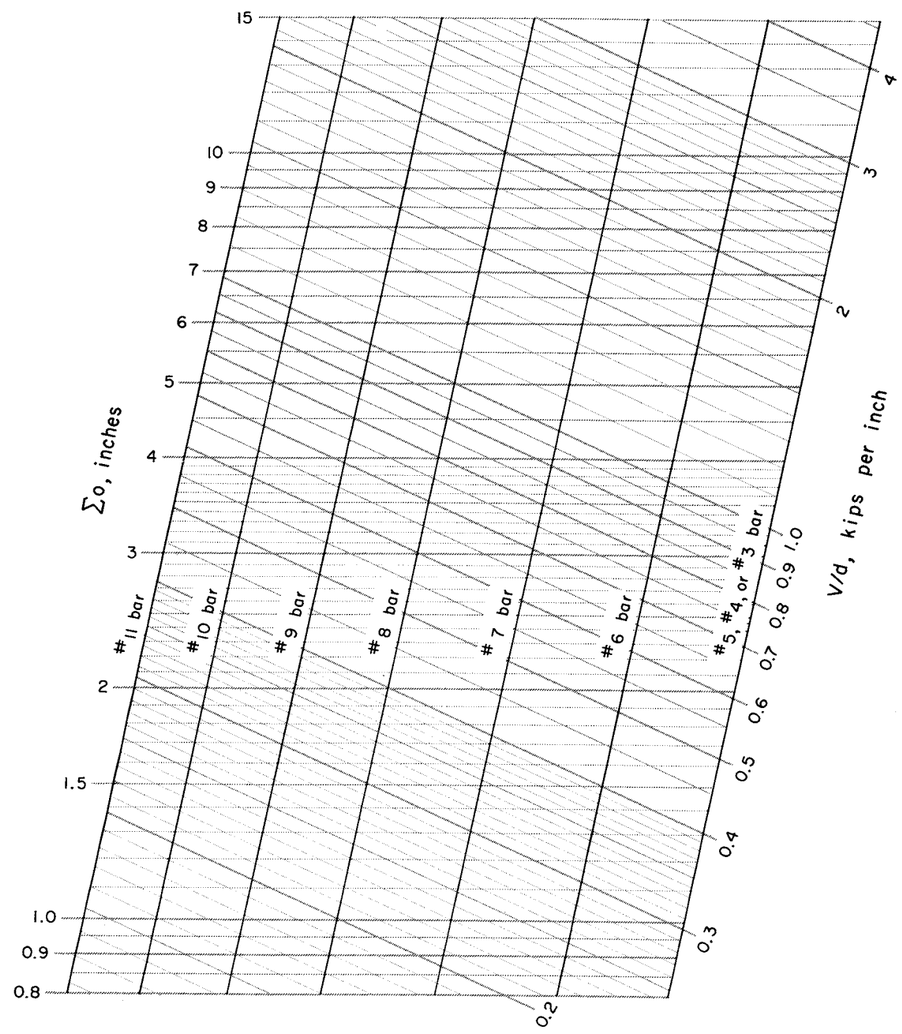
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 165
SHEET 2 OF 3
DATE 7-64

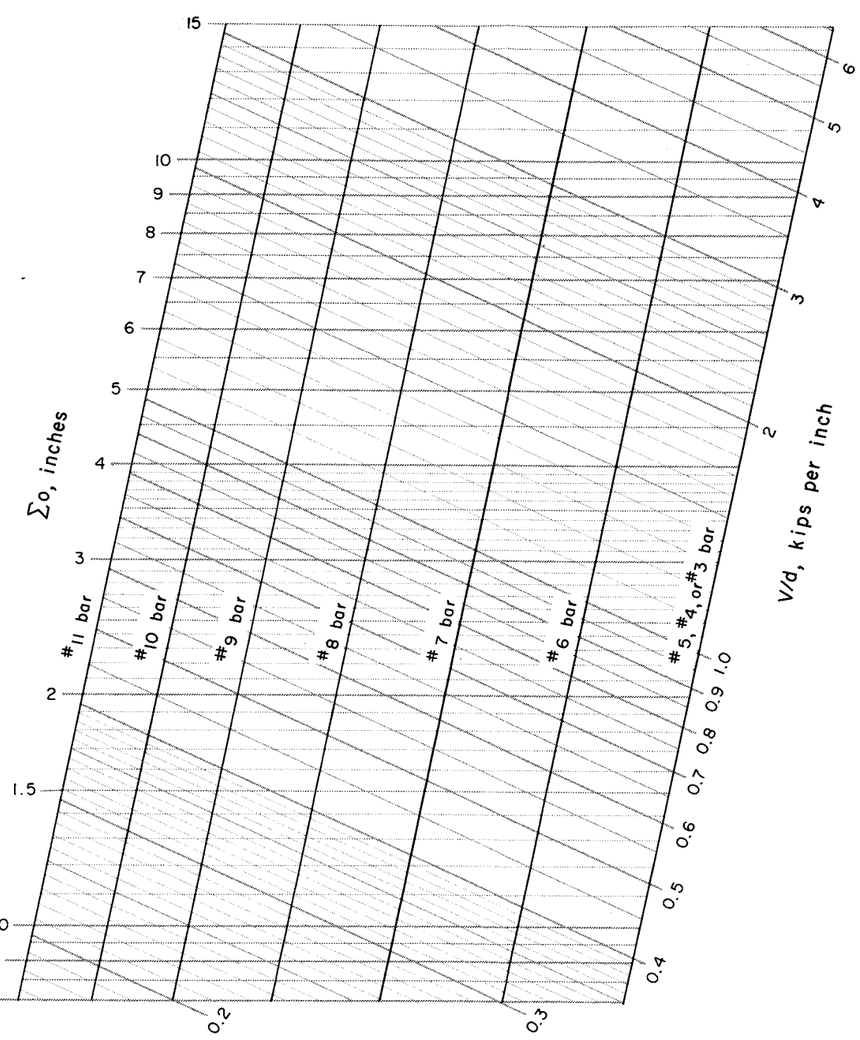
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 4500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

ACI Building Code (ACI 318 - 63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 165
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN
BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE.
FOR 12 INCH WIDTH

$f'_c = 5000$ psi

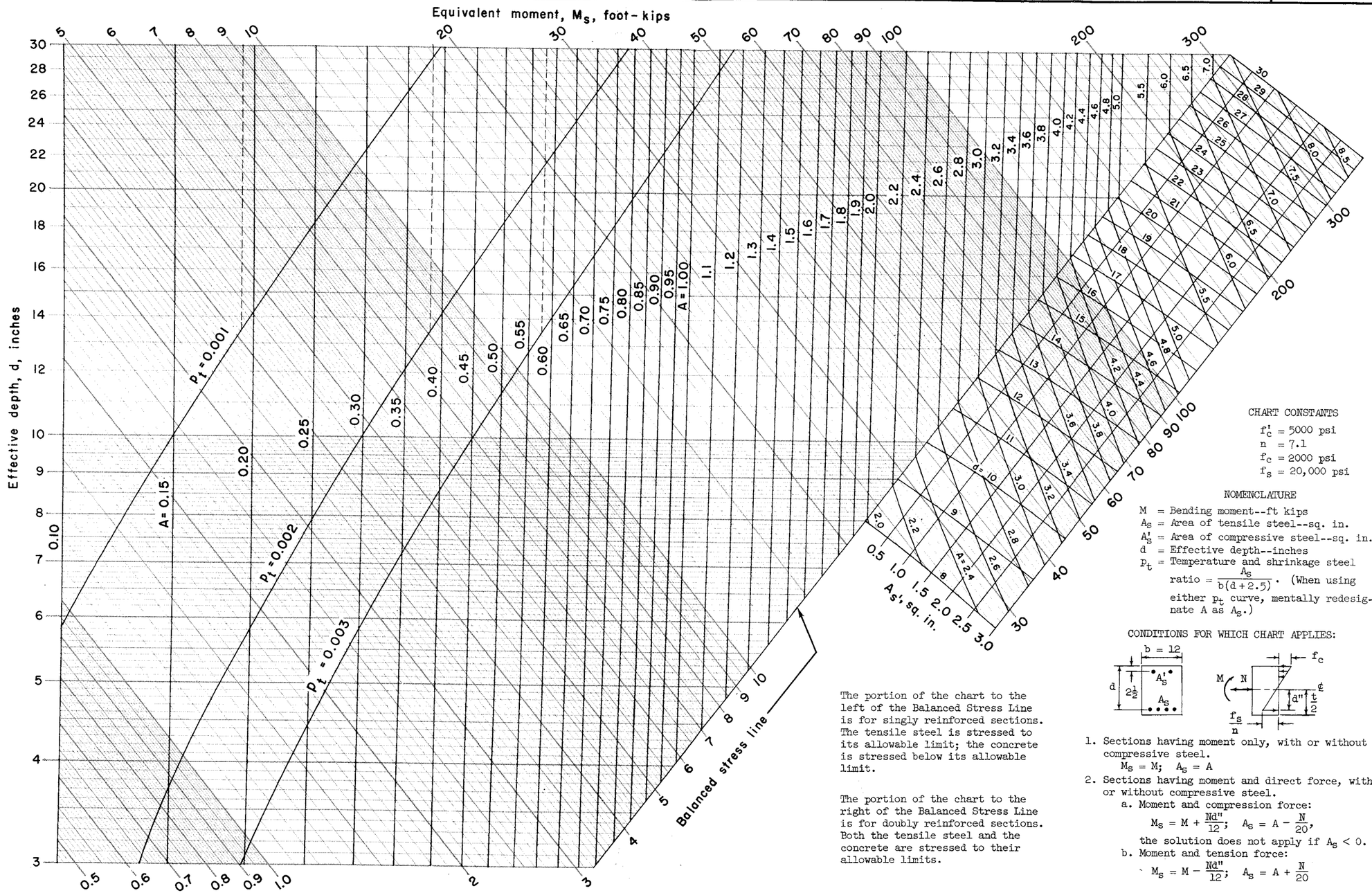


CHART CONSTANTS

$f'_c = 5000$ psi
$n = 7.1$
$f_c = 2000$ psi
$f_s = 20,000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

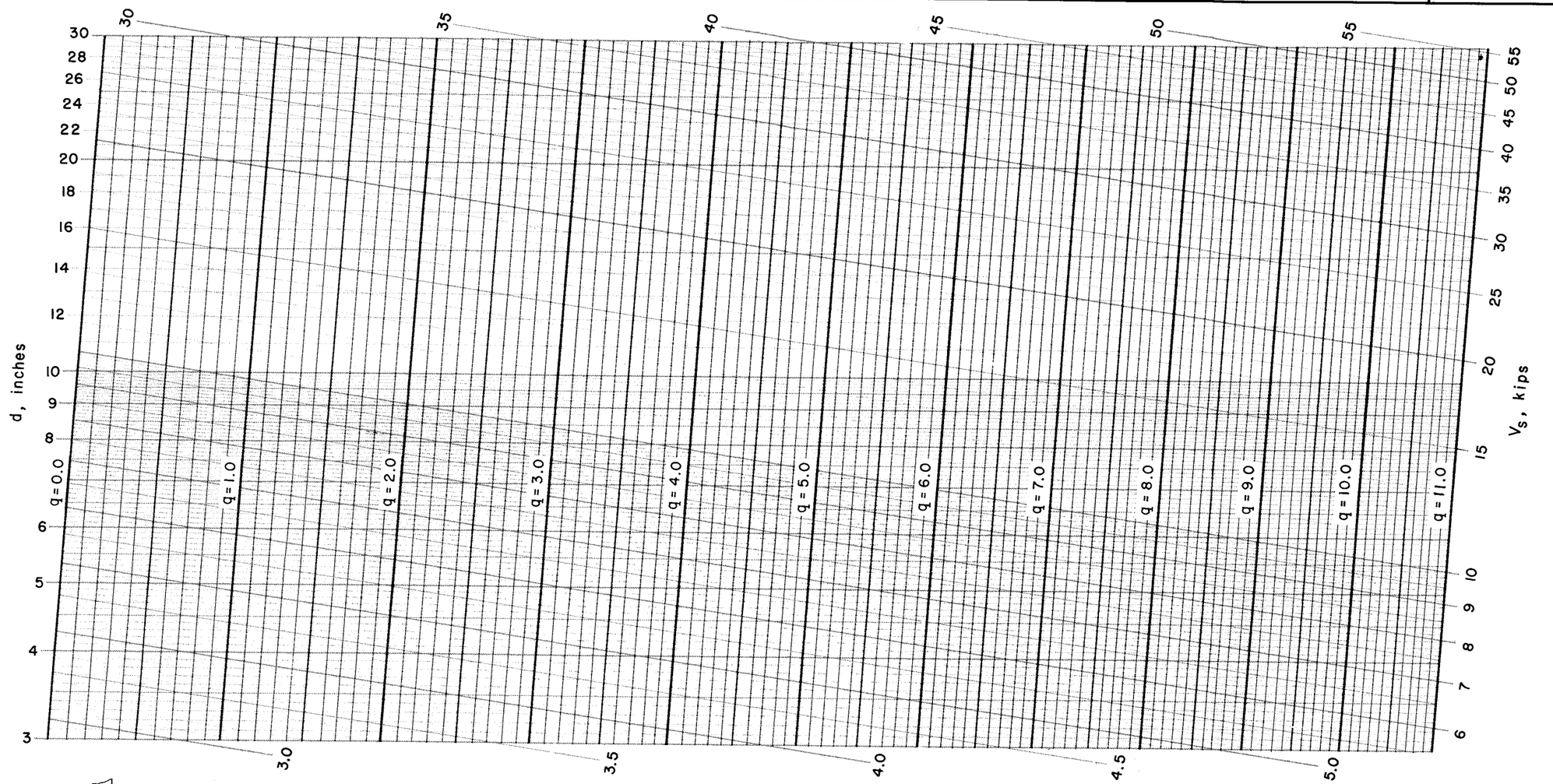
REFERENCE

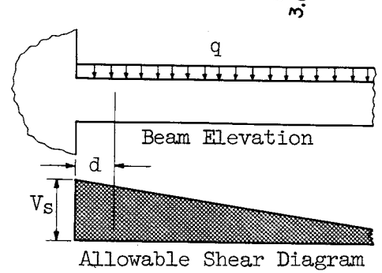
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 166
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED
BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 5000$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

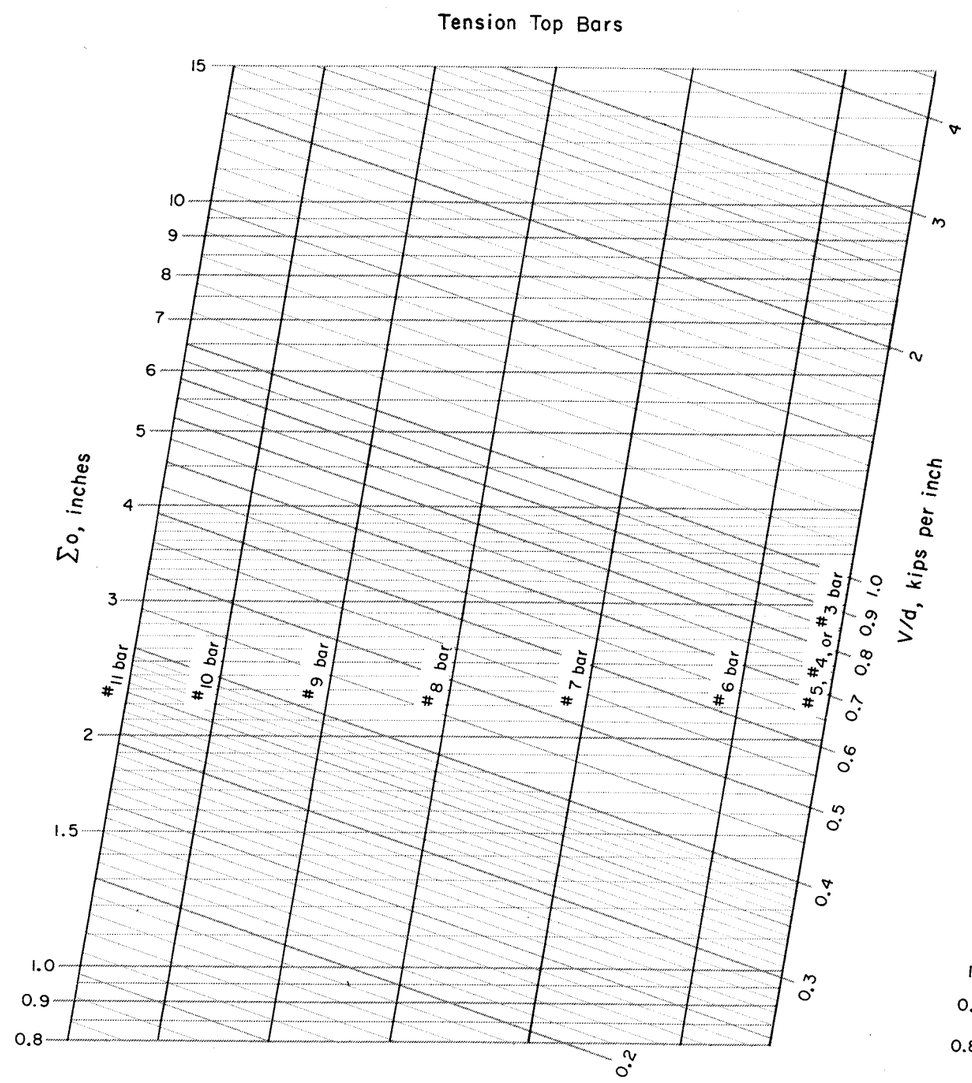
REFERENCE
ACI Building Code (ACI 318-63)

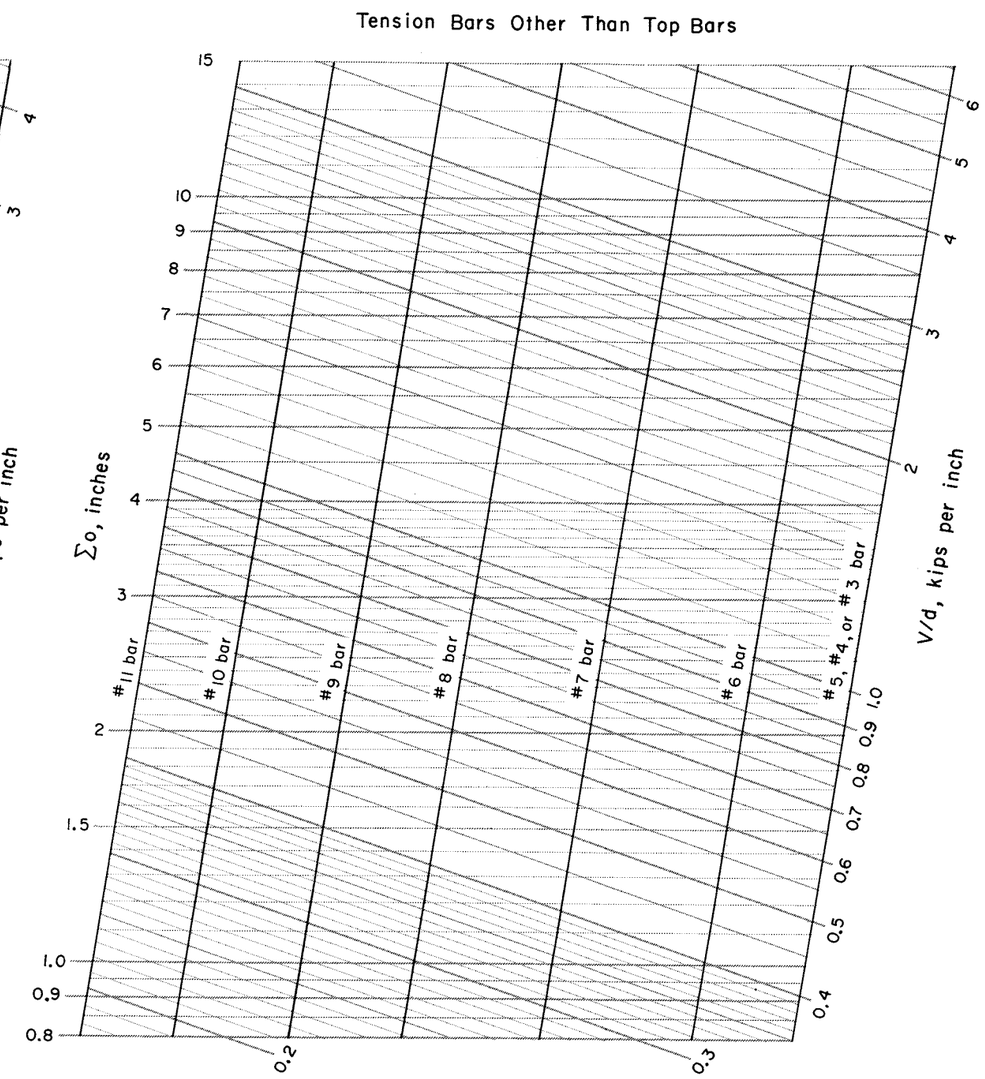
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 166
SHEET 2 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 5000$ psi





$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

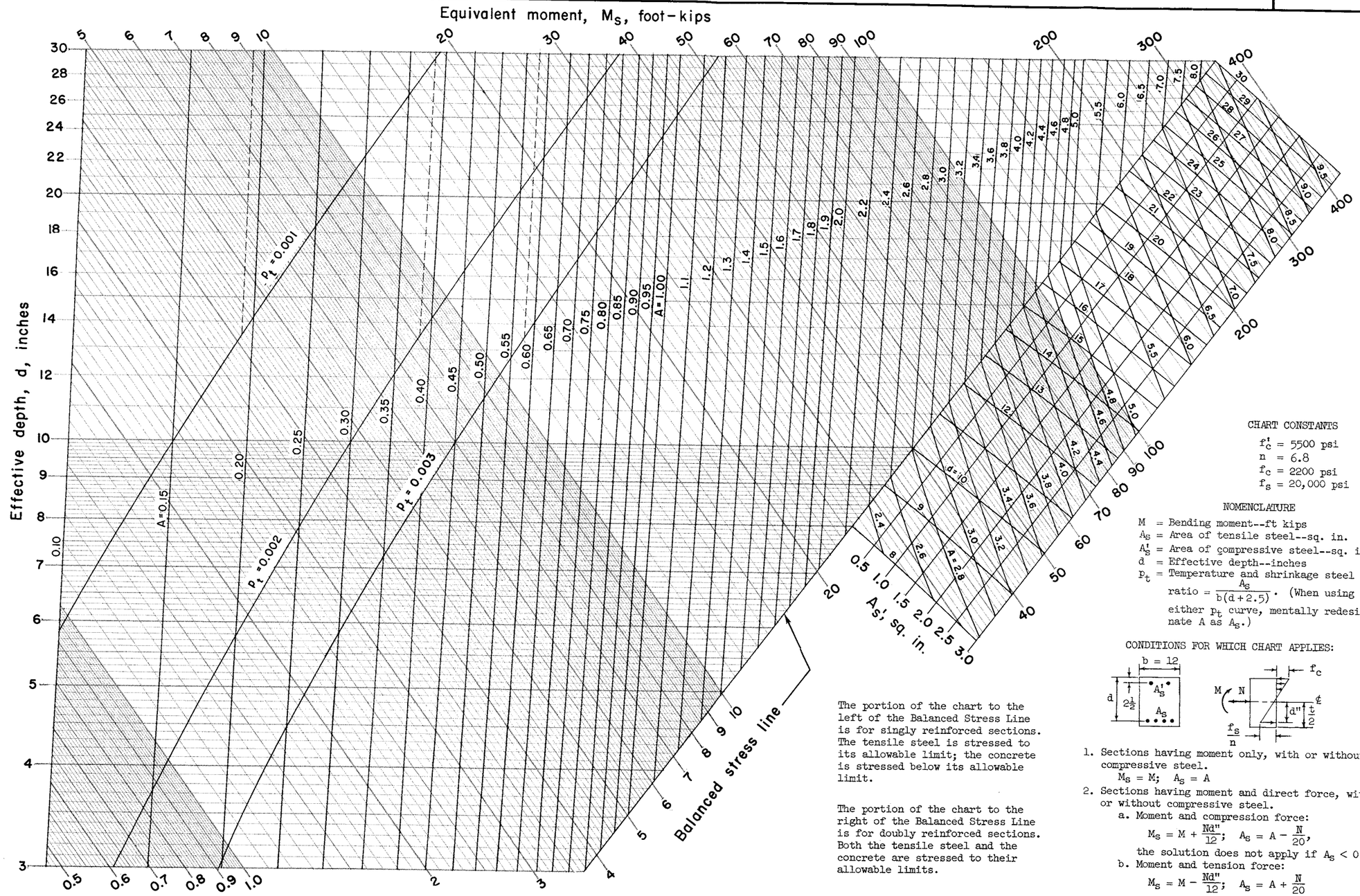
ACI Building Code (ACI 318 - 63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 166
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 5500$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

$f'_c = 5500$ psi
$n = 6.8$
$f_c = 2200$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

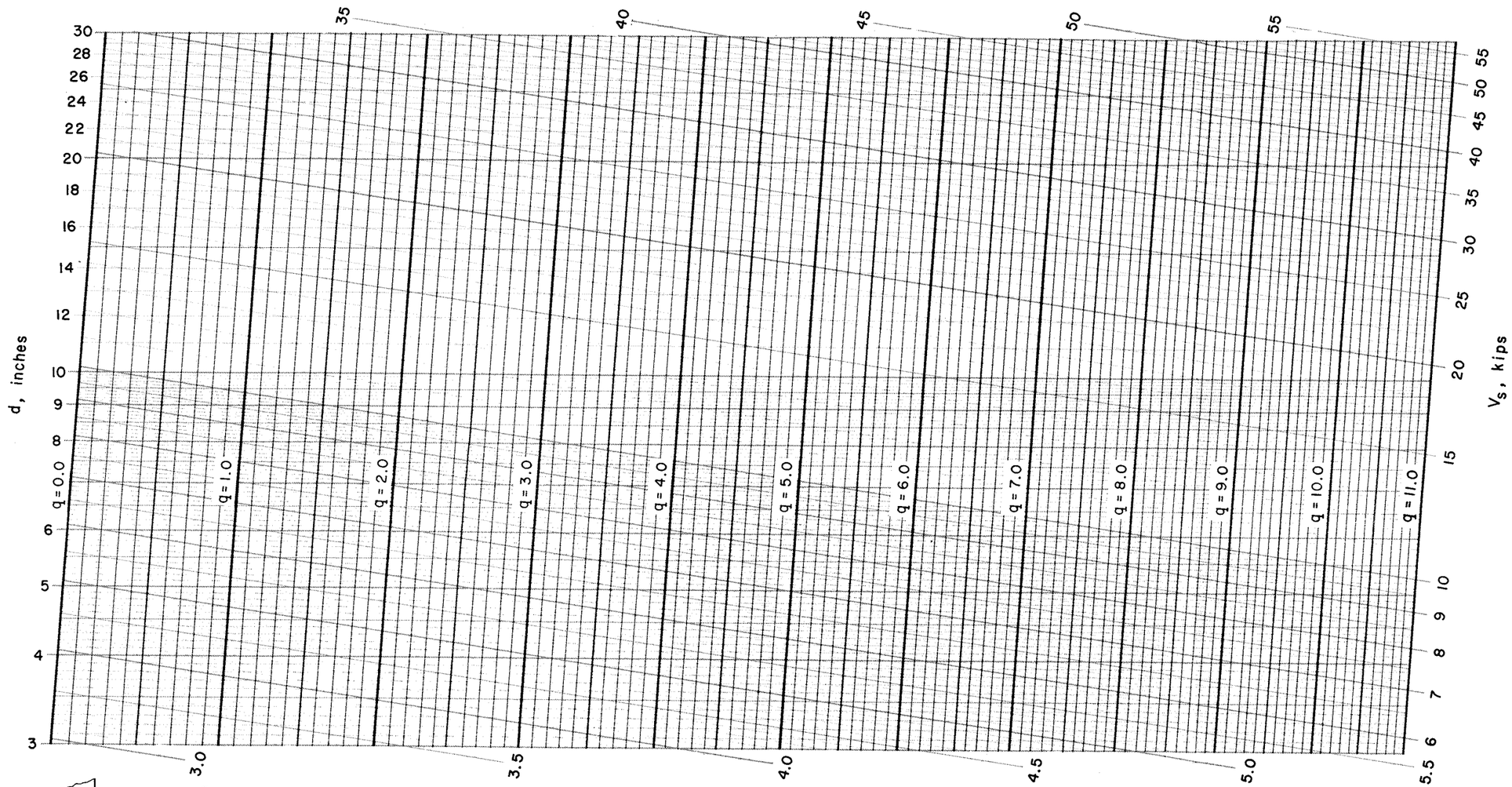
REFERENCE

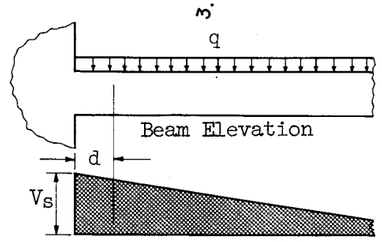
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 167
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 5500$ psi





Allowable Shear Diagram

$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

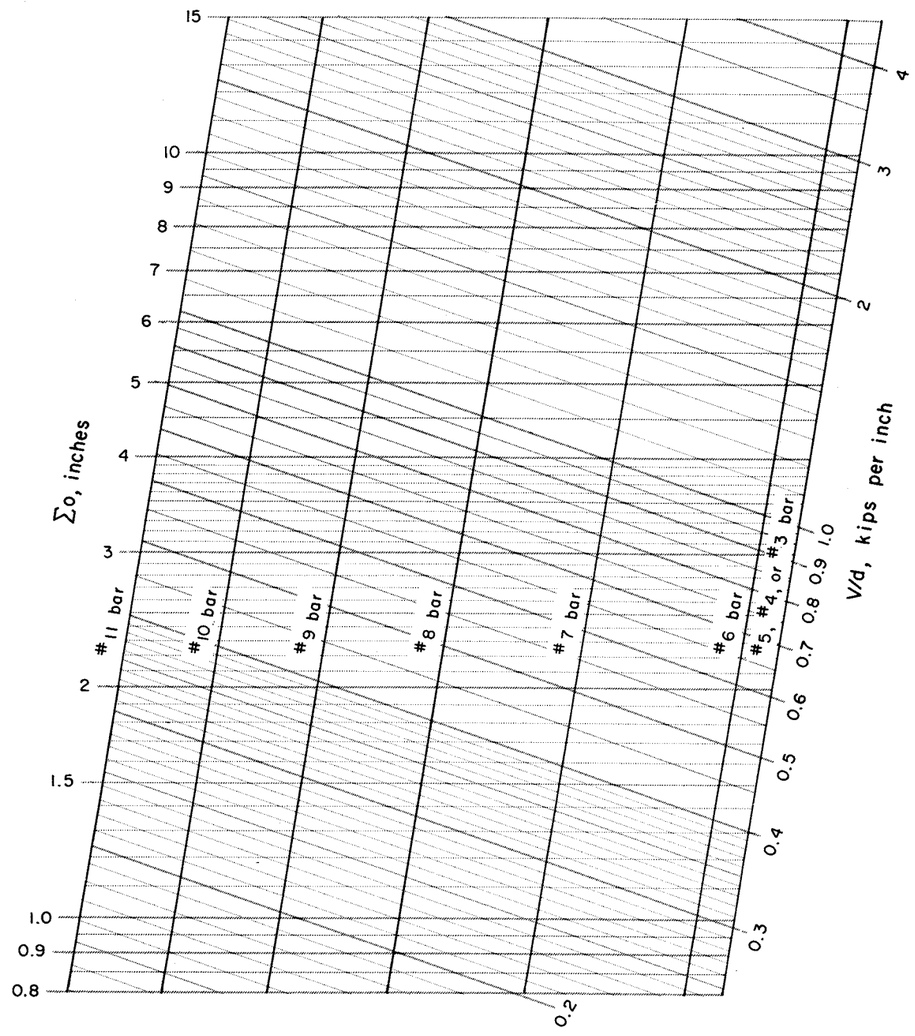
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 167
SHEET 2 OF 3
DATE 7-64

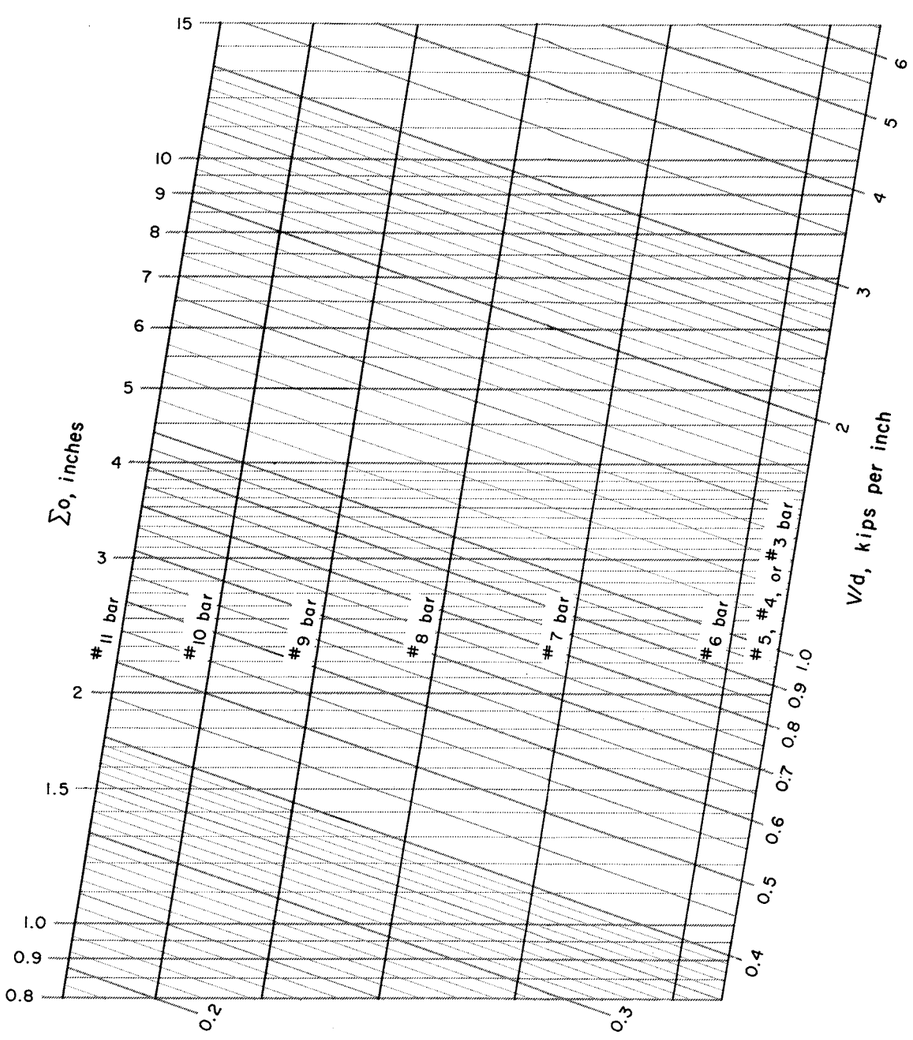
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 5500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-167
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 6000$ psi

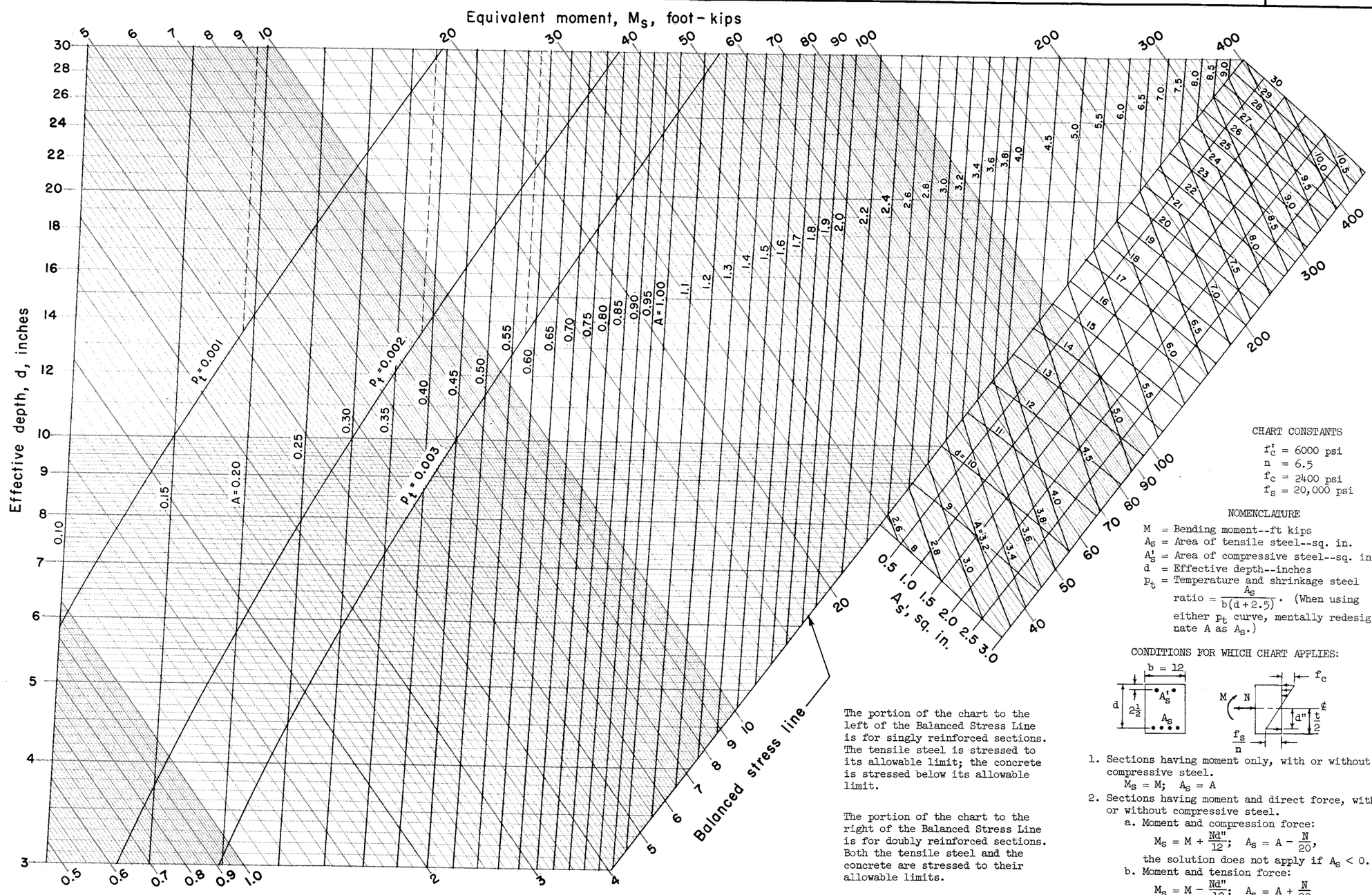


CHART CONSTANTS

f'_c = 6000 psi
n = 6.5
f_c = 2400 psi
f_s = 20,000 psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio = $\frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

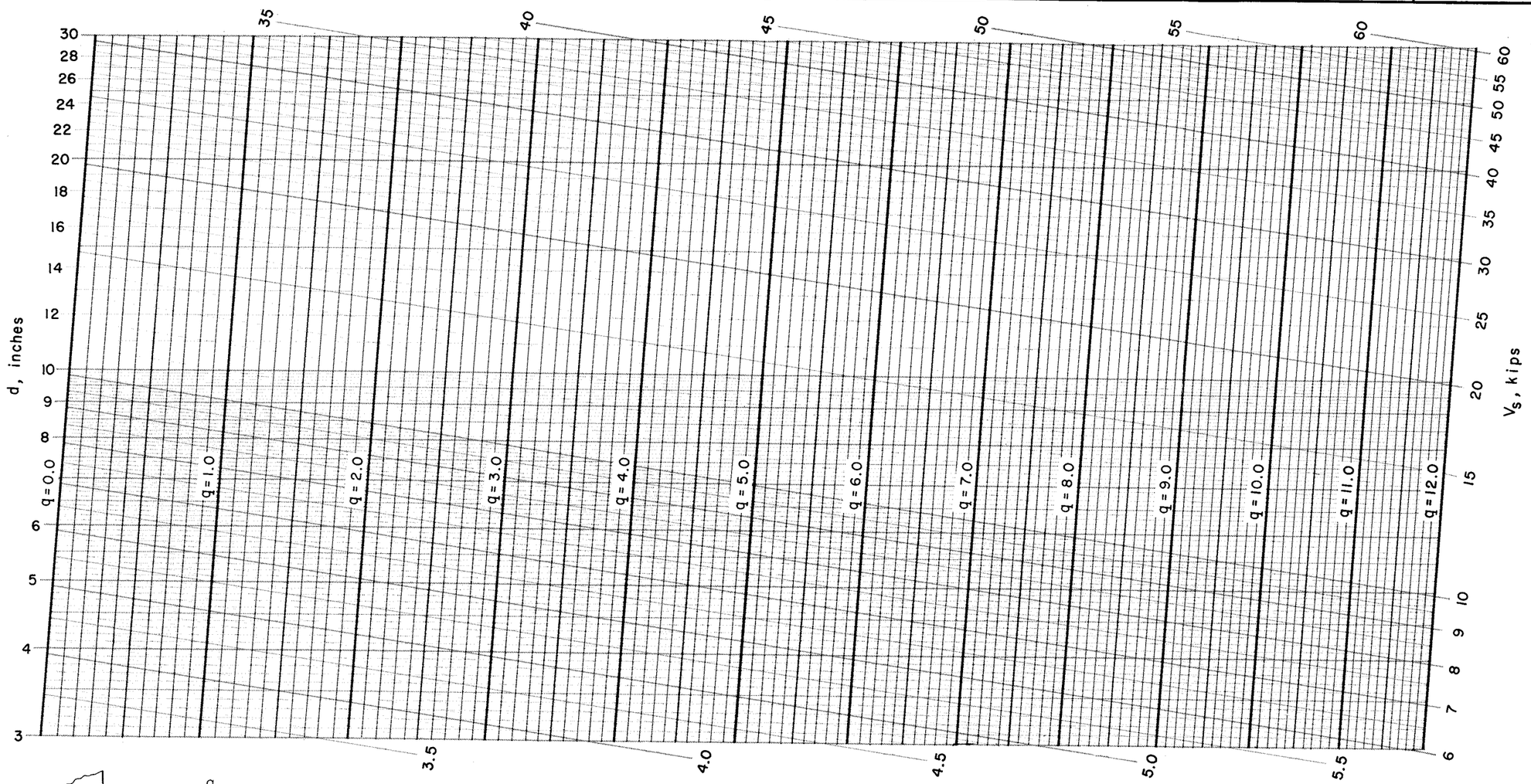
REFERENCE

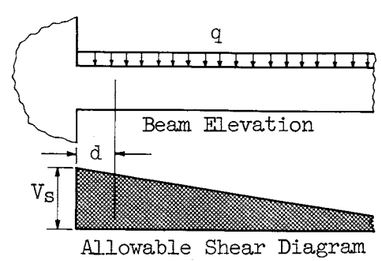
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO. ES- 168
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 6000$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

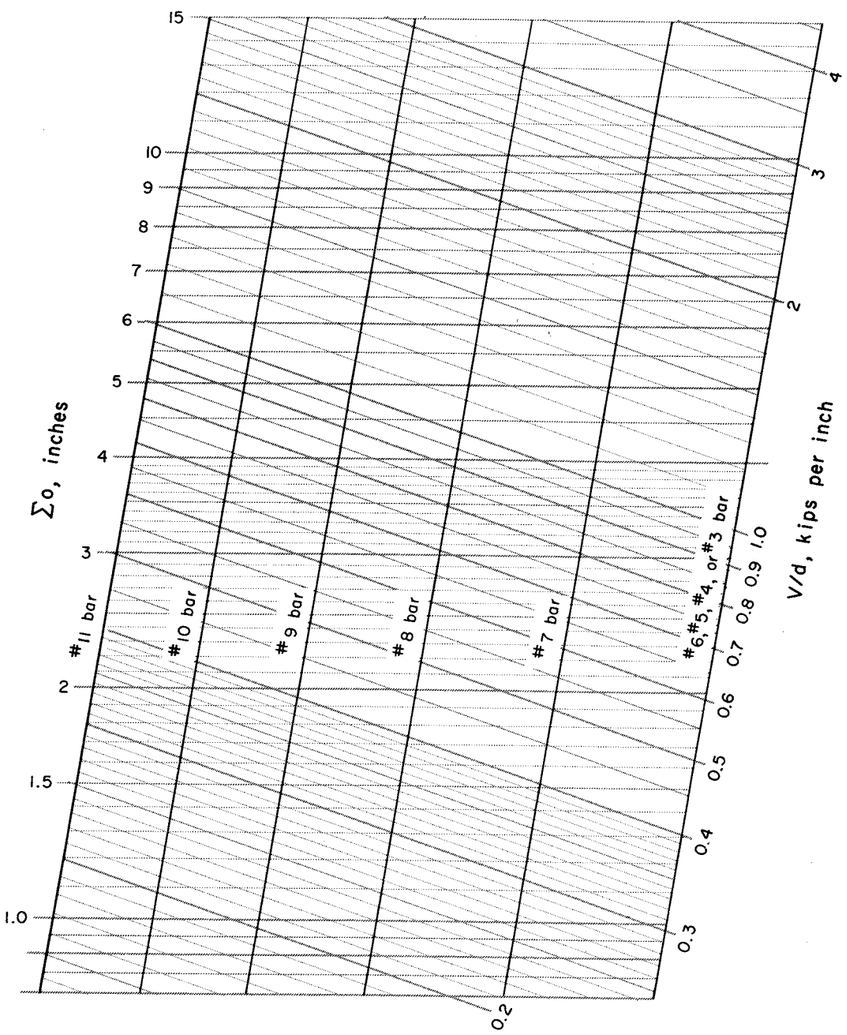
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 168
SHEET 2 OF 3
DATE 7-64

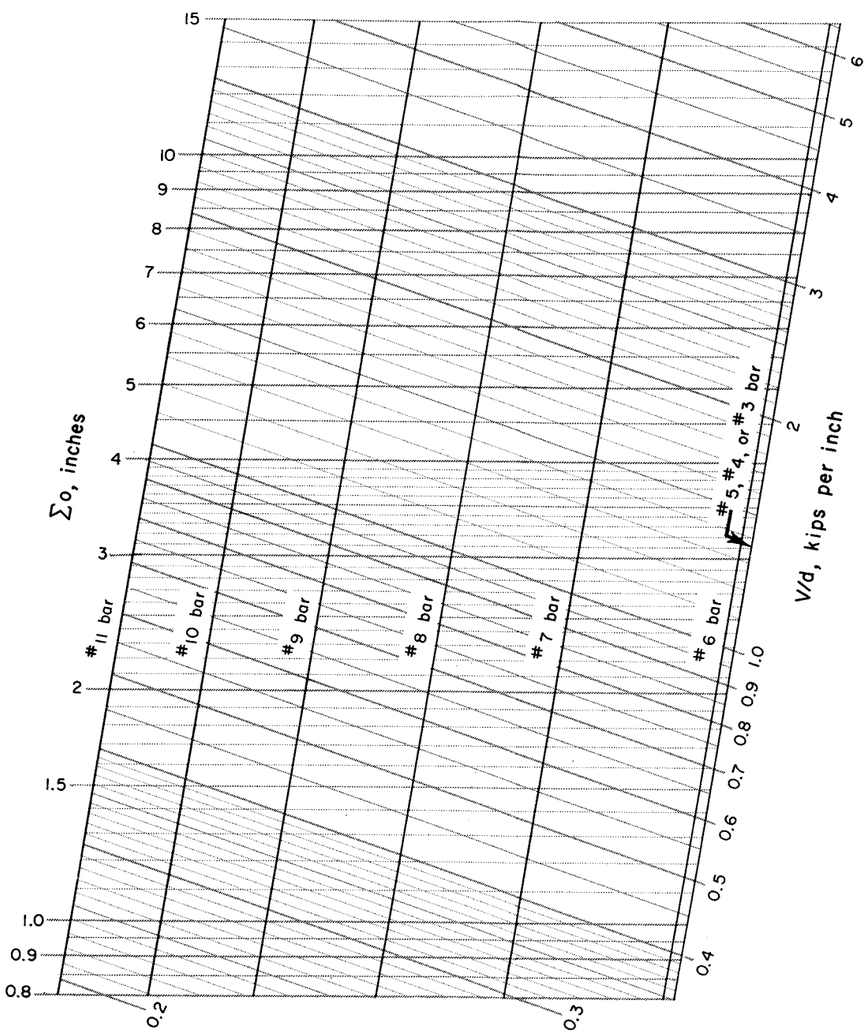
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 6000$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

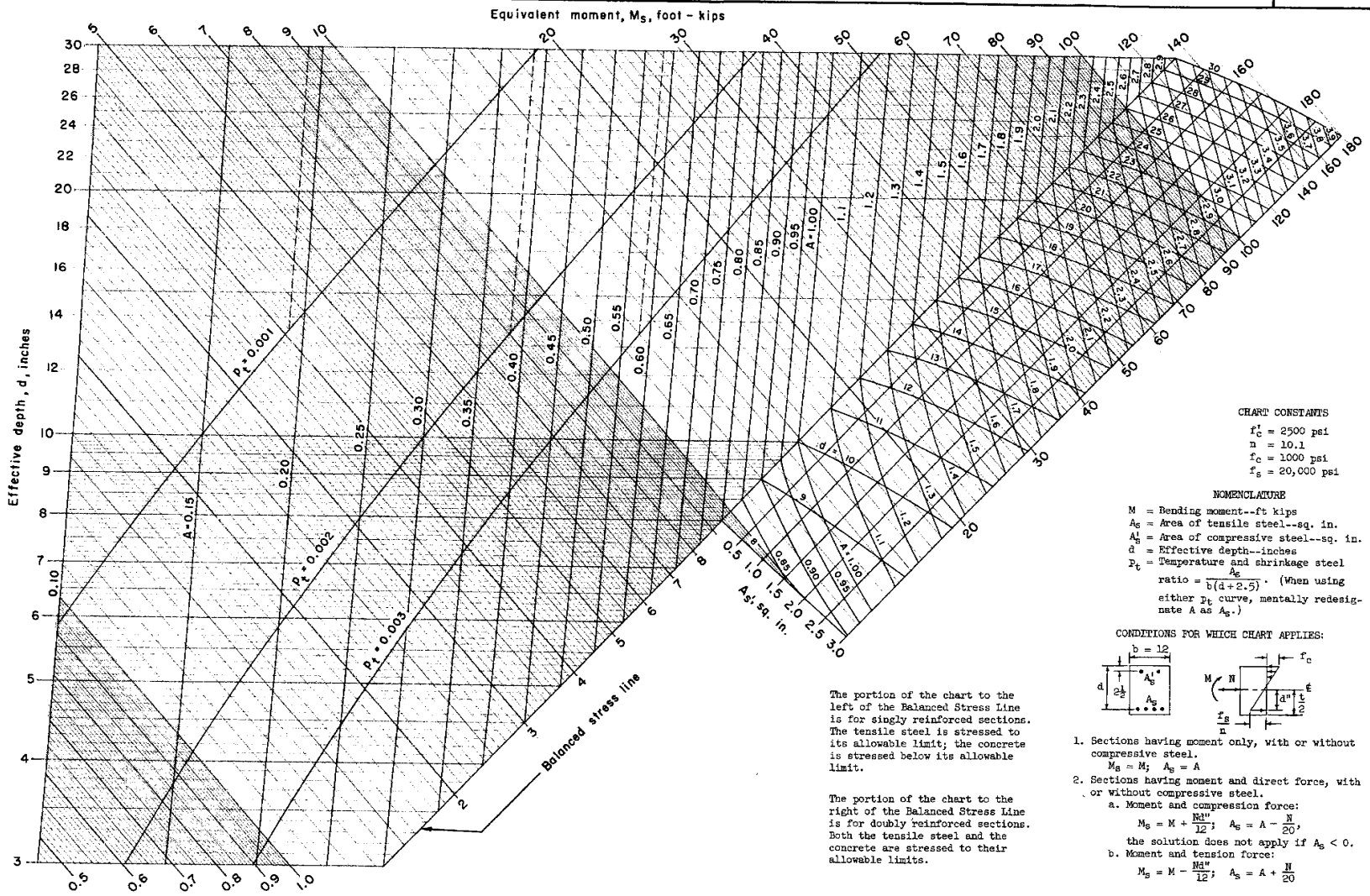
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 168
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 2500$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

$f'_c = 2500$ psi
$n = 10.1$
$f_c = 1000$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

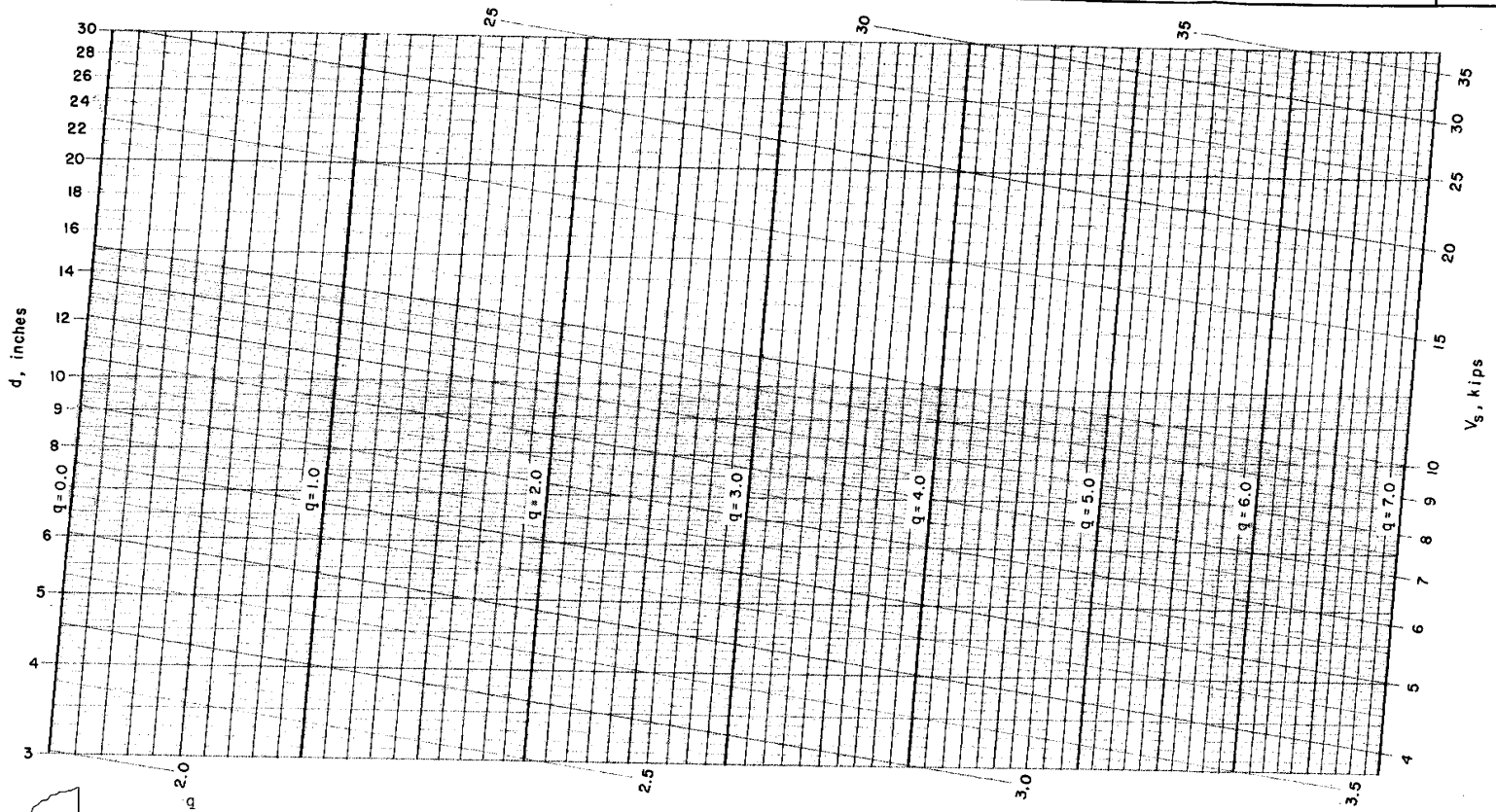
REFERENCE

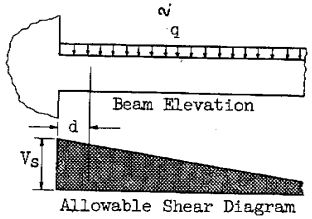
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION · DESIGN SECTION

STANDARD DWG. NO. ES- 161
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 2500$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1. + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

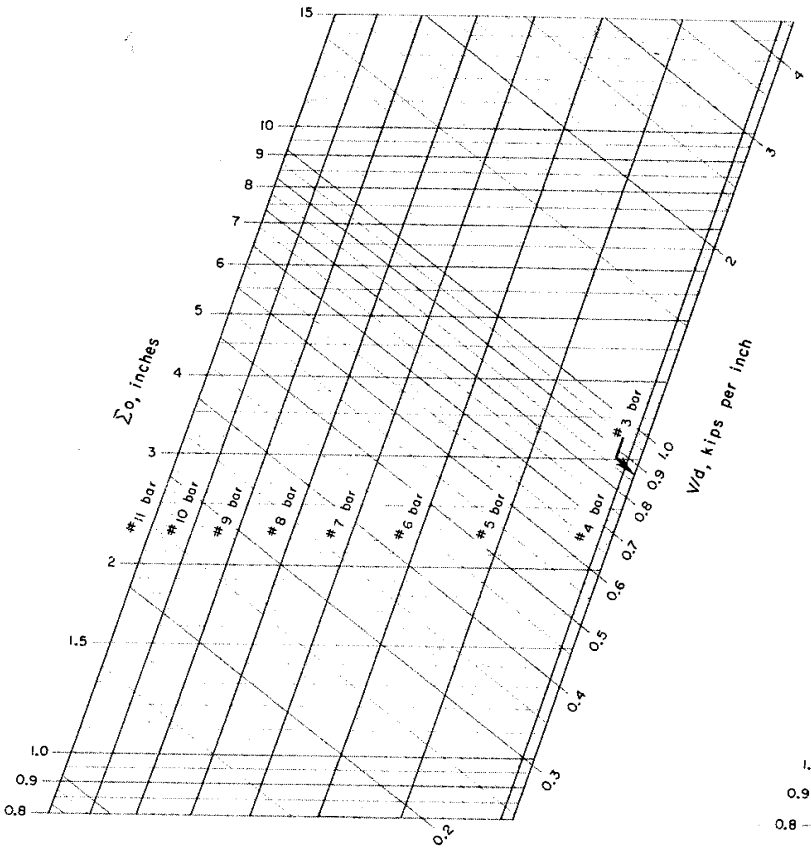
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO. ES-161
SHEET 2 OF 3
DATE 7-64

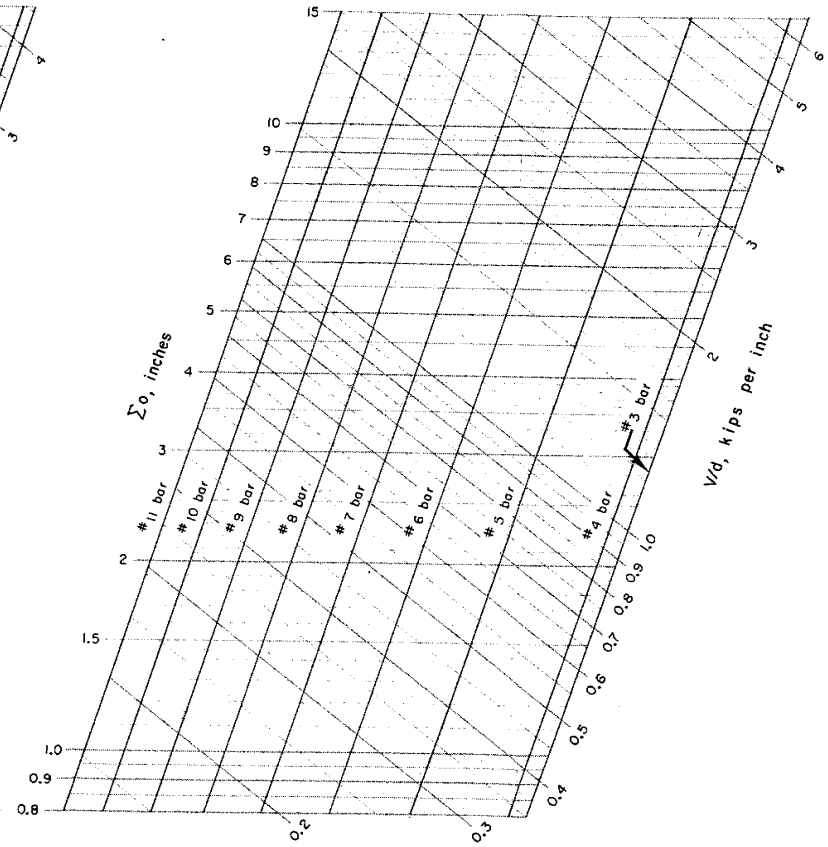
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 2500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

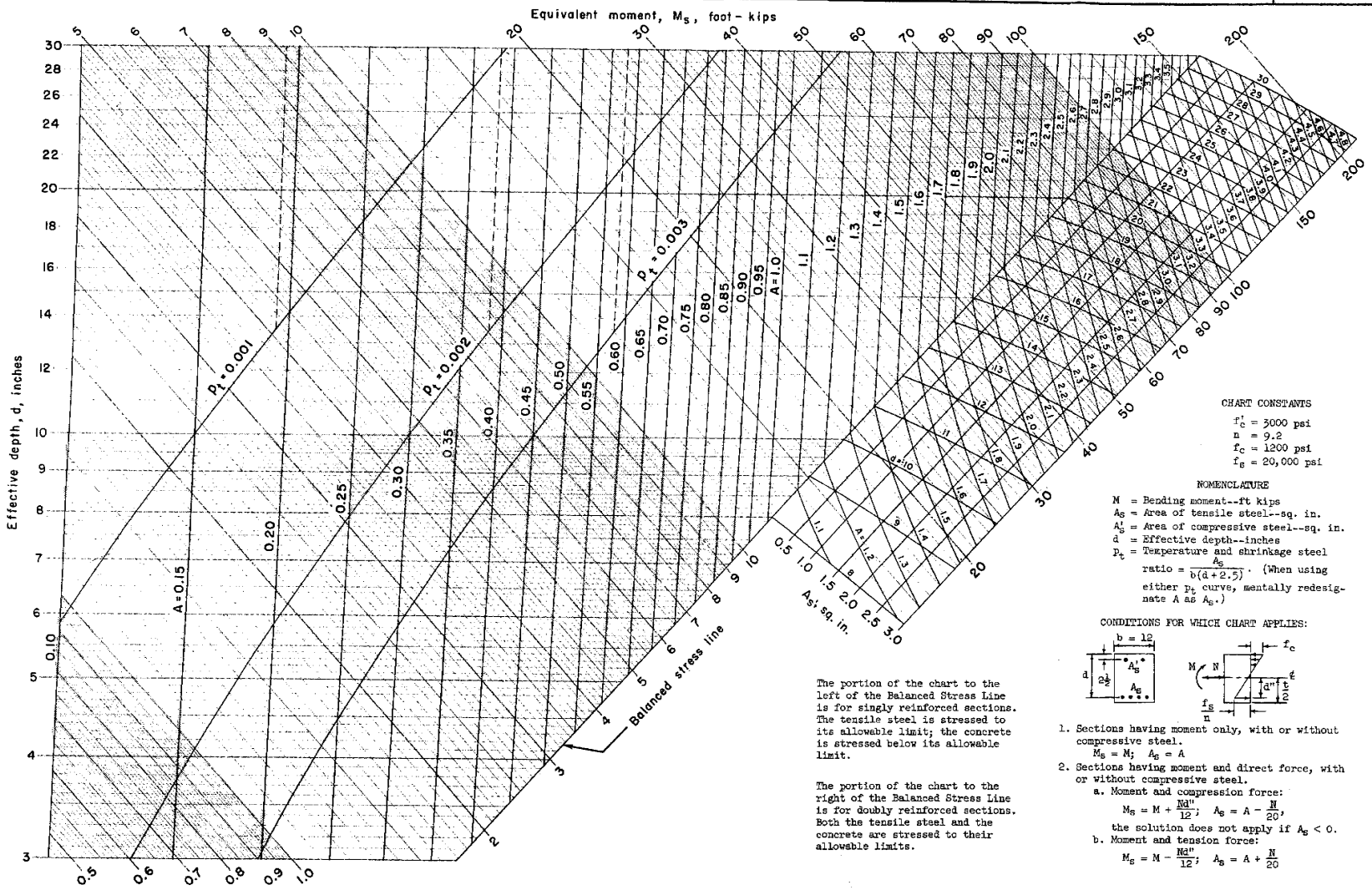
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-161
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 3000$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

$f'_c = 3000$ psi
$n = 9.2$
$f_c = 1200$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

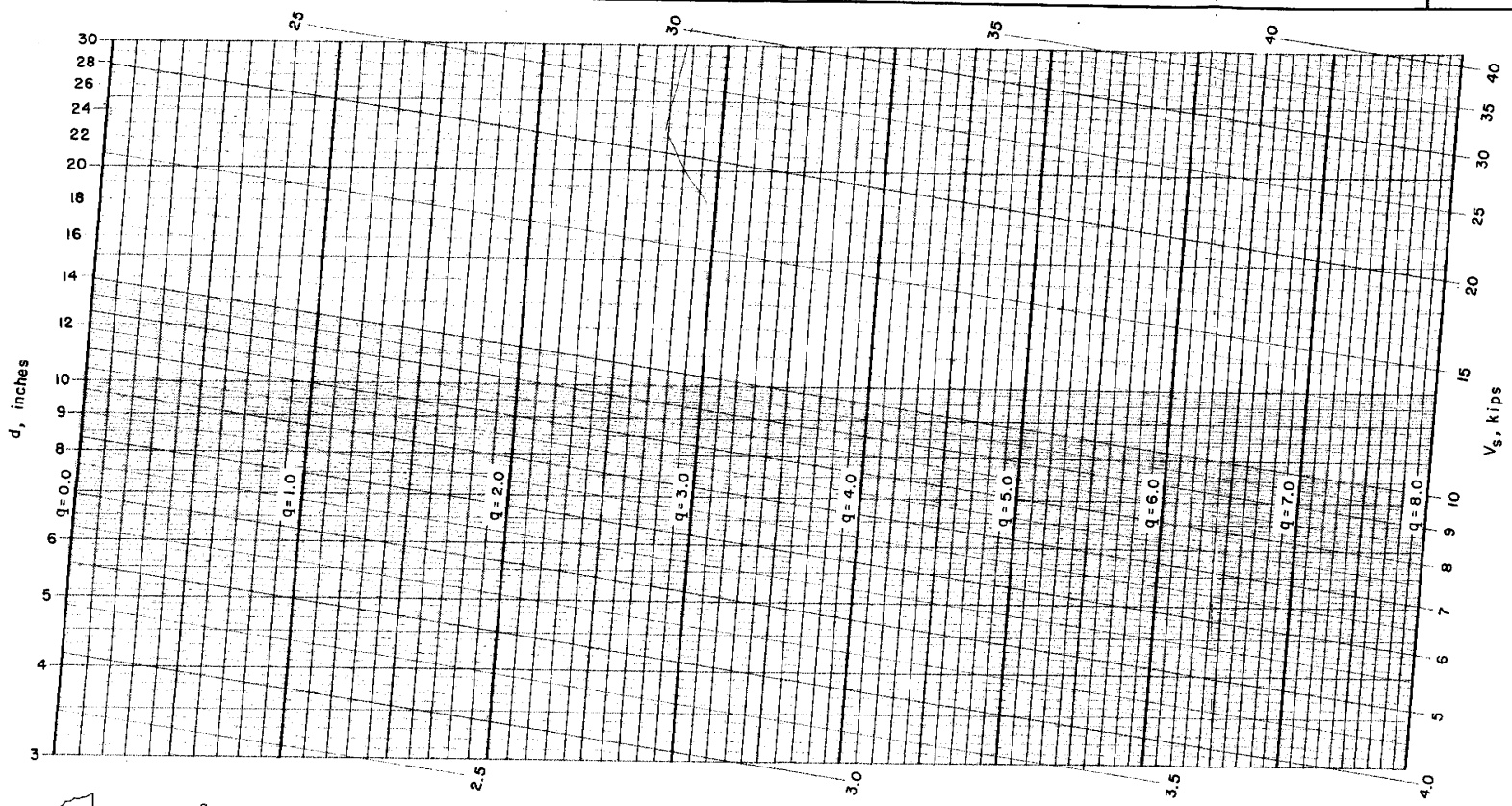
REFERENCE

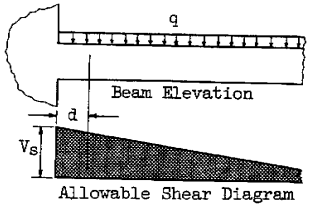
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 162
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 3000$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

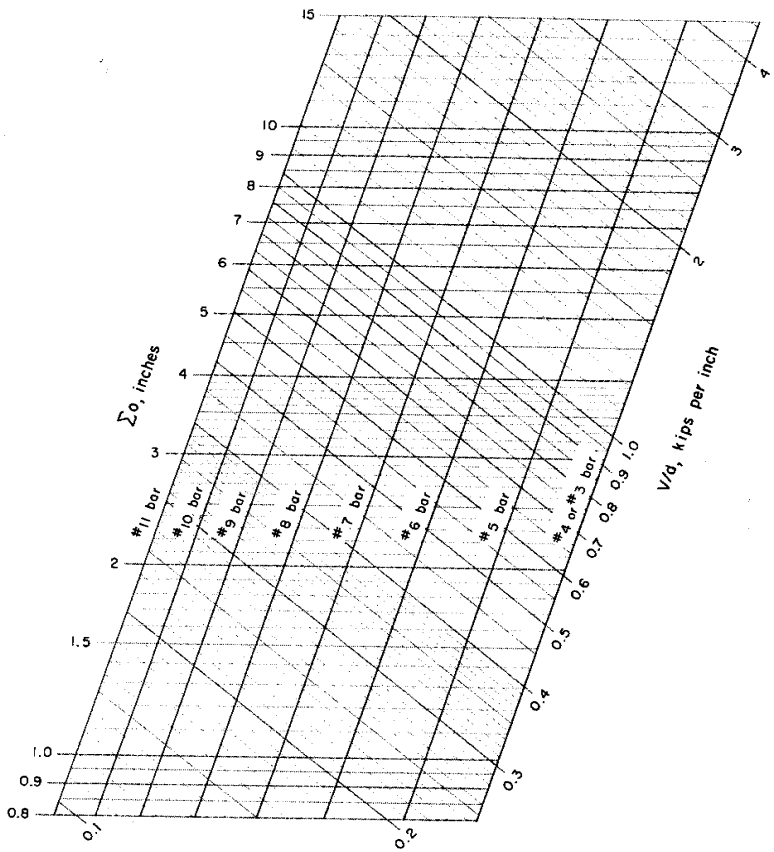
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 162
SHEET 2 OF 3
DATE 7-64

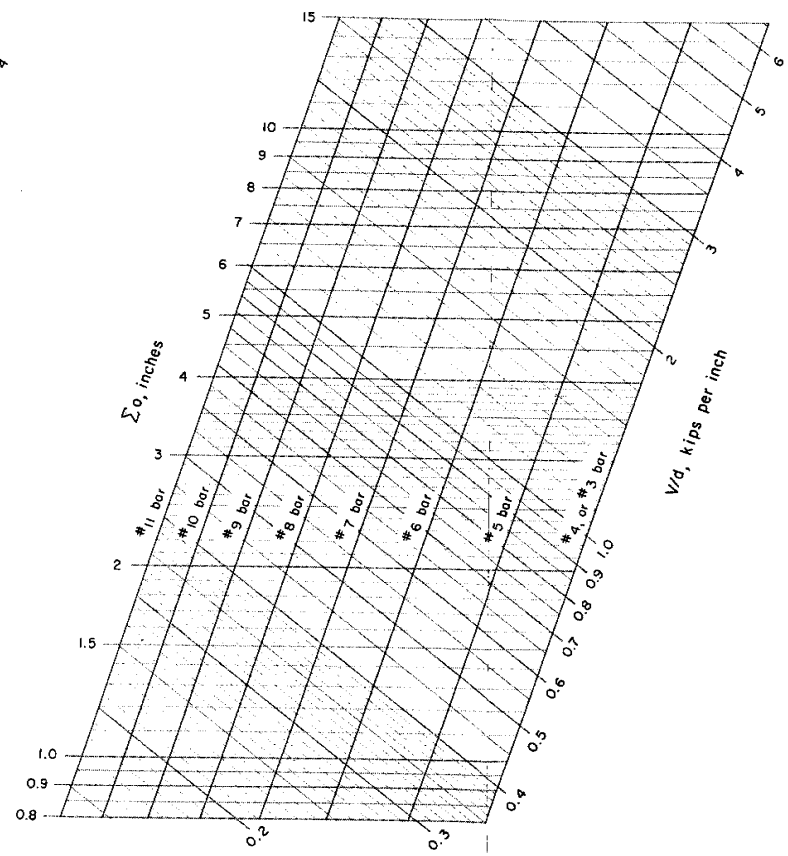
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 3000$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

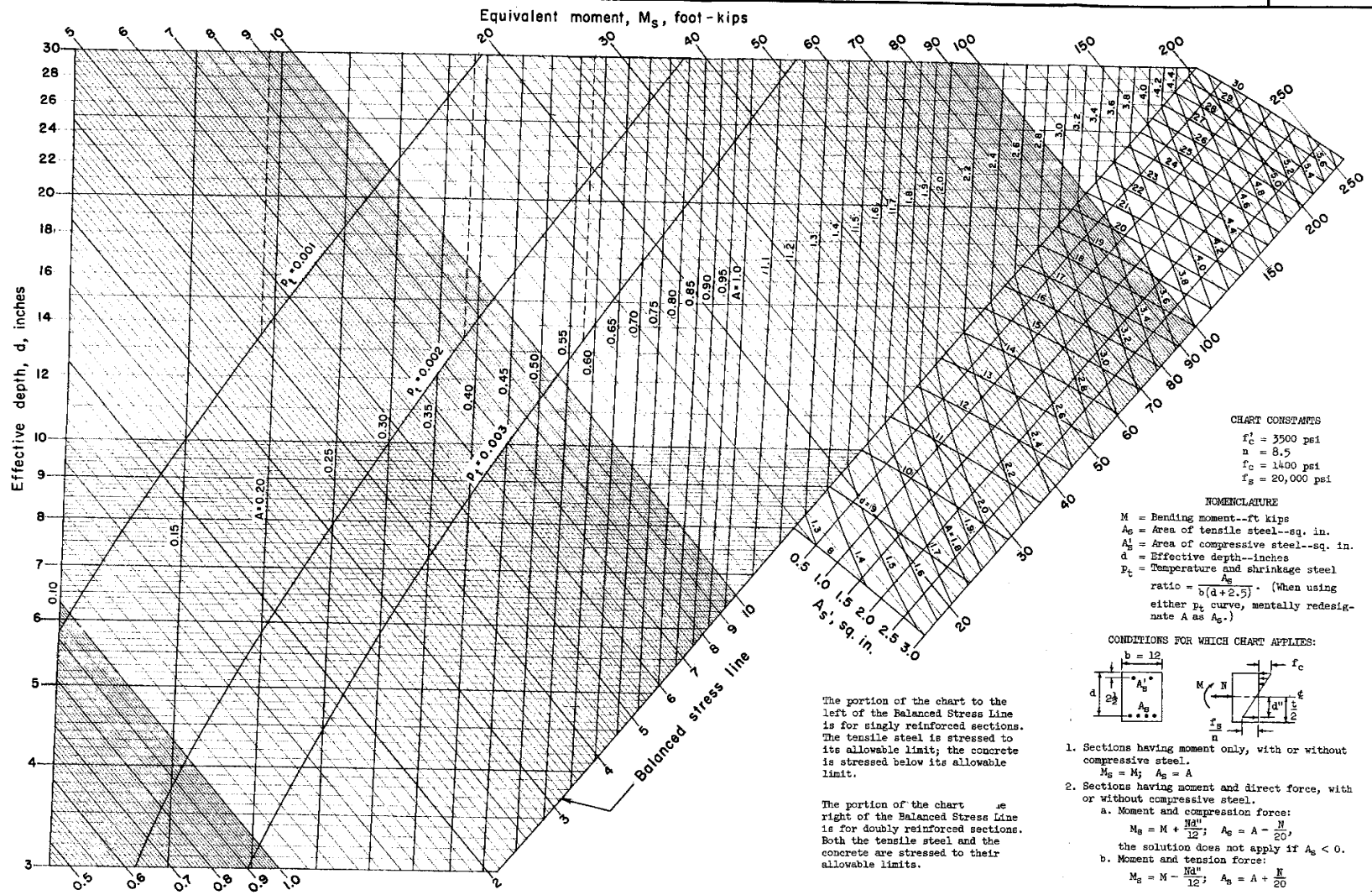
ACI Building Code (ACI 318 - 63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-162
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 3500$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart [illegible]e right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

$f'_c = 3500$ psi
$n = 8.5$
$f_c = 1400$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio = $\frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

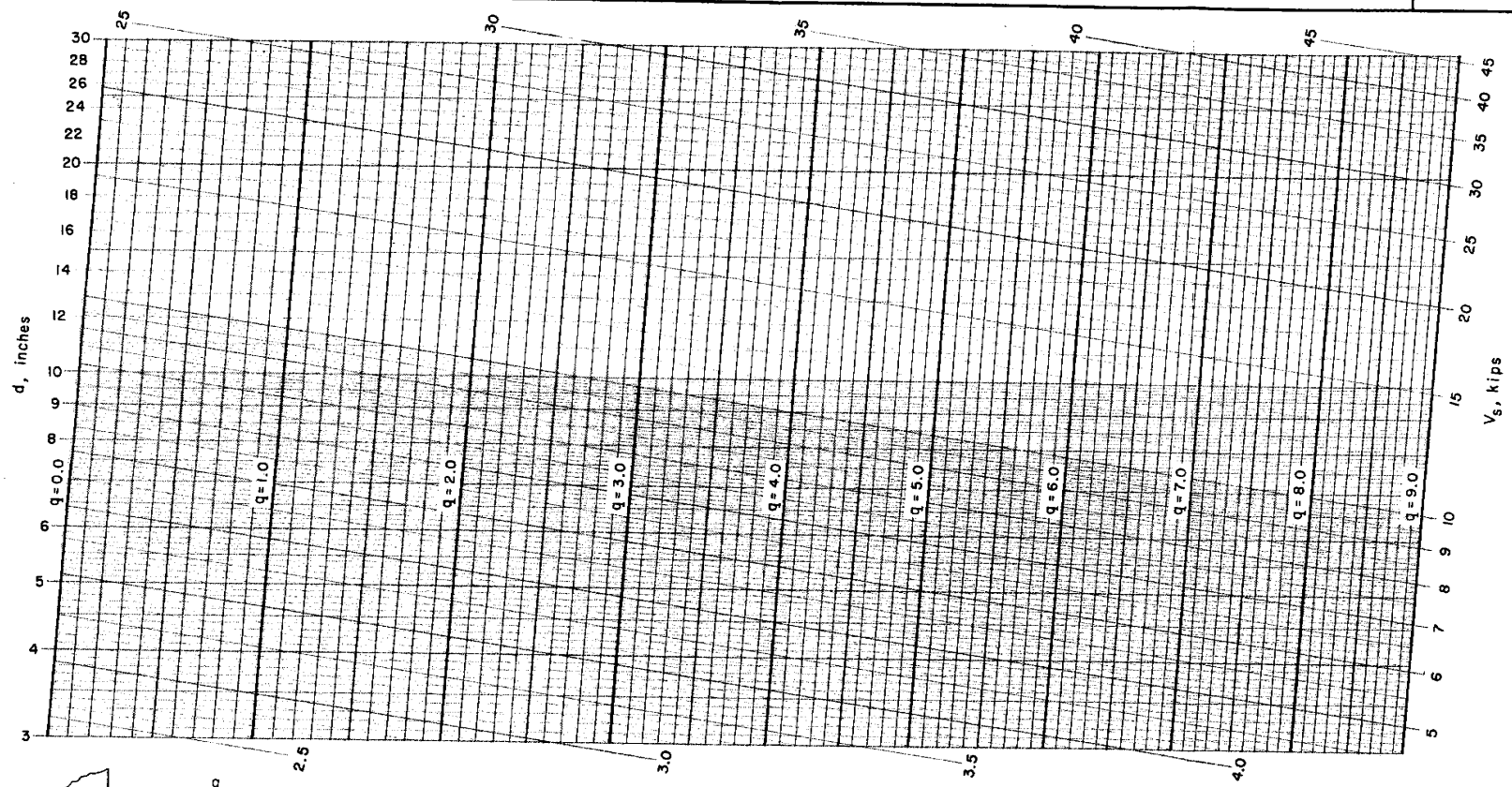
REFERENCE

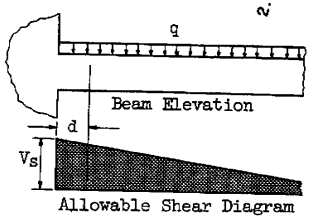
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION, DESIGN SECTION

STANDARD DWG. NO. ES- 163
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED
BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 3500$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

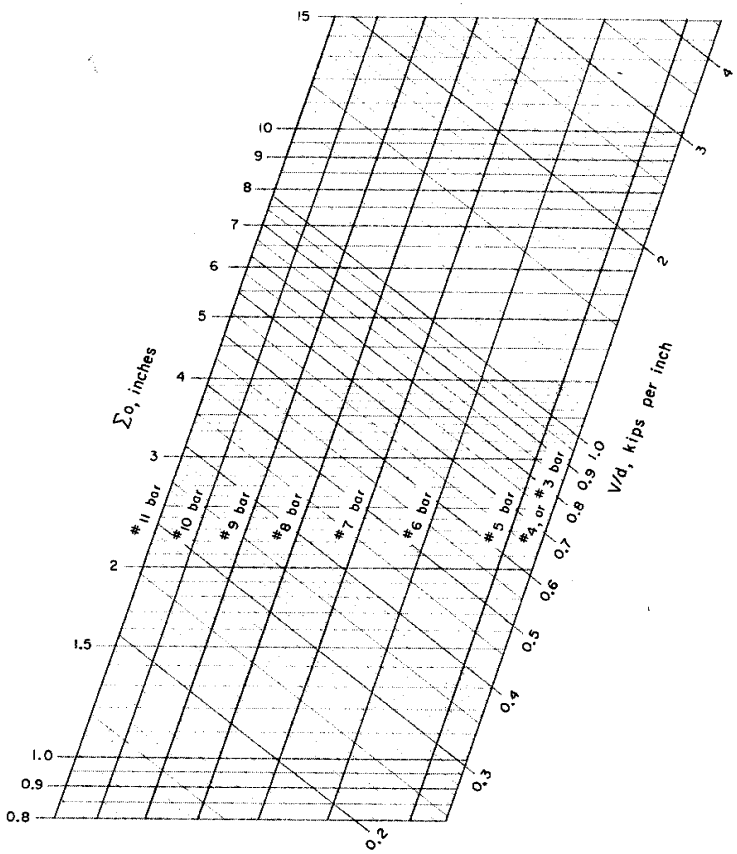
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 163
SHEET 2 OF 3
DATE 7-64

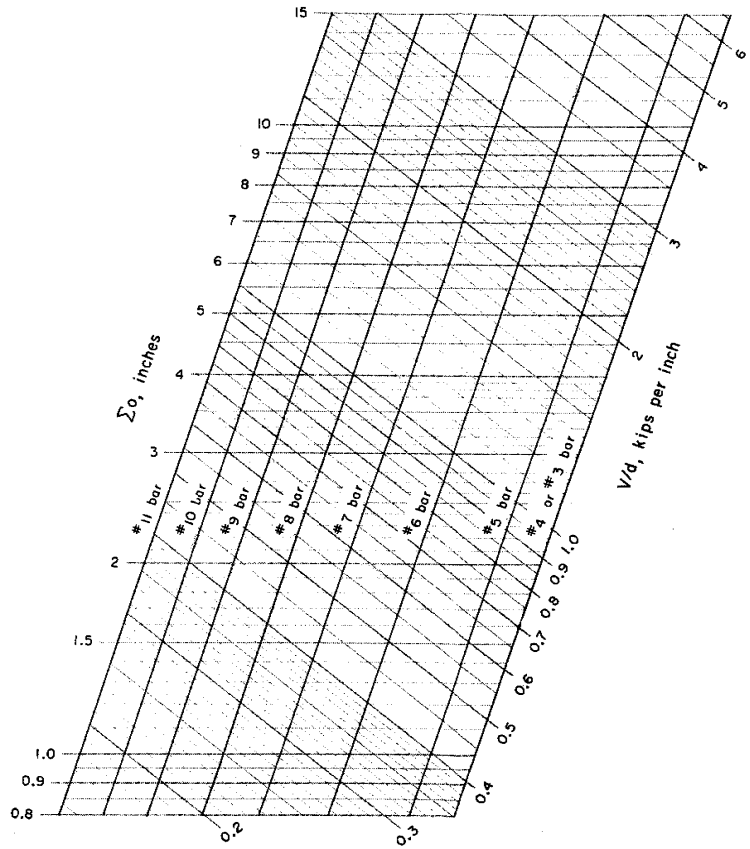
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 3500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

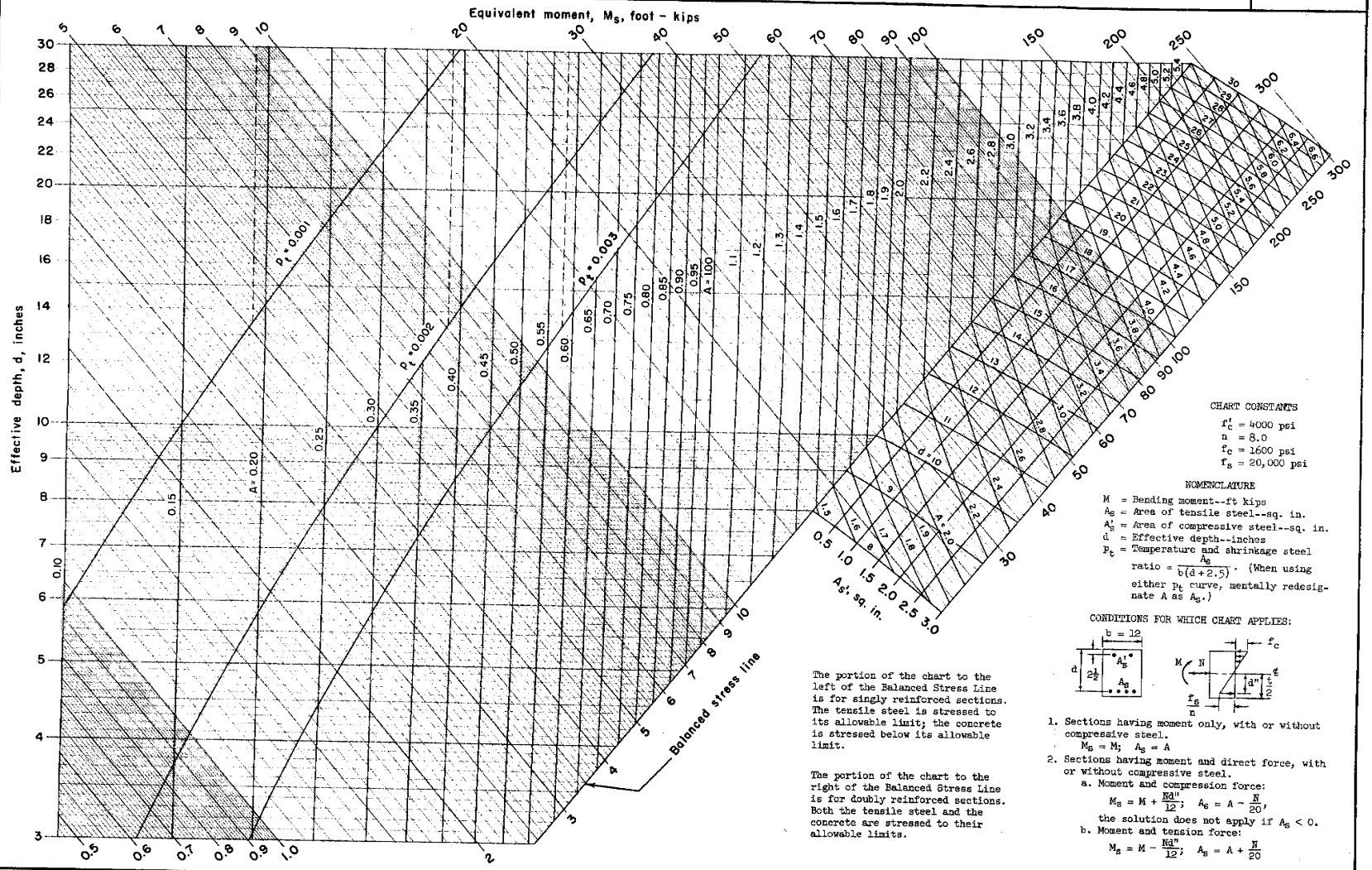
REFERENCE
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-163
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

f'_c = 4000 psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

f'_c = 4000 psi
n = 8.0
f_c = 1600 psi
f_s = 20,000 psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio = $\frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

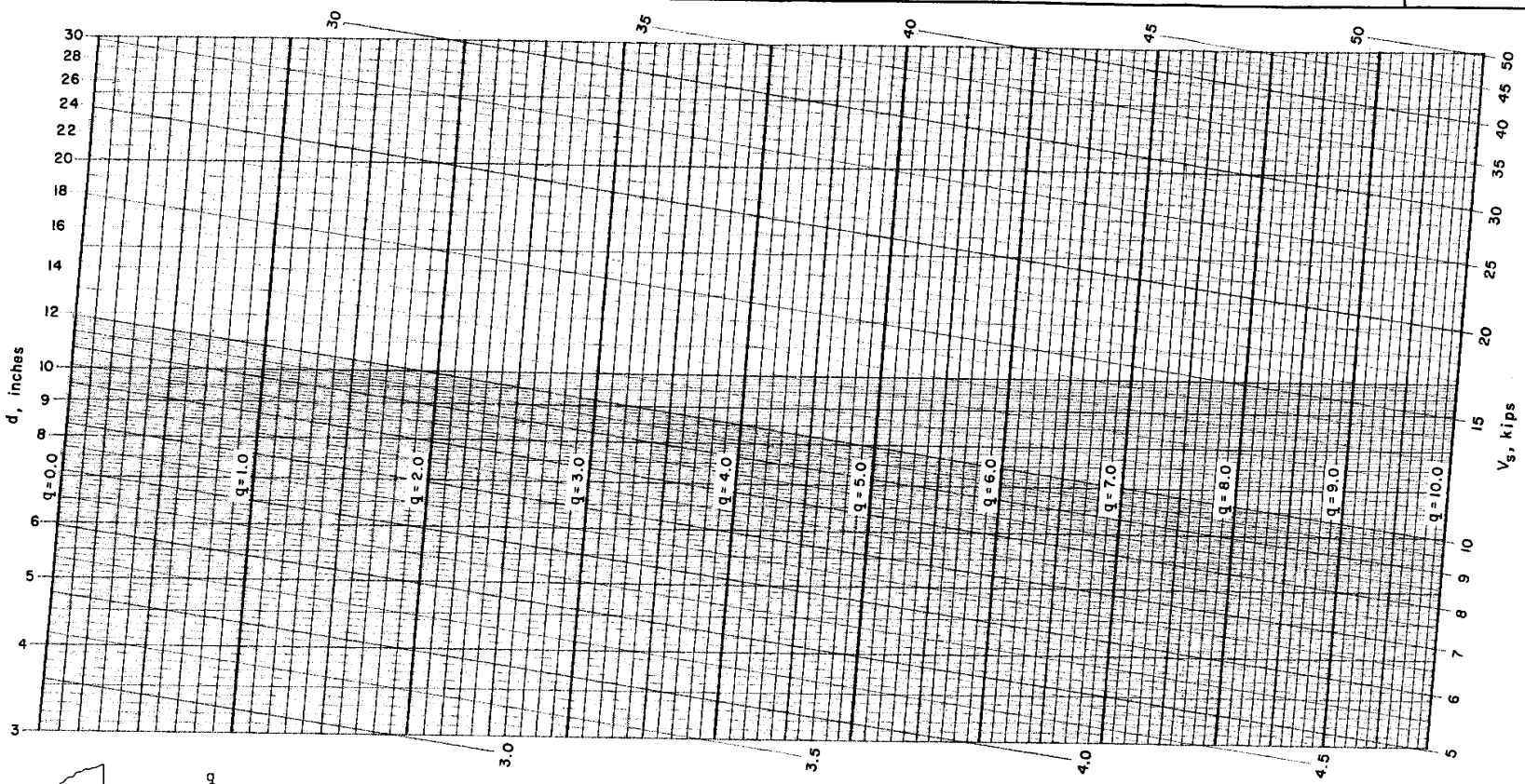
REFERENCE

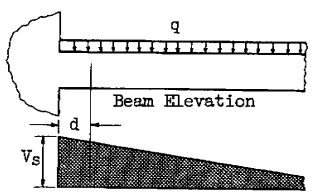
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO. ES- 164
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED
BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 4000$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

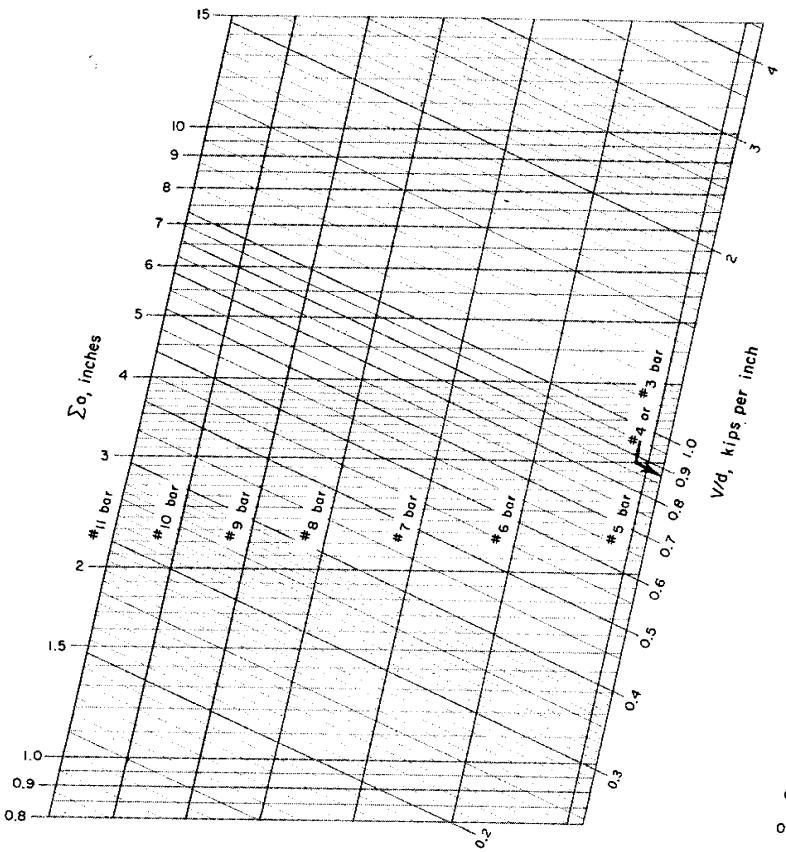
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 164
SHEET 2 OF 3
DATE 7-64

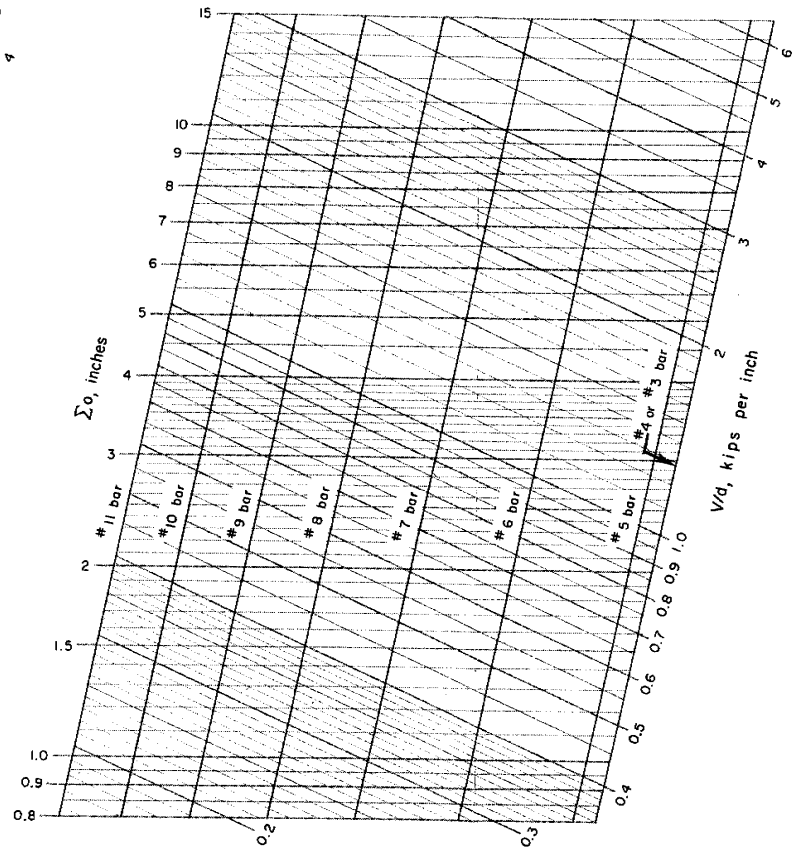
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 4000$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

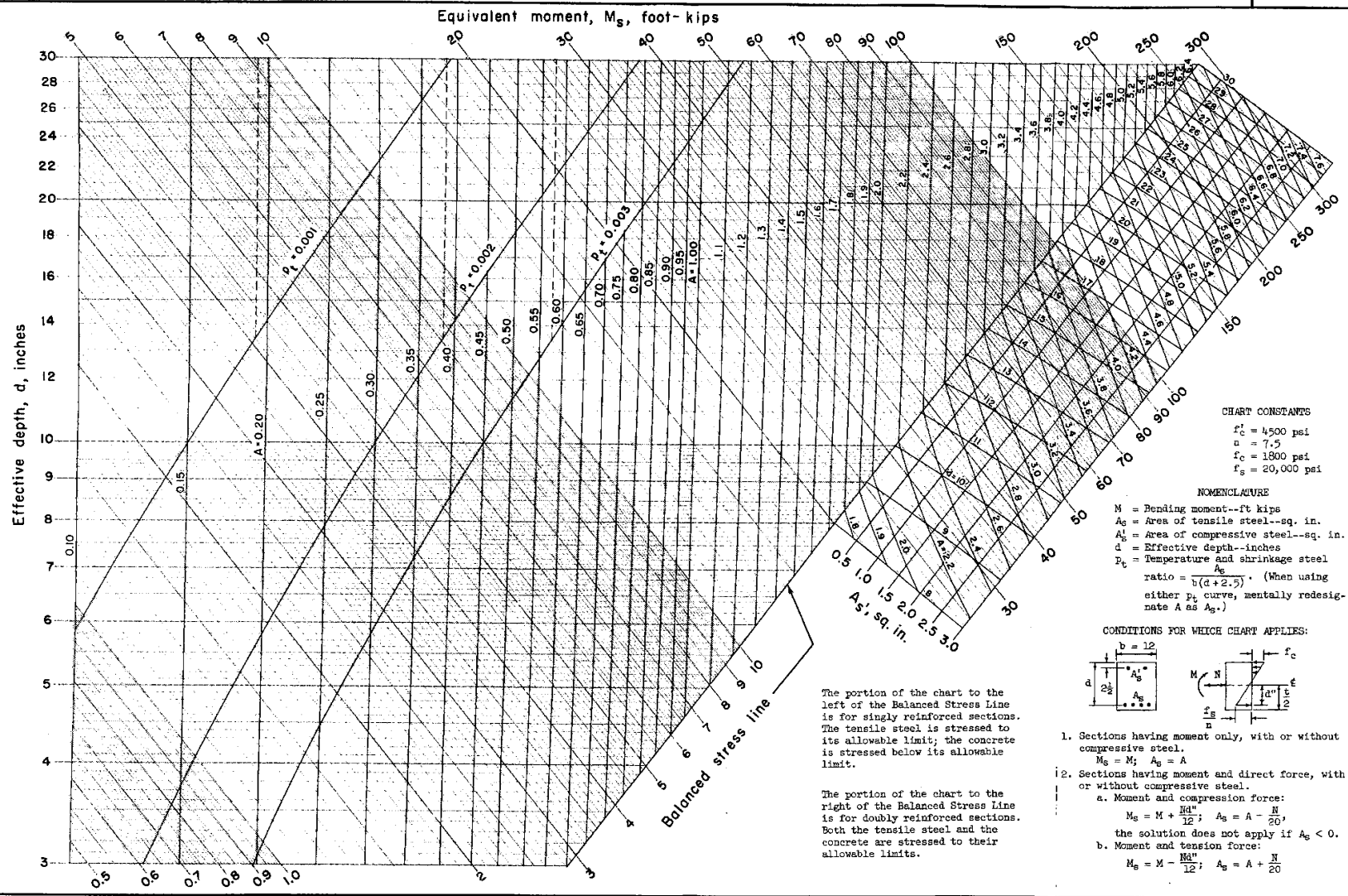
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-164
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

f'_c = 4500 psi



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The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

f'_c = 4500 psi
n = 7.5
f_c = 1800 psi
f_s = 20,000 psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio = $\frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

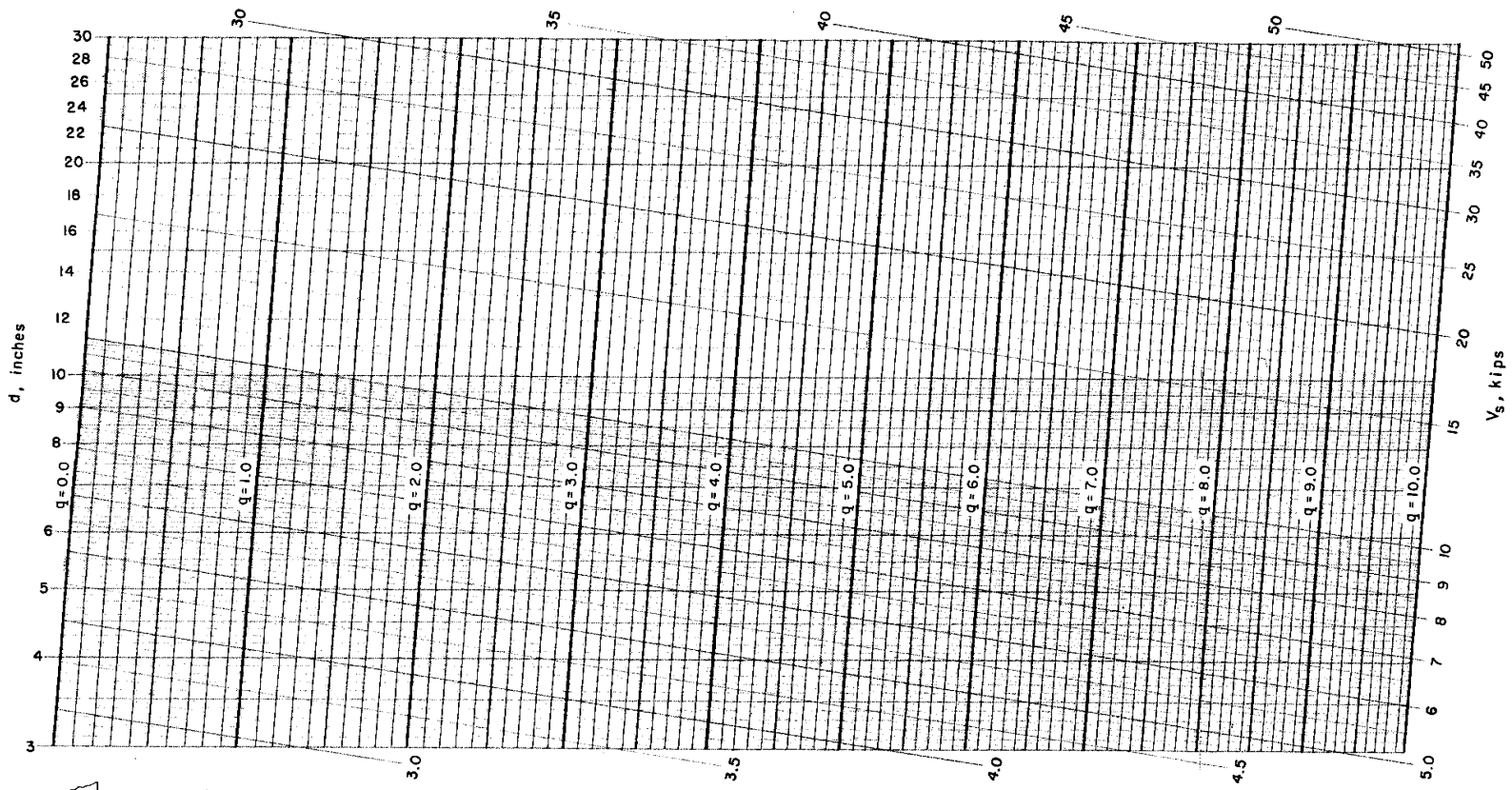
REFERENCE

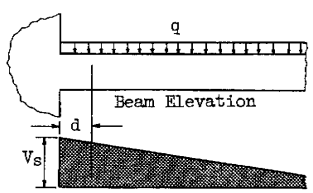
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION · DESIGN SECTION

STANDARD DWG. NO. ES- 165
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED
BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 4500$ psi





Allowable Shear Diagram

$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$. psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

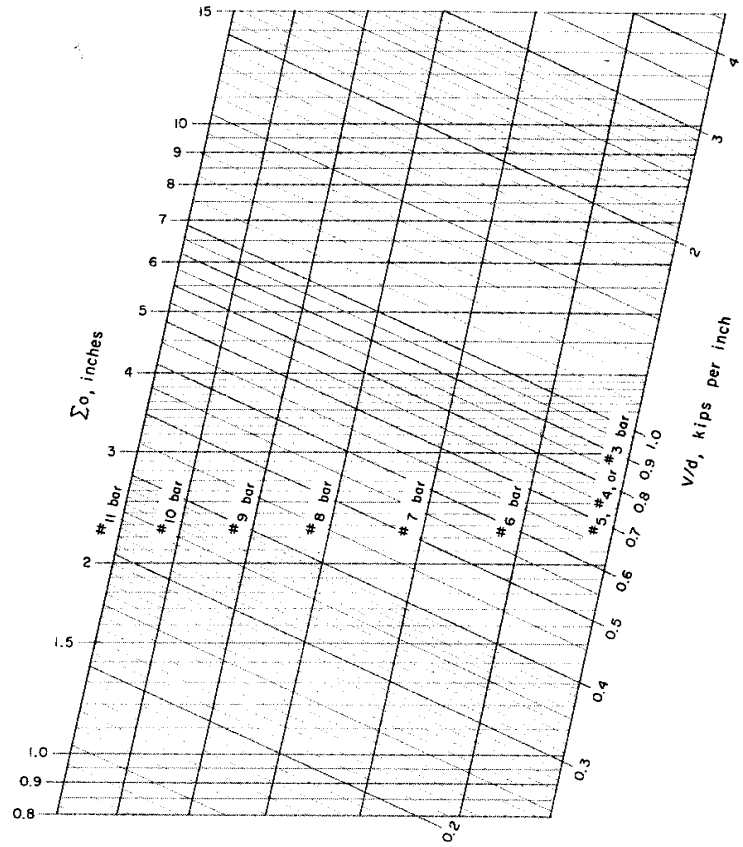
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 165
SHEET 2 OF 3
DATE 7-64

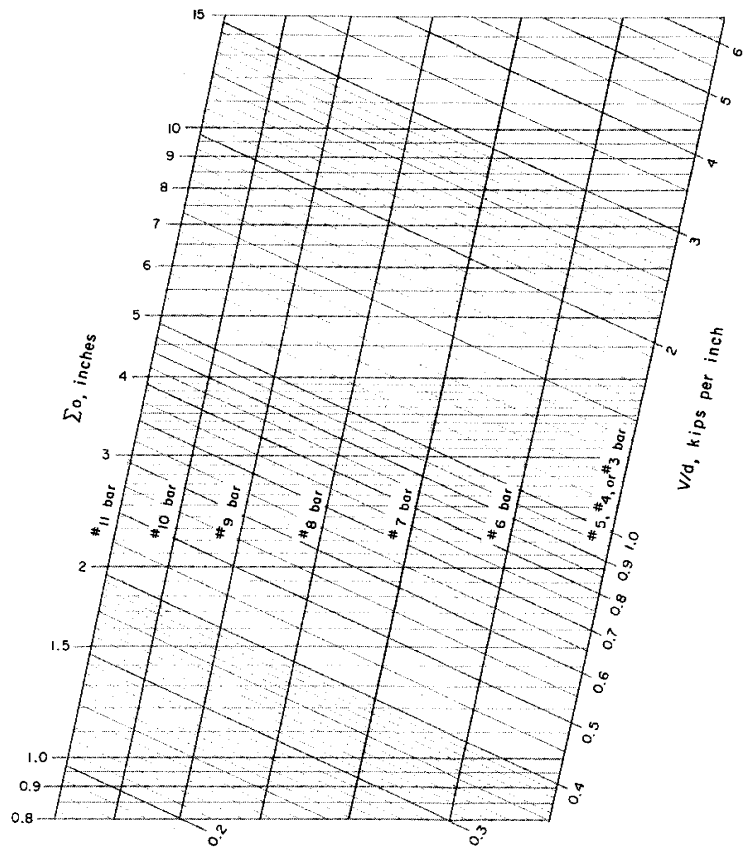
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 4500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi

For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$

For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

REFERENCE

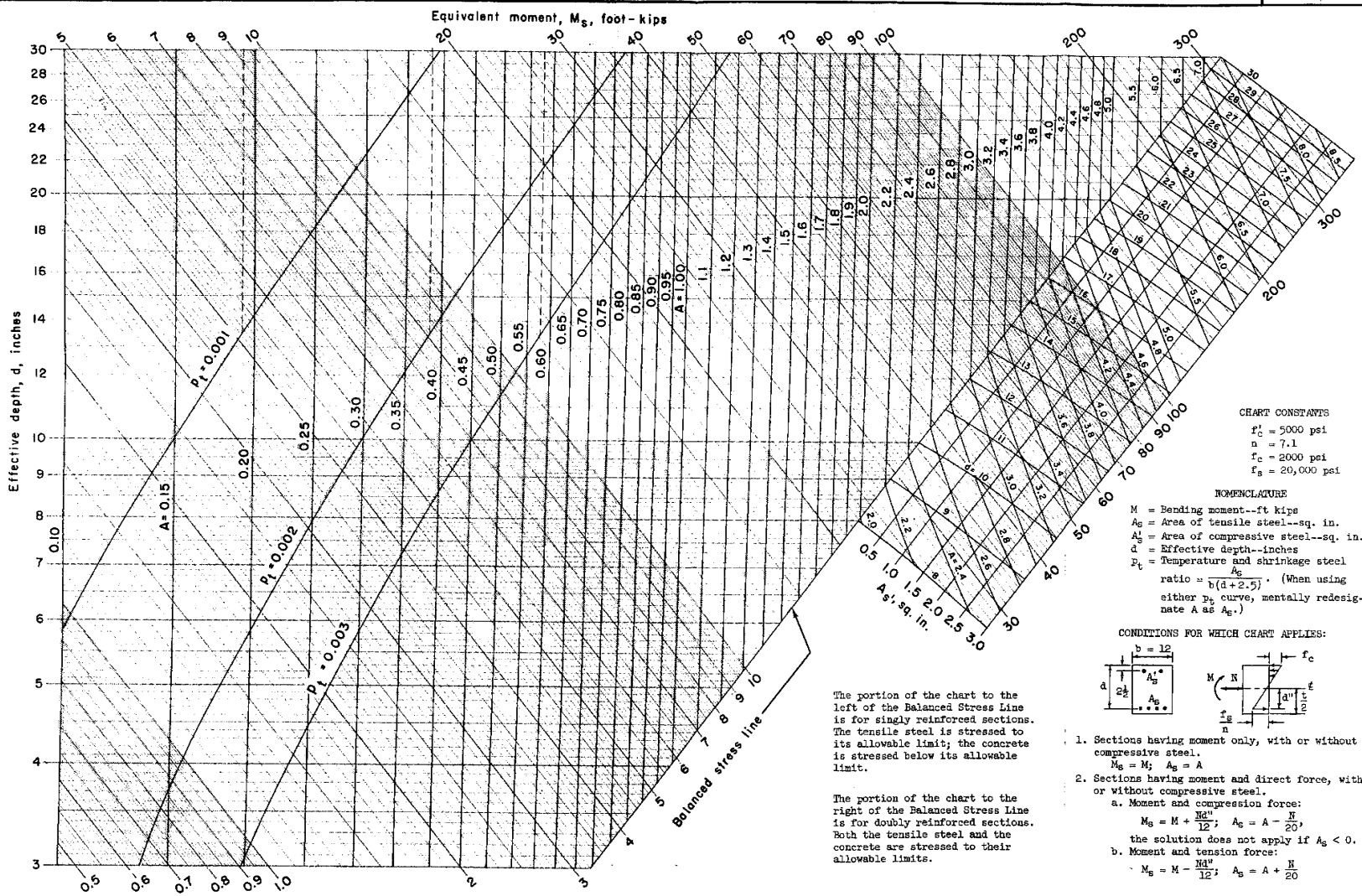
ACI Building Code (ACI 318 - 63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES 165
SHEET 3 OF 3
DATE 7-61

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN
BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE.
FOR 12 INCH WIDTH

f'_c = 5000 psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

f'_c = 5000 psi
n = 7.1
f_c = 2000 psi
f_s = 20,000 psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
p_t = Temperature and shrinkage steel ratio = $\frac{A_s}{b(d+2.5)}$. (When using either p_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

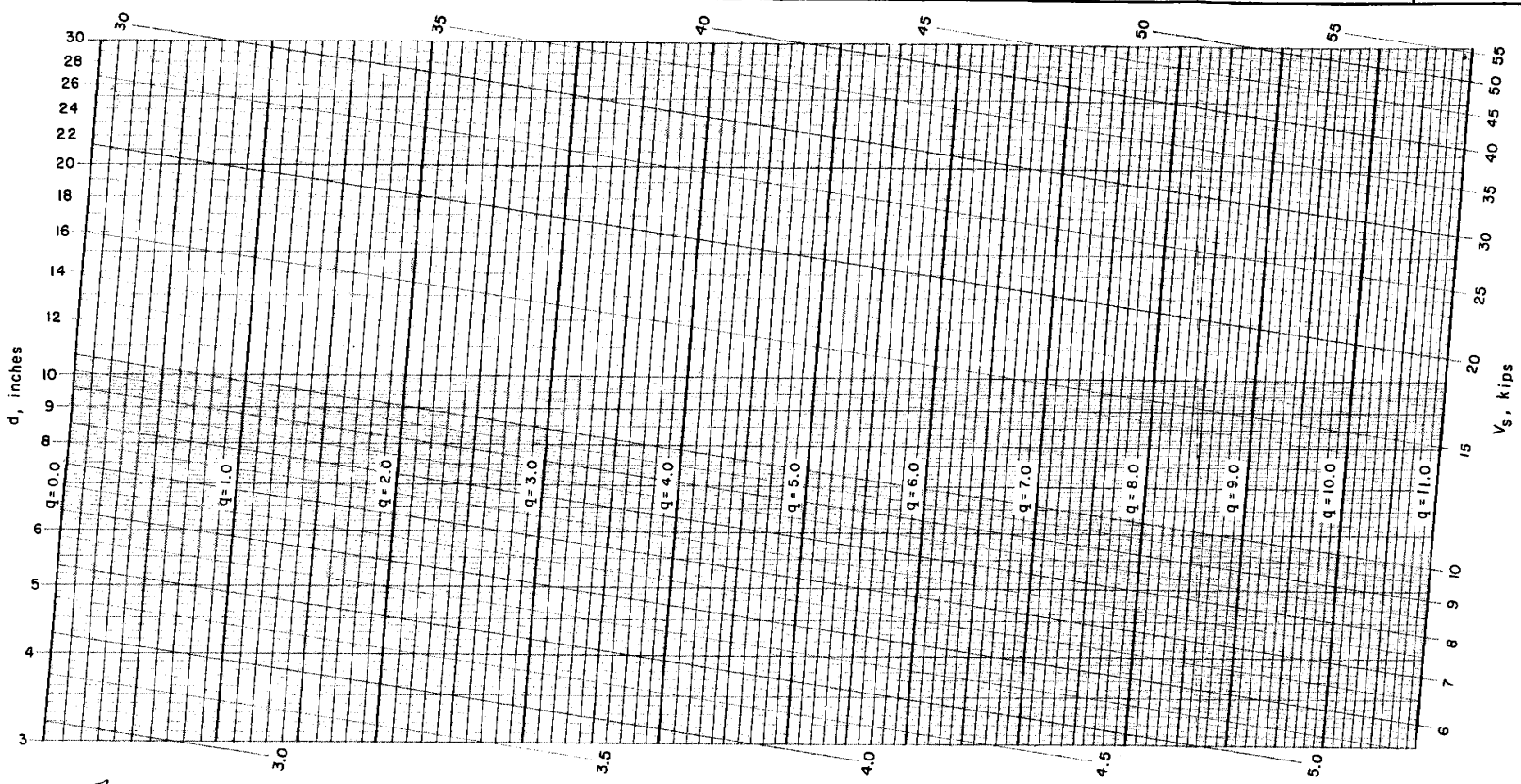
REFERENCE

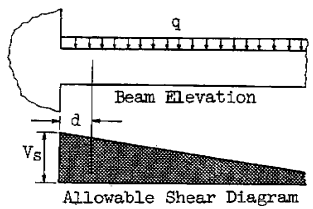
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 166
SHEET 1 OF 3
DATE 4-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED
BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 5000$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

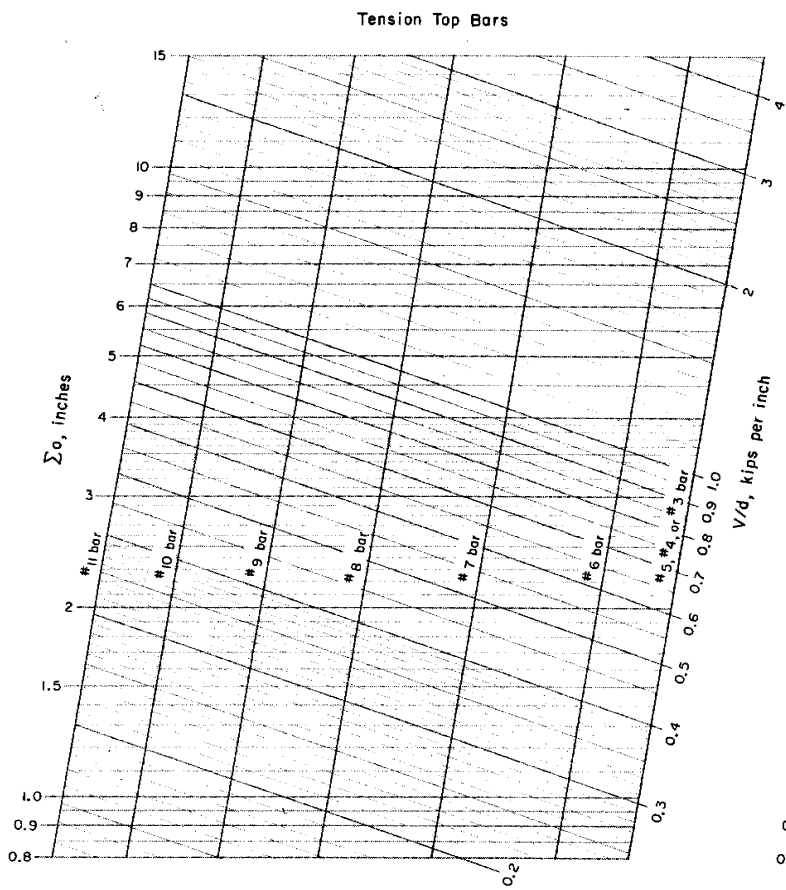
REFERENCE
ACI Building Code [ACI 318-63]

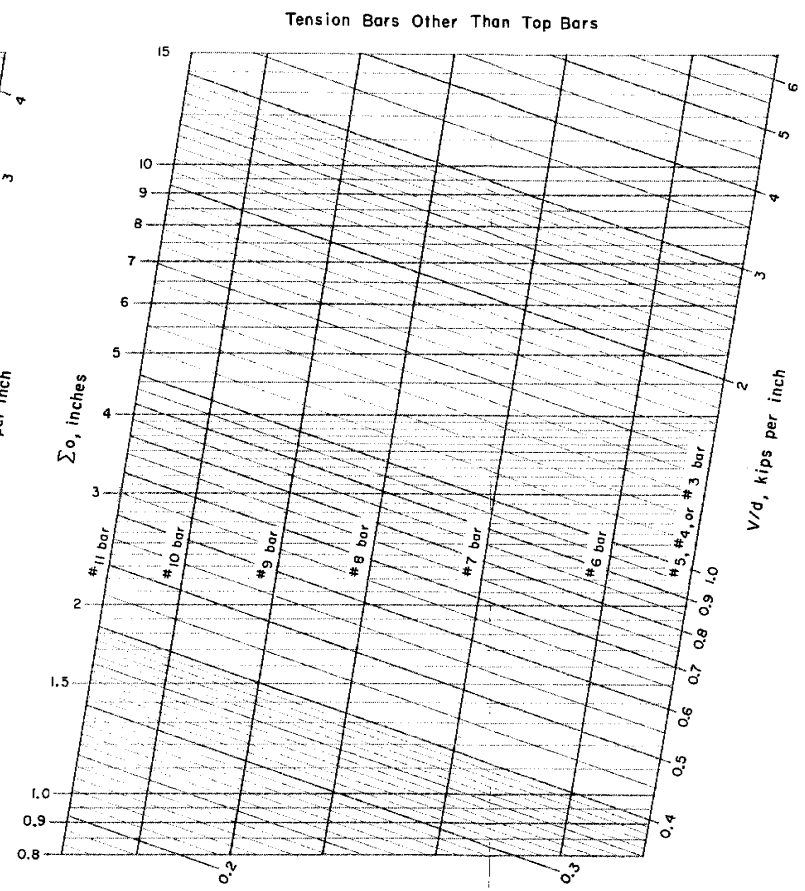
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 166
SHEET 2 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 5000$ psi





$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

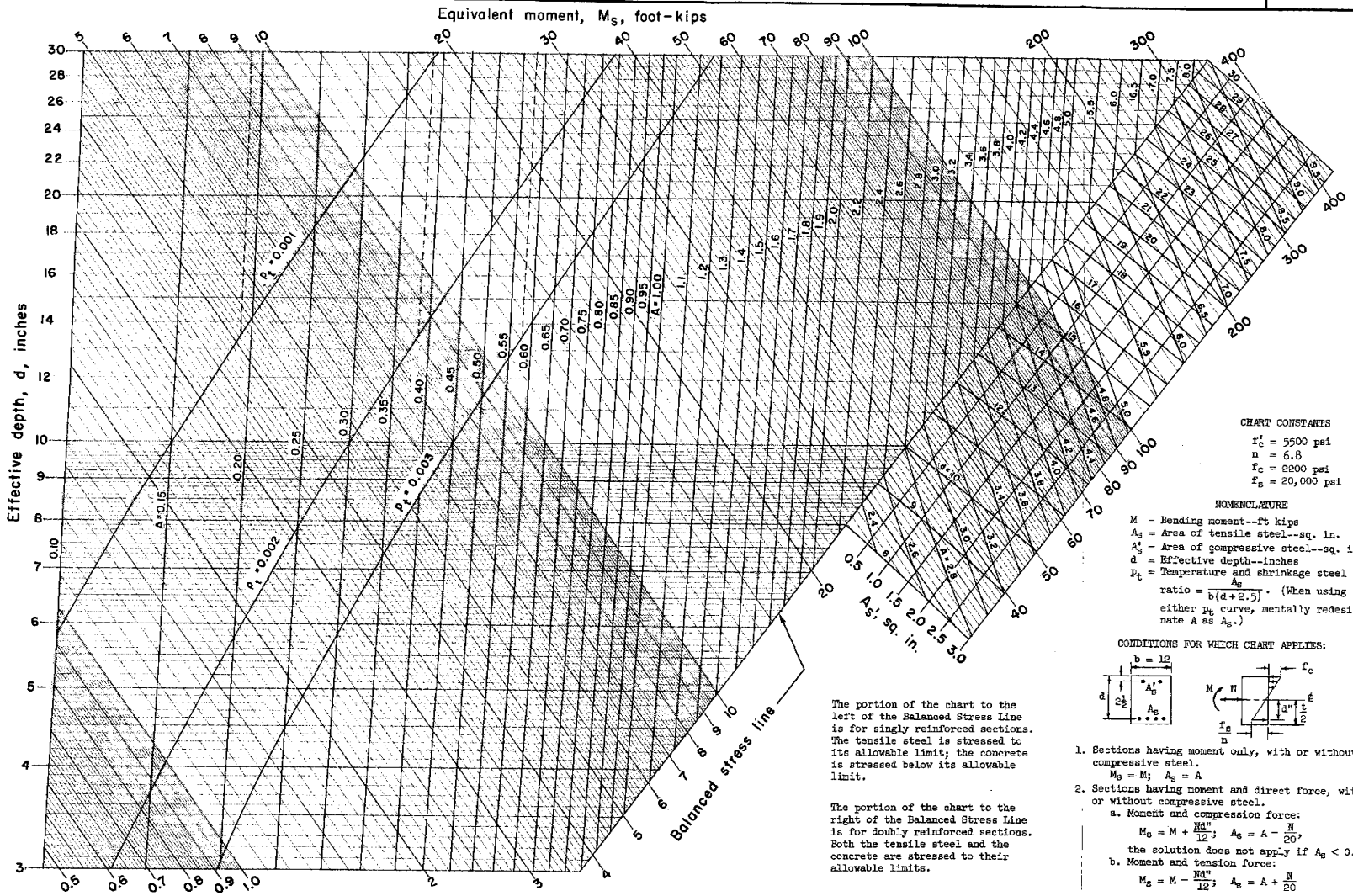
REFERENCE
ACI Building Code (ACI 318 - 63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 166
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN
BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE.
FOR 12 INCH WIDTH

$f'_c = 5500$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

f'_c = 5500 psi
n = 6.8
f_c = 2200 psi
f_s = 20,000 psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
P_t = Temperature and shrinkage steel ratio = $\frac{A_s}{b(d+2.5)}$. (When using either P_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

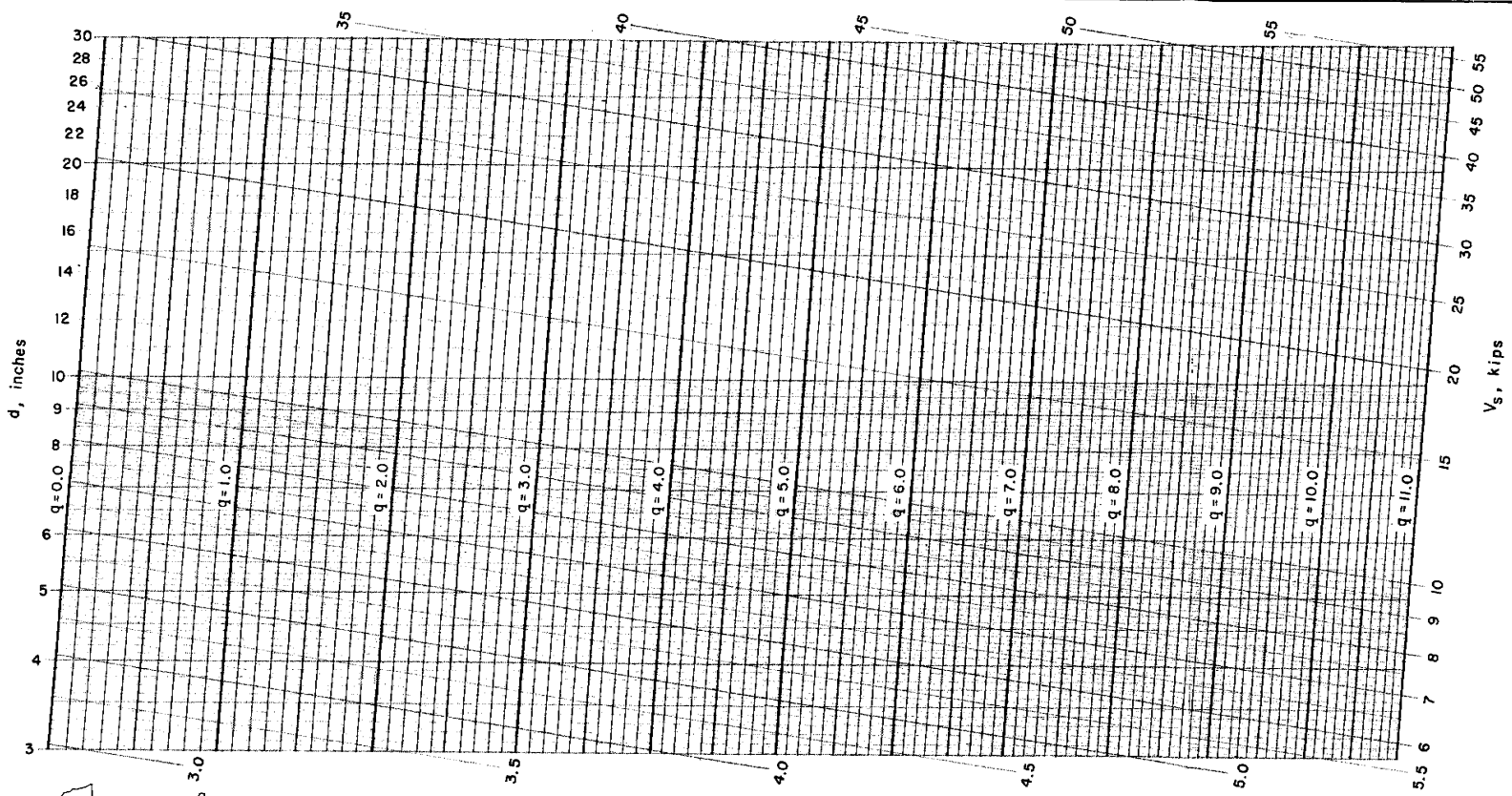
REFERENCE

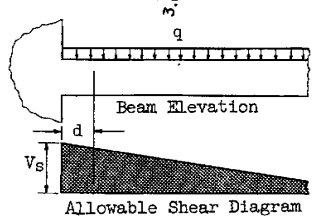
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 167
SHEET 1 OF 3
DATE 4-54

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

$f'_c = 5500$ psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

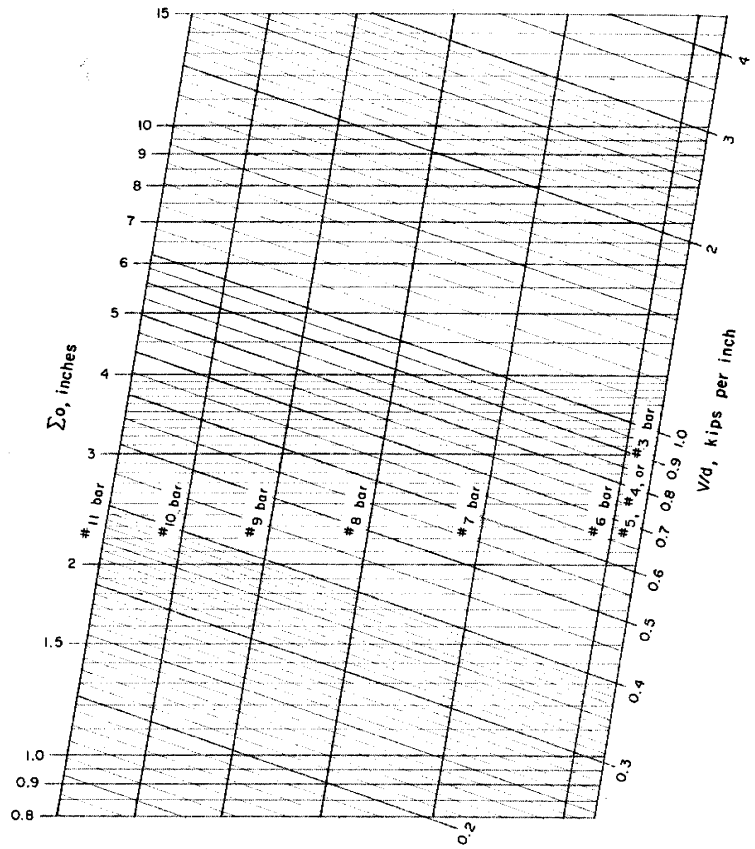
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 167
SHEET 2 OF 3
DATE 7-64

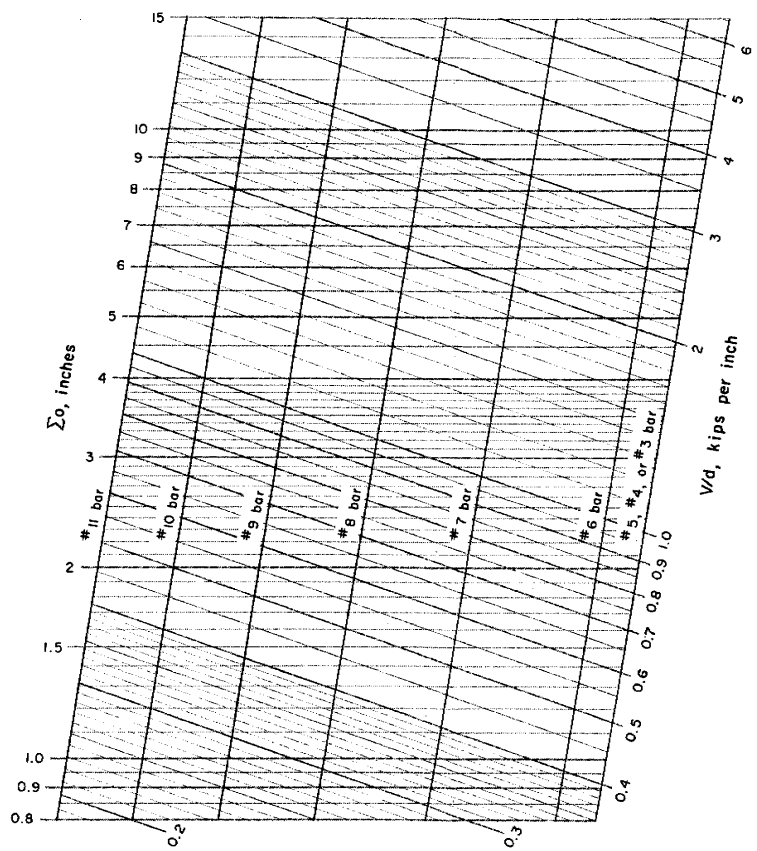
STRUCTURAL DESIGN : REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 5500$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

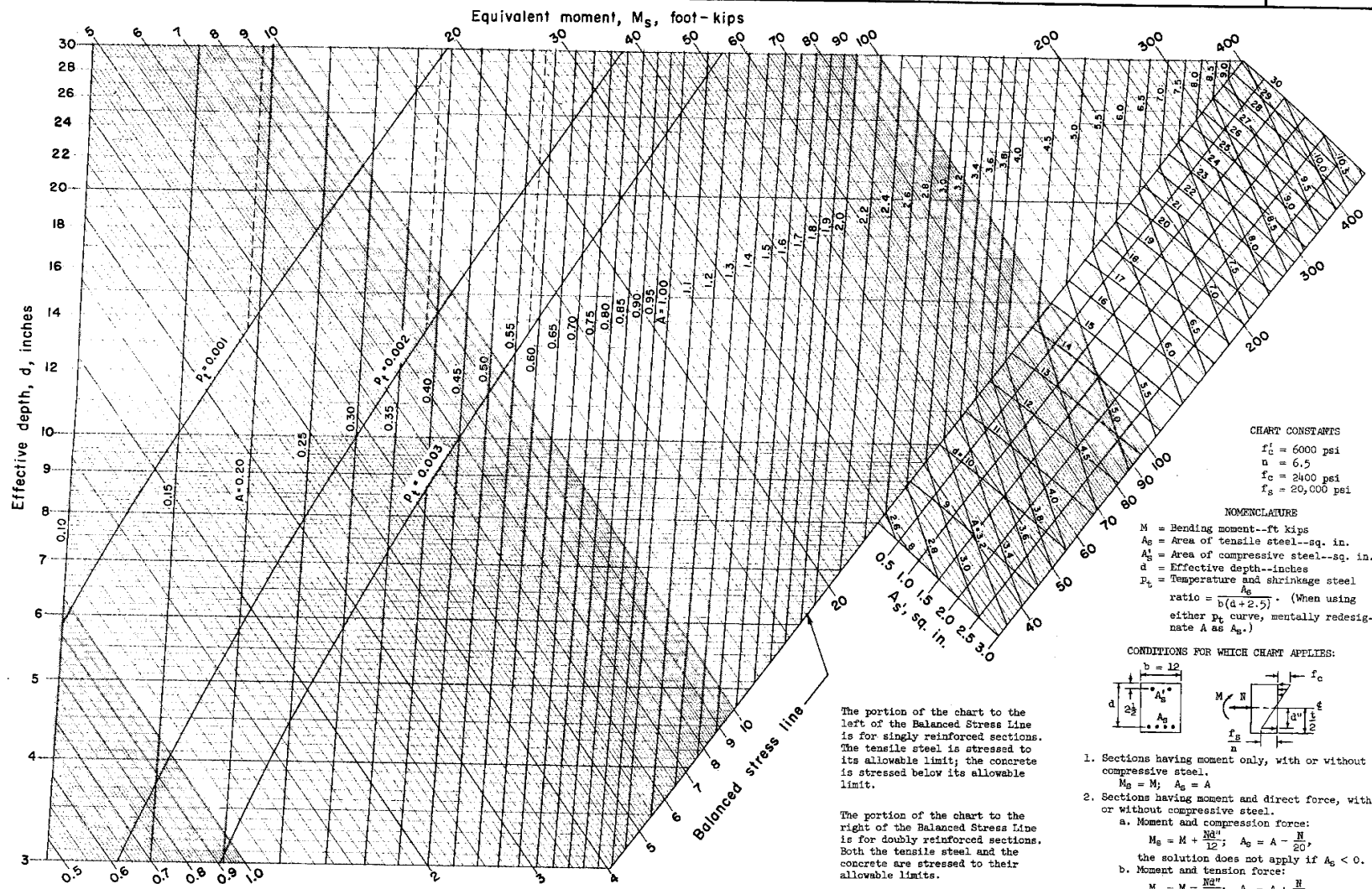
REFERENCE
ACI Building Code (ACI 318-63)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES-167
SHEET 3 OF 3
DATE 7-64

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN BENDING ONLY OR BENDING COMBINED WITH DIRECT FORCE. FOR 12 INCH WIDTH

$f'_c = 6000$ psi



The portion of the chart to the left of the Balanced Stress Line is for singly reinforced sections. The tensile steel is stressed to its allowable limit; the concrete is stressed below its allowable limit.

The portion of the chart to the right of the Balanced Stress Line is for doubly reinforced sections. Both the tensile steel and the concrete are stressed to their allowable limits.

CHART CONSTANTS

$f'_c = 6000$ psi
$n = 6.5$
$f_c = 2400$ psi
$f_s = 20{,}000$ psi

NOMENCLATURE

M = Bending moment--ft kips
A_s = Area of tensile steel--sq. in.
A'_s = Area of compressive steel--sq. in.
d = Effective depth--inches
P_t = Temperature and shrinkage steel ratio $= \frac{A_s}{b(d+2.5)}$. (When using either P_t curve, mentally redesignate A as A_s.)

CONDITIONS FOR WHICH CHART APPLIES:

1. Sections having moment only, with or without compressive steel.
   $M_s = M$; $A_s = A$
2. Sections having moment and direct force, with or without compressive steel.
   a. Moment and compression force:
   $M_s = M + \frac{Nd''}{12}$; $A_s = A - \frac{N}{20}$,
   the solution does not apply if $A_s < 0$.
   b. Moment and tension force:
   $M_s = M - \frac{Nd''}{12}$; $A_s = A + \frac{N}{20}$

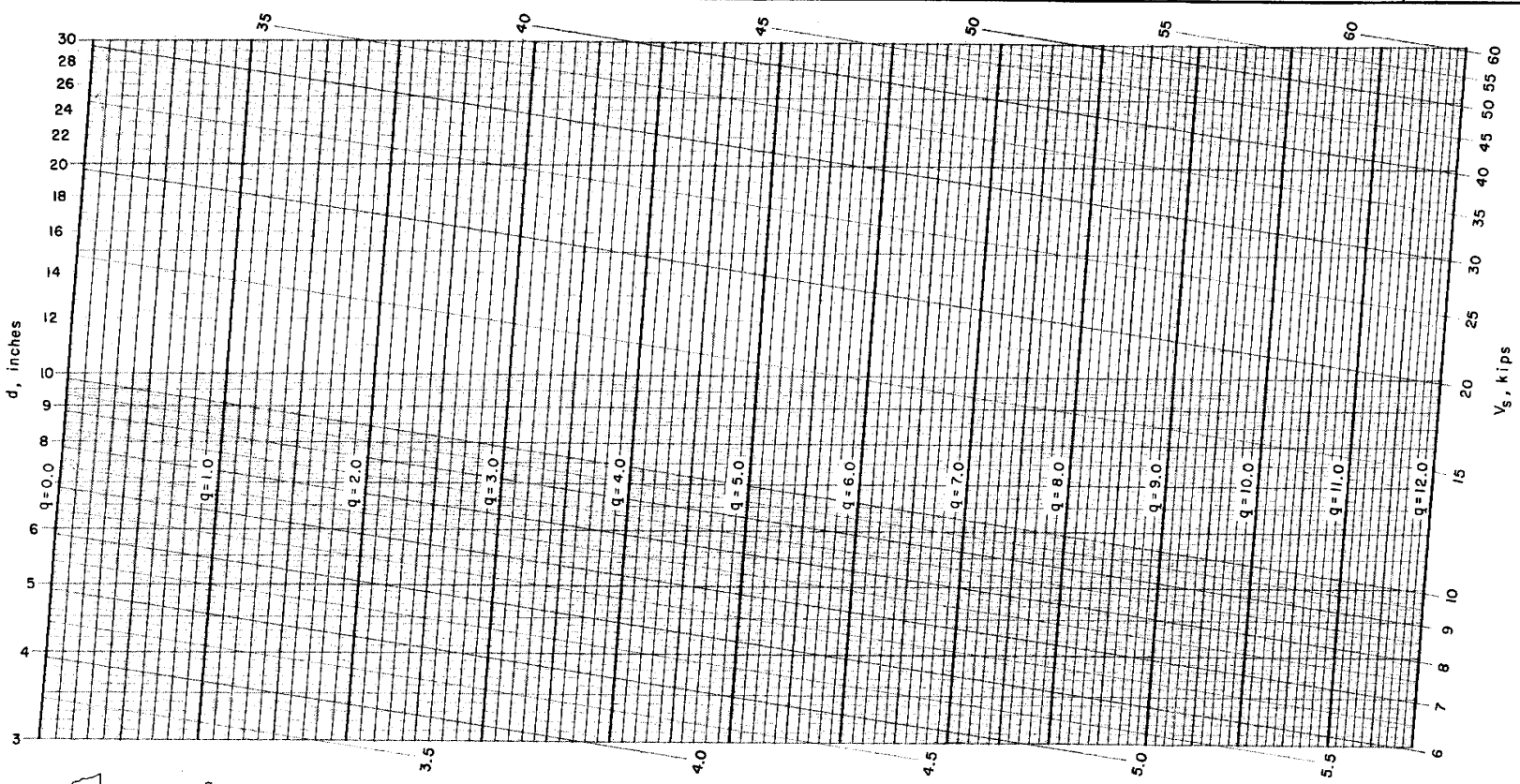
REFERENCE

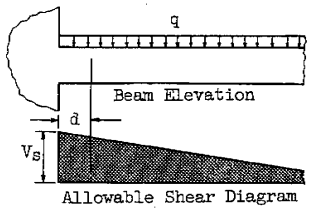
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO. ES- 168
SHEET 1 OF 3
DATE 4-54

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
ALLOWABLE TOTAL SHEAR AT FACE OF SUPPORT OF UNIFORMLY LOADED BEAM WITHOUT WEB REINFORCEMENT. FOR 12 INCH WIDTH.

f'_c=6000 psi





$$V_s = \frac{12 v_c d}{1000}\left(1 + \frac{1000q}{144 v_c}\right)$$

V_s = allowable total shear at face of support, kips
v_c = allowable shear stress at distance equal to [d] from face of support = $1.1\sqrt{f'_c}$, psi
d = effective depth, inches
q = unit load, kips per lineal foot

Solution is valid if, within the interval [d]:
(1) there is no concentrated load, and
(2) the unit load is constant.

REFERENCE
ACI Building Code (ACI 318-63)

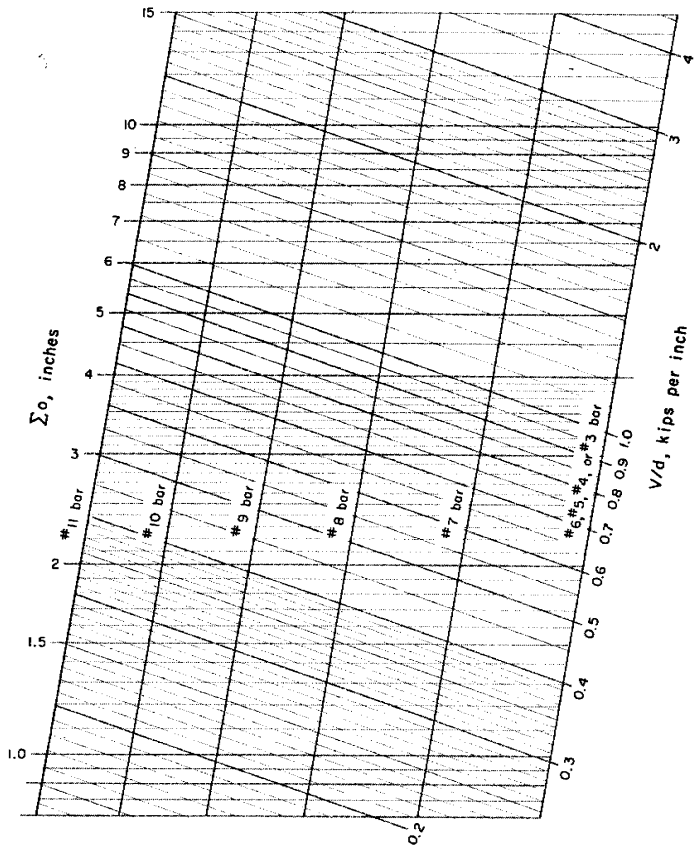
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 168
SHEET 2 OF 3
DATE 7-64

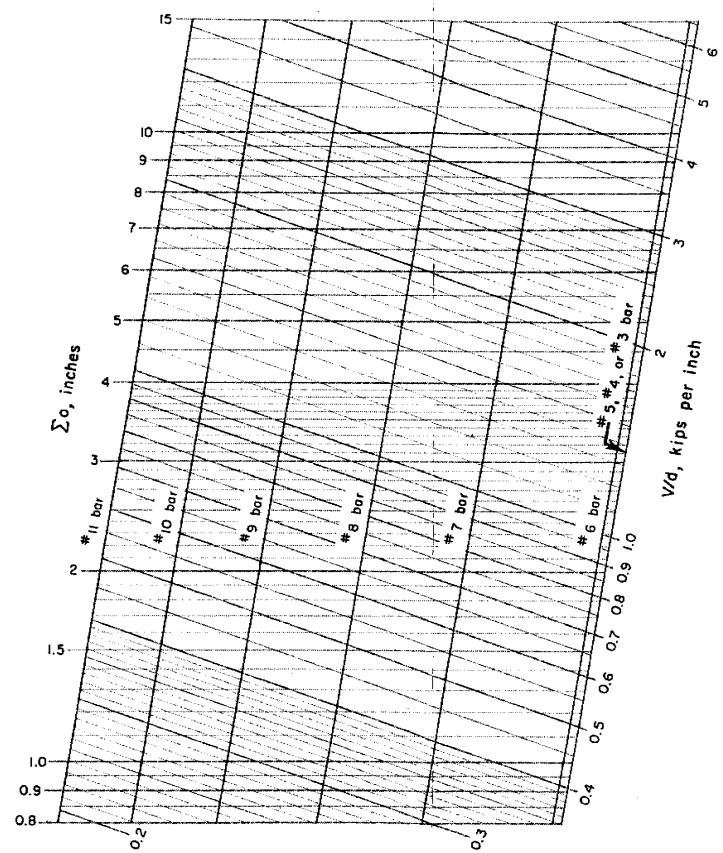
STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN, WORKING STRESS DESIGN.
PERIMETER OF TENSILE REINFORCEMENT REQUIRED FOR FLEXURAL BOND.
FOR 12 INCH WIDTH

$f'_c = 6000$ psi

Tension Top Bars



Tension Bars Other Than Top Bars



$$\Sigma o = \frac{8000}{7u}(V/d)$$

Σo = required perimeter of tensile reinforcement at the section, inches
V = total shear at the section, kips
d = effective depth, inches

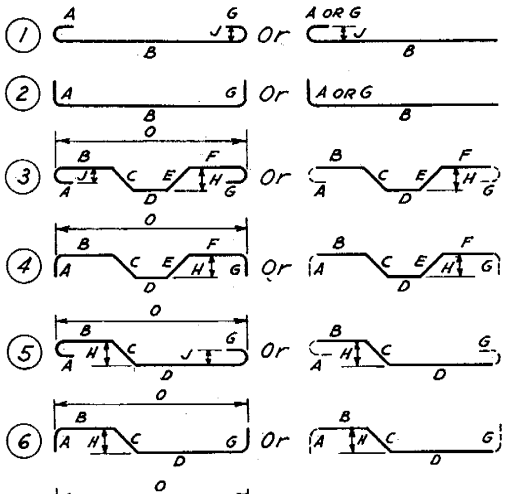
u = allowable bond stress, psi
For tension top bars $u = 3.4\sqrt{f'_c}/D \leq 350$
For tension bars other than top bars $u = 4.8\sqrt{f'_c}/D \leq 500$

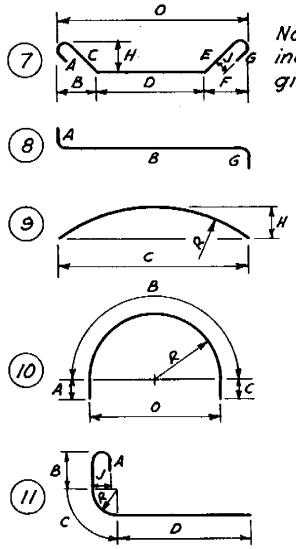
REFERENCE
ACI Building Code (ACI 318-63)

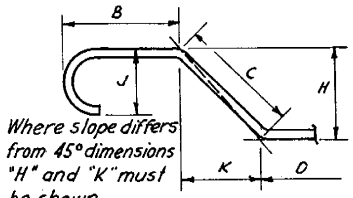
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - DESIGN SECTION

STANDARD DWG. NO.
ES- 168
SHEET 3 OF 3
DATE 7-64

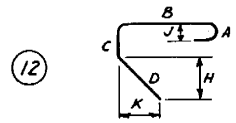
STRUCTURAL DESIGN: REINFORCED CONCRETE
TYPICAL BAR TYPES

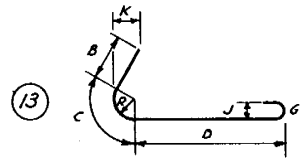


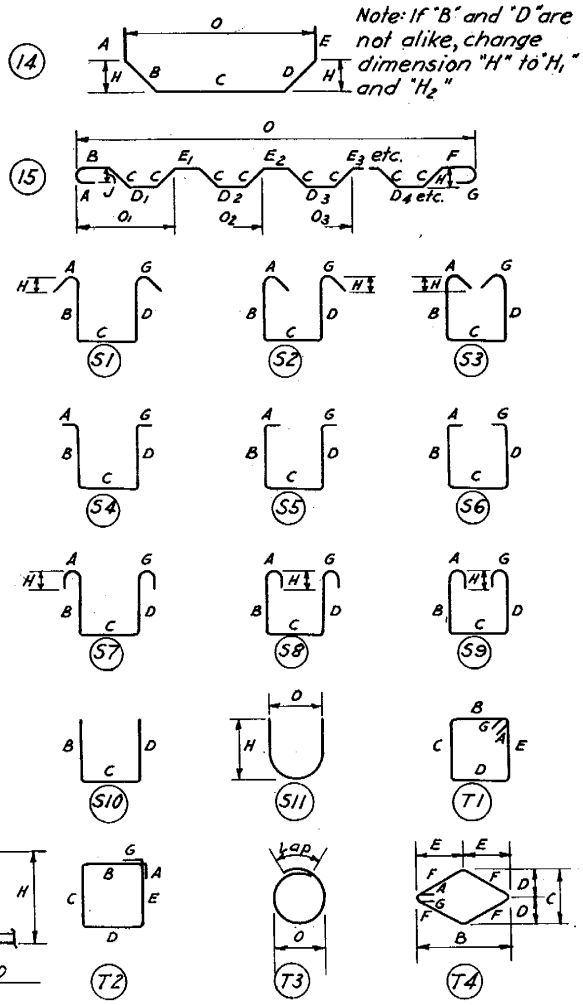




ENLARGED VIEW SHOWING BAR BENDING DETAILS







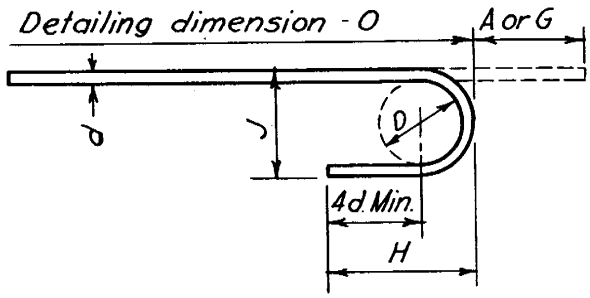
NOTES

1. All dimensions are out to out of bar.
2. "J" dimension on 180° hooks to be shown only where necessary to restrict hook size. Otherwise, standard hooks are to be used.
3. Where "J" is not shown, "J" will be kept equal to or less than "H." Where "J" can exceed "H", it should be shown.
4. "H" dimension on stirrups to be shown where necessary to restrict hooks.
5. Where bars are to be bent more accurately than standard bending tolerances, bending dimensions which require closer working should have limits indicated.
6. Figures in circles show types.

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING STANDARDS UNIT	STANDARD DWG. NO. ES-18 SHEET 1 OF 1 DATE 4-12-50
ACI Standard 315-48		

STRUCTURAL DESIGN: REINFORCED CONCRETE
STANDARD HOOK DETAILS, ACI CODE

RECOMMENDED SIZES OF 180° HOOK



D = 6 d for #3 thru #7
D = 8 d for #8 thru #11

Bar Size	Hook A or G	J	Approx. H
#3	4	3	3
#4	6	4	4 1/2
#5	7	5	5
#6	8	6	5 3/4
#7	10	7	7 1/2
#8	1-1	10	9
#9	1-3	11 1/4	10 1/4
#10	1-5	1-0 1/2	11 3/4
#11	1-8	1-2 1/4	1-2 1/4

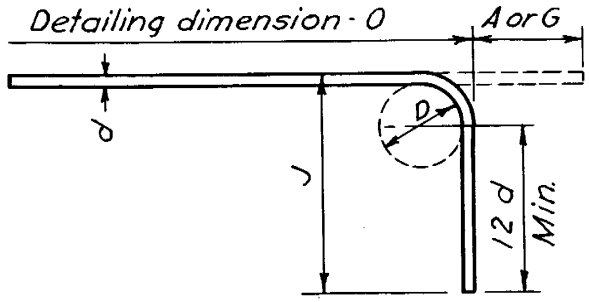
MINIMUM SIZES OF 180° HOOK

D = 5 d Min.
D = 11 d Max.

NOTE: This table to be used only for special conditions where hook smaller than recommended sizes is necessary. Not appropriate for hard grades of steel.

Bar Size	Hook A or G	J	Approx. H
#3	4	2 3/4	3
#4	5	3 1/2	3 3/4
#5	6	4 1/2	4 1/2
#6	8	5 1/4	6 1/4
#7	9	6 1/4	6 3/4
#8	10	7	7 1/2
#9	12	8	9 1/4
#10	1-1	8 3/4	10
#11	1-2	10	10 3/4

RECOMMENDED SIZES & MINIMUM SIZES OF 90° HOOK



D = 7 d

Bar Size	Hook A or G	Approx. J
#3	5	6
#4	7	8 1/4
#5	9	10 3/4
#6	10	1-0
#7	1-0	1-2 1/4
#8	1-2	1-4 3/4
#9	1-4	1-7
#10	1-6	1-9 1/2
#11	1-8	2-0

REFERENCE
ACI Standard 315-48

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING STANDARDS UNIT

STANDARD DWG. NO. ES - 20
SHEET 1 OF 1
DATE 4-18-50

Revised 12-22-50

"(d) Do's and Don'ts. Experienced designers and detailers will develop a list of "do's and don'ts" such as the following:

1. Give complete and accurate dimensions on engineering drawings.

2. Show details at corners and intersections of walls and at window and door openings.

3. Use notations which cannot be misinterpreted, such as "each way" rather than "both ways";"No. 5 at 12, each face staggered" rather than "No. 5 at 12 staggered."

4. Congestion of steel should be avoided at points where members intersect. Make certain that all reinforcement shown can be properly placed. For example, at the intersection of a beam and girder, the beam bars should be bent at a different elevation than those in the girder so as to avoid interference when the steel is being placed. Another very troublesome point is the intersection of columns with beams and girders.

5. Make certain that hooked and bent bars can be placed and have adequate concrete protection.

6. All bars, straight or bent, requiring hooks should be so designated by the designer.

7. Length of laps, points of bend, and extension of bars should be specified by the designer. Do not use the ratios L/7, L/5, and L/4 shown on Typical Drawings unless justified by structural analysis.

8. Be sure that unusual bends can be made with standard bending equipment.

9. Avoid ordering accessories such as bolsters and high-chairs in 1/8-inch increments of heights, as stock sizes come in 1/4-inch increments.

10. It is advisable to prepare placing drawings the same size as the engineering drawings.

11. For special or unusual conditions, be sure that adequate details are shown for proper placing of the reinforcement as the average steel setter does not understand engineering principles. Examples are cantilevers and continuous footings in which the reinforcement is in the opposite side from which the steel setter is accustomed.

12. Schedule dowels with the footings rather than in the column schedule.

13. Do not forget to splice column bars at top of upturned beams rather than at floor level.

14. Do not detail bar lengths to fractions of an inch. See Section 203 for standard tolerances. Increments of 3 inches for straight bars are recommended.

15. Where the lengths are not specifically fixed, such as for temperature steel, slabs on ground, and walls, use stock lengths or lengths which can be cut from stock lengths with a minimum of waste.

16. When a member has a break in its direction so that the reinforcement in tension tends to separate from the body of the concrete, special anchorage must be provided and shown in detail. Examples are the junction of stairs and landing, and where the soffit of a beam forms an angle.

17. Be sure that bent bars are not so large and unwieldy that they cannot be transported."

4.4.7 Fabricating Shop Practice. It is important that the designer and detailer are acquainted with practices of the fabricating shop, so the fabricating may be kept as simple and economical as possible. We are therefore quoting the following articles from the Manual of Standard Practice for Detailing Reinforced Concrete Structures (ACI Standard 315-48).

"202. Warehouse Stock

"There is some variation in the stock carried in different localities and also by fabricators in the same locality. The information which follows should be supplemented by information from local fabricators.

"Fabricators ordinarily stock only one or two grades of reinforcing steel. For bars, intermediate grade billet steel and rail steel are by far the most common, although other grades may at times be available. For spirals, hot rolled rods of intermediate grade are commonly stocked, although other grades and cold drawn wire may be available."

The following table of standard sizes of reinforcing bars is from ASTM Specification A305.

Bar No.	Unit Wt Lbs/Ft	Nominal Dimensions Round Sections		
		Diameter-Inches Decimal	Cross-Sectional Area Sq In.	Perimeter
2	0.167	0.250	0.05	0.785
3	0.376	0.375	0.11	1.178
4	0.668	0.500	0.20	1.571
5	1.043	0.625	0.31	1.963
6	1.502	0.750	0.44	2.356
7	2.044	0.875	0.60	2.749
8	2.670	1.000	0.79	3.142
9	3.400	1.128	1.00	3.544
10	4.303	1.270	1.27	3.990
11	5.313	1.410	1.56	4.430

Bar numbers are based on the number of 1/8 inches in the nominal diameter of the section.

Bar No. 2 in plain rounds only.

Bars numbered 9, 10, and 11 correspond to former 1" square, 1-1/8" square, and 1-1/4" square sizes and are equivalent to those former standard bar sizes in weights and nominal cross-sectional areas.

The quotation from ACI Standard 315-48 is continued below.

"The quality of reinforcing steel is governed by specifications of the American Society for Testing Materials, designated as follows:

"Billet-Steel Bars for Concrete Reinforcement,
Designation A-15.
Rail-Steel Bars for Concrete Reinforcement,
Designation A-16.
Axle-Steel Bars for Concrete Reinforcement,
Designation A-160.
Cold-Drawn Steel Wire for Concrete Reinforcement,
Designation A-82.
Welded-Steel Wire Fabric for Concrete Reinforcement,
Designation A-185.

"With the exception of the No. 2, all of these sizes are ordinarily furnished as deformed bars, the type of deformation depending upon the rolling mill. The No. 2 bar is generally available only as a plain bar.

"Bars are stocked by most fabricators in lengths of sixty feet. By special arrangement longer bars can sometimes be obtained but shipping limitations must be considered. Usually No. 2 bars are stocked in twenty-foot lengths because of the difficulty of handling such light bars in greater lengths.

"203. Tolerances

"Practical limitations of equipment and speed of production make it necessary to establish certain tolerances in fabrication which can be met with standard shop equipment. Where greater accuracy is required than given by the tolerances which follow, it must be definitely stated, as an extra charge is made for this type of fabrication.

"Reinforcing bars are cut to length by shearing with a tolerance of one inch more or one inch less than the specified length. Where more exact lengths or finished ends are required, the bars must be cut by special shears, or by attachments to regular shears, or by cold sawing.

"The dimensions of a bent bar are measured out to out of bar. The tolerance for the over-all bent length is one-half inch more or one-half inch less than the specified dimension for No. 7 bars or smaller, and one inch more or one inch less for larger bars. For a truss bar the tolerance in height is one-half inch less than the specified dimension. No greater height is permitted so that there is assurance that the bars can be placed within the depth of slab or beam specified.

"The diameter of column spirals is measured to the outside of the spiral. The tolerance is one-half inch more or one-half inch less than the specified diameter."