BUILDING CODE FOR REINFORCED CONCRETE

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Approved :

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Dean of the School of Engineering A.U.B.

BUILDING CODE FOR REINFORCED CONCRETE

THESIS

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OUTLINE

BUILDING CODE
For
REINFORCED CONCRETE

SECTION O. GENERAL

SECTION 0 - GENERAL

0.1 Scope -

This report is intended to cover the use of concrete & reinforced concrete in buildings.

0.2 Permits and Drawings -

Drawings and typical details of all reinforced concrete construction showing the sizes and position of all structural members, metal reinforcement, design strength of concrete, and the live load used in the design shall be filed with the building department as a permanent record before a permit to construct such work shall be issued. Calculations pertaining to the design shall be filed with the drawings when required by the Commissioner of Buildings.

0.3 Definitions -

The following terms are defined for use in this code :

Aggregate - Inert material which is mixed with portland cement and water to produce concrete.

Column - An upright compression member the length of which exceeds three times its least lateral dimension.

Combination column - A column in which a structural steel section designed to carry the principal part of the load, is wrapped with wire and encased in concrete of such quality that some additional load may be allowed.

Composite column - A column in which a steel or cast-iron section is completely encased in concrete containing reinforcement of spiral reinforcement and longitudinal bars.

Concrete - A mixture of portland cement, fine aggregate, coarse aggregate and water.

Consistency - A general term used to designate the relative mobility of freshly mixed concrete or mortar.
Deformed bar - Reinforcement bar with projections, shoulders or lugs on the surface of the bar formed during rolling.
Effective area of concrete - The area of a section which lies between the centroid of the tensile reinforcement and the compression face of a slab or beam.
Effective area of reinforcement - The area obtained by multiplying the normal cross-sectional area of the reinforcement by the cosine of the angle between its direction and the direction for which the effectiveness is to be determined.
Effective depth of beam - The distance from the compression face to the centroid of the area of the tensile reinforcement.
Fineness Modulus - An empirical factor obtained by taking 1/100 of the sum of the percentages of a sample of aggregate retained on each of a specified series of sieves.
Honeycomb - A surface or interior defect in a concrete mass characterized by the lack of mortar between the coarse aggregate particles.
Laitance - Extremely fine material of little or no hardness which may collect on the surface of freshly placed concrete or mortar, resulting from the use of excess mixing water.
Modular ratio - The ratio of the modulus of elasticity of steel to that of concrete.
Pipe column - A steel pipe filled with concrete.
Plastic Flow - The inelastic deformation in concrete resulting from the continued application of load.
Ratio of Reinforcement - The ratio of the effective area of the reinforcement to the effective area of the concrete at any section of a structural member.
Saturated and Surface Dry - A term used to describe the condition of an aggregate in which the pores of all the particles are completely filled with water, but their surfaces are free from moisture.
Slump - The shortening of a standard test mass of freshly mixed concrete, used as a measure of consistency in accordance with the standard method.

Strut - A compression member other than a column or pedestal.

Stiffness Factor - The value obtained by dividing the moment of inertia of a member by its length.

Vibration - A method of compacting concrete by mechanically producing wave motion of high frequency in the concrete.

0.4 Notations -

A = total area of top of pedestal or footing

A' = loaded area of pedestal or footing at the column base.

A_c = Area of core of a spirally-reinforced column measured to the outside diameter of the spiral; net area of concrete section of a composite column.

A_g = The overall or gross area of spirally-reinforced or tied columns; the total area of the concrete encasement of combination columns.

A_r = Area of the steel or cast-iron core of a composite column; the area of the steel core in a combination column.

A_s = Effective cross-sectional area of reinforcement in tension in beams or in compression in columns;

A_v = Total area of web reinforcement in tension within a distance of s (measured perpendicular to the direction of the web reinforcement bar), or the total area of all bars b ent up in any one plane.

b = Width of rectangular beam or width of flange of T-beam.

b' = Thickness of web in beams of I or T sections.

B_s = Bending moment coefficient in short direction.

B_l = Bending moment coefficient in long direction.

c = distance from gravity axis to extreme fiber in compression.

d = Depth from compression face of beam or slab to center of longitudinal tensile reinforcement.

e = Eccentricity of the resultant load on a column, measured from the gravity axis.

F = (Pipe columns) $\frac{\text{yield point of pipe}}{45{,}000}$

f_c = Compressive unit stress in extreme fiber of concrete in flexure or axial compression in concrete columns.

f'_c = Ultimate compressive strength of concrete usually at age of 28 days.

f_r = Permissible unit stress in the metal core of a composite column.

f'_r = Permissible unit stress on unencased steel columns and pipe columns.

f_s = Tensile unit stress in longitudinal reinforcement; nominal working stress in vertical column reinforcement.

f'_s = Useful limit stress of spiral reinforcement.

f_v = Tensile unit stress in web reinforcement.

h = Unsupported length of column.

I = Moment of inertia of a section about the neutral axis for bending.

j = Ratio of distance between centroid of compression and centroid of tension to the depth.

K = least radius of gyration of metal core section.

l = Span length of beam or slab.

l' = Clear span for positive moment and the average of the two adjacent clear spans for negative moment.

l_s = span in short direction

l_l = span in long direction

n = Ratio of modulus of elasticity of steel to that of concrete.

= sum of the perimeters of the bars in the tensile reinforcements.

P = Total allowable axial load on a column

P' = Total allowable axial load on a long column

p' = Ratio of volume of spiral reinforcement to the volume of the concrete core (out to out of spirals) of a spirally reinforced concrete column.

p_g = ratio of the effective cross-sectional area of vertical reinforcement to the gross area A_g.

r_a = Permissible unit working stress in concrete over the loaded area of a pedestal, pier or footing.

R = Least radius of gyration of equivalent concrete section; ratio of gross area to core area of column, A_g/A_c.

S = spacing of stirrups

u = Bond stress per unit of surface area of bar.

v = Shearing unit stress

v_c = Unit shearing stress permitted on the concrete of the web.

V = Total shear

V' = Excess of the total shear over that permitted on the concrete.

w = Uniformly distributed load per unit length of beam or slab.

w' = Uniformly distributed dead and live load per unit of area of a floor or roof.

W_s = Total load on short span beam.

W_l = Total load on long span beam.

SECTION 1 ALLOWABLE STRESSES

ALLOWABLE UNIT STRESSES

Description		For any strength of concrete as fixed by test $n = \frac{30,000}{f'_c}$	$f'_c =$ 2000 p.s.i. $n = 15$	$f'_c =$ 2500 p.s.i. $n = 12$	$f'_c =$ 3000 p.s.i. $n = 10$	$f'_c =$ 3750 p.s.i. $n = 8$
Flexure :						
Extreme fiber stress in compression	f_c	$0.40\ f'_c$	800	1000	1200	1500
Extreme fiber stress in compression adjacent to supports of continuous or fixed beams or of rigid frames	f_c	$0.45\ f'_c$	900	1125	1350	1688
Shear :						
Beams with no web reinforcement and without special anchorage of longitudinal steel	v_c	$0.02\ f'_c$	40	50	60	75
Beams with no web reinforcement but with special anchorage of longitudinal steel	v_c	$0.03\ f'_c$	60	75	90	113
Beams with properly designed web reinforcement but without special anchorage of longitudinal steel	v	$0.06\ f'_c$	120	150	180	225
Beams with properly designed web reinforcement and with special anchorage of longitudinal steel	v	$0.12\ f'_c$	240	300	360	450
Flat slabs at distance d from edge of column capital or drop panel	v_c	$0.03\ f'_c$	60	75	90	113
Footings	v_c		60	75	75	75
Bond :						
In beams and slabs and one-way footings :						
Plain bars	u	$0.04\ f'_c$	80	100	120	150
Deformed bars	u	$0.05\ f'_c$	100	125	150	188
In two-way footings :						
Plain bars	u	$0.045\ f'_c$	90	113	135	169
Deformed bars	u	$0.056\ f'_c$	112	140	168	210
Bearing :						
On full area	f_c	$0.25\ f'_c$	500	625	750	938
Pedestals	f_{ra}	$0.25\ f'_c \sqrt[3]{\frac{A}{A'}}$				

ALLOWABLE UNIT STRESSES IN REINFORCEMENT

a) Tension -

(f_s = tensile unit stress in longitudinal feinforcement)

(f_v = tensile unit stress in web reinforcement)

20,000 p.s.i. for rail-steel concrete reinforcement bars, billet-steel concrete reinforcement bars (of intermediate and hard grades), axle-steel concrete reinforcement bars (of intermediate and hard grades), and cold drawn steel wire for concrete reinforcement.

18,000 p.s.i. for billet-steel concrete reinforcement bars (of structural grade), and axle-steel concrete reinforcement bars (of structural grade).

b) Compression, vertical column reinforcement :

(f_s = nominal working stress in vertical column reinforcement)

20,000 p.s.i. for rail or hard grade steel.

16,000 p.s.i. for intermediate grade steel.

SECTION 2 D E S I G N

SECTION 2.1 - GENERAL CONSIDERATIONS

2.11 Basic assumptions.

Computation of stresses should accord with the laws of mechanics and the recognised general principles relating to the design of reinforced concrete.

The design of reinforced concrete members shall be made with reference to working stresses and safe loads. The accepted theory of flexure as applied to reinforced concrete shall be applied to all members resisting bending.

It may be assumed :

a) that both steel and concrete are elastic within the range of the permissible stresses and that the modular ratio, n, is equal to $\frac{30,000,000}{1,000 \ f'c}$

b) that plane sections remain plane, and

c) that all tensile stresses are taken by the reinforcement except, that the concrete may be assumed to resist diagonal tension within the limits of shear stress specified for plain concrete in Section 1.

2.12 Loadings -

The provisions for design herein specified are based on the assumption that all structures shall be designed for all dead and live-loads coming upon them.

2.121 Dead loads - For the purpose of calculating dead loadings, the weights of materials should, unless otherwise agreed, be taken to be as set forth in the "Schedule of unit weights of building materials".

For ordinary constructions the weight of reinforced concrete may be taken as 150 lb. per cubic foot, but, when the percentage of steel exceeds 2 per cent, some greater weight may be more appropriate. Where light weight aggregates are used a smaller appropriate weight may be taken.

2.122 Live loads -

The live loads should be in accordance with Table 2, with such reductions for girders and lower storey columns as are permitted in Section 2.13

2.13 Reductions -

The following reductions in assumed live loads shall be permitted in design of columns, piers, walls, foundations and girders.

1) No reduction of the assumed live load shall be allowed in the design of any slabs, joists or beams.

2) A reduction of the total live load used in the design of girders based on a certain tributary floor area shall be permitted as noted in the following schedule. This reduction shall not be carried into the columns nor shall such reduction be used in design of buildings to be used or occupied as warehouses or for storage purposes.

Reduction allowed	Tributary floor area
5%	100 sq. ft.
10%	200 sq. ft.
15%	300 or more sq. ft.

3) For determining the total live loads carried by columns, the following reductions shall be permitted, the reductions being based on the assumed live loads (Table 2) applied to the entire tributary floor area :

Allowable reductions for warehouses & Storage Buildings

Carrying the roof	0%
Carrying 1 floor & roof	0%
Carrying 2 floors & roof	5%
Carrying 3 floors & roof	10%
Carrying 4 floors & roof	15%
Carrying 5 or more floors & roof	20%

Live Load Reductions for Manufacturing Buildings, Stores & Garages

Carrying the roof	0%
Carrying 1 floor & roof	0%
Carrying 2 floors & roof	10%
Carrying 3 floors & roof	20%
Carrying 4 or more floors & roof	30%

Allowable Live Load Reductions for all other Buildings

Carrying the roof	0%
Carrying 1 floor & roof	0%
Carrying 2 floors & roof	10%
Carrying 3 floors & roof	20%
Carrying 4 floors & roof	30%
Carrying 5 floors & roof	40%
Carrying 6 floors & roof	45%
Carrying 7 or more floors & roof	50%

2.14 Structures in Earthquake Regions -

In structures subject to earthquake shocks special analysis should be made to determinethe probable stresses which should be added to those resulting from static or moving loads.

2.15 Resistance to Wind Forces -

a) The resisting elements in structures required to resist wind forces shall be limited to the integral structural parts.

b) The moments, shears, and direct stresses resulting from wind forces determined in accordance with recognized methods shall be added to the maximum stresses which obtain at any section for dead and live-loads.

c) In proportioning the component parts of the structure for the maximum combined stresses, including wind stresses, the unit stresses shall not exceed the allowable stresses for combined live and dead-loads provided in Section 1 by more than one-third. The structural members and their connections shall be so proportioned as to provide suitable rigidity of structure.

TABLE - 2

FLOOR & ROOF LOADS+

The range of minimum live-load values in pounds per square foot of floor or roof area, is as follows :

Apartments	40
Auditoriums and theaters :	
With fixed seats	50-80
Without fixed seats	100
Dwellings	40
Hospitals	40
Hotels :	
Rooms	40
Corridors, lobbies, dining rooms	100
Manufacturing buildings :	
Light manufacturing	75-125
Heavy manufacturing	125-200
Office buildings :	
Office space	50-60
Corridors, public spaces	100-125
Roofs, flat	30-40
School buildings :	
Classrooms	50-60
Corridors, public spaces	100
Garages :	
All types of vehicle	100-175
Passengers cars only	75-125
Store buildings :	
Retail	75-125
Wholesale	100-125
Warehouses :	
Light storage	75-150
Heavy storage	200-250

+ The specified minimum live loads cannot always be used. The type of occupancy should be considered & the probable loads should be computed as accurately as possible.

SECTION 2.2 - BEAMS & SLABS

2.21 General -

2.211 General Requirements -

All members shall be designed to resist at all sections the maximum bending moments and shears produced by dead load, live load and wind load, as determined by the principle of continuity+.

+In the case of approximately equal spans with loads uniformly distributed, where the intensity of live load does not exceed three times the intensity of dead load, the clause is satisfied essentially by the following moments :

Negative moment at face of first interior support

For beams and girders and for slabs exceeding 10 feet

Two spans $\frac{1}{8}\ wl'^2$

More than two spans $\frac{1}{10}\ wl'^2$

For slabs not exceeding 10 feet in span

Two spans $\frac{1}{10}\ wl'^2$

More than two spans $\frac{1}{12}\ wl'^2$

Negative moment at face of other interior supports

$\frac{1}{12}\ wl'^2$

Positive moment at center of span

End spans $\frac{1}{10}\ wl'^2$

Interior spans $\frac{1}{12}\ wl'^2$

Shear in end members at first interior support $1.20\ \frac{wl'}{2}$

(Foot note + cont'd)

Shear at other supports $\frac{wl'}{2}$

For the purpose of applying this method "approximately" shall be construed to mean that the longer of two adjacent spans shall not exceed the shorter by more than 20 per cent. In these expressions l' = the clear span for positive moments and the average of the two adjacent clear spans for negative moment.

2.212 Effective span -

The effective span, l, of a beam or slab should be taken as the lesser of the two following : -

1) the distance between the centers of supports; or

2) the clear distance between supports plus the effective depth of the beam or slab, the effective depth being the distance between the center of the tension and the edge of the compression section.

In slabs built integrally with supports capable of fully restraining the slab the effective span length may be taken as the clear distance between supports.

2.213 Slender beams -

Where the length l of a beam between adequate lateral restraints exceeds 20 times the least breadth b of its compression flange, the maximum compressive stress in the concrete should not exceed the product of the permissible compressive stress due to bending given in Section 1 of this code, and the appropriate coefficient given in the following Table.:

STRESS REDUCTIONS FACTORS FOR SLENDER BEAMS

Slenderness ratio l/b	20	30	40	50	60
Coefficients +	1-00	0-75	0-50	0-25	0

+ Intermediate values may be obtained by linear interpolation.

2.214 Permissible assumptions -

In the application of the principle of continuity, the following assumptions shall be permissible :

1) Consideration may be limited to combinations of dead load on all spans with full live load on two adjacent spans and with full live load on alternate spans.

2) Any reasonable and consistent assumptions may be made as to the relative stiffness of the floor construction and columns. In computing the relative stiffness of floors to columns, the value "I" of the floor members may be based on the entire concrete sections neglecting the reinforcement, and that of columns on the entire concrete section plus the transformed steel section. The moment of inertia assumed for the columns in computing bending moments must also be used in computing stresses.

3) The far ends of columns above and below the floor under consideration may be considered fixed.

4) When members are deepened near their ends by haunches they may be analyzed as members of constant section provided the minimum depth is used throughout in computing stresses due to bending; otherwise a complete analysis is required. Where members are widened near their supports the additional width may be neglected in computing moments but may be used in computing stresses.

Additional section at the end may in any case be utilized in resisting shear.

5) In the application of the principle of continuity, center to center distances may be used in the moment determination of all members.

Moments prevailing at the faces of support may be used to proportion the members at these sections.

2.215 Limitations -

1) Wherever at any section positive (tension) reinforcement is indicated by analysis, the amount provided shall be not less

than 5% b'd except in slabs of uniform thickness.

2) Not less than 5% b'd of negative (compression) reinforcement shall be provided at the outer end of all members built integrally with their supports.

3) The compression reinforcement should be effectively anchored in two directions at right angles over the distance where it is required to act in compression, at points not further apart, center to center, than sixteen times the diameter of the anchored bar or 48 tie diameters. The subsidiary reinforcement used for this purpose should pass round, or be hooked over, both the compressive and tensile reinforcement.

4) In slabs of uniform thickness the minimum amount of reinforcement in the direction of principal stress shall be

For structural, intermediate and hard grades and rail steel.. 0025 bd
For steel having a minimum yield point of 56000 lb. per sq.in. 002 bd

2.216 Depth of Beam or Slab -

The depth of the beam or slab shall be taken as the distance from the centroid of the tensile reinforcement to the compression face of the structural members. Any floor finish not placed monolithically with the floor slab shall not be included as a part of the structural member. When the finish is placed monolithically with the structural slab in buildings of the warehouse or industrial class, there shall be placed an additional depth of ½ inch over that required by the design of the member.

2.217 Expansion joints -

It is recommended that the question of the provision of the expansion joints should be left to the direction of the reinforced concrete designer, owing to the large number of factors which are involved.

2.22 T-Beams -

a) In T-beam construction the slab and beam shall be built integrally. The effective flange width to be used in the design of symmetrical T-beams shall not exceed the least of the following values :

1) One third of the effective span of the T-beams

2) the distance between the centers of the ribs of the T-beams

3) the breadth of the rib plus twelve times the thickness of the slab.

b) Where the principal reinforcement in a slab which is considered as the flange of a T-beam (not a rib in ribbed floors) is parallel to the beam, transverse reinforcement shall be provided in the top of the slab. This reinforcement shall be designed to carry the load on the portion of the slab assumed as the flange of the T-beam. The spacing of the bars shall not exceed five times the thickness of the flange, nor in any case 18 inches.

c) The overhanging portions of the flange of the T-beam shall not be considered as effective in computing the shear and diagonal tension resistance of T-beams.

d) Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness not less than one-half the width of the web and a total flange width not more than four times the web thickness.

2.23 L-Beams -

In L-beams the breadth of the flange assumed as taking compression should not exceed the least of the following :

1) One sixth of the effective span of the L-beams

2) the breadth of the rib plus one-half of the clear distance between ribs;

3) the breadth of the rib plus four times the thickness of the slab.

When a part of a slab is considered as the flange of a T-beam or L-beam, the reinforcement in the slab transverse to the beam should cross the full breadth of the flange. Where the slab is assumed to be spanning independently in the same direction as the beam such transverse reinforcement should be near the top surface of the slab.

The quantity of such reinforcement should be related to the shear stress in the slab produced by its acting as the compression member of the T-beam of L-beam.

2.24 <u>One-way Ribbed Floor Construction</u> -

a) Ribbed floor construction consists of concrete ribs and slabs placed monolithically with or without burned clay or concrete block fillers. The ribs shall not be farther apart than 30 inches face to face. The ribs shall be straight, not less than 4 inches wide, nor of a depth more than 3 times the width.

b) When burned clay or concrete block fillers, of materials having a unit compressive strength at least equal to that of the designed strength of the concrete in the ribs are used, and the fillers are so placed that the joints in alternate rows are staggered, the shells of the fillers in contact with the ribs may be included in the calculations involving shear or negative bending moment. No other portion of the fillers may be included in the design calculations.

c) The concrete slab over the fillers shall be not less than $1\frac{1}{2}$ inches in thickness, nor less in thickness than one-twelfth of the clear distance between ribs. Shrinkage reinforcement in the slab shall be provided as required in Section

d) Where removable forms or fillers not complying with (b) are used, the thickness of the concrete slab shall not be less than one-twelfth of the clear distance between ribs and in no case less than two inches. Such slab shall be reinforced at right angles to the ribs with a minimum of .049 sq.in. of reinforcing steel per foot of width, and in slabs on which the prescribed live load does not exceed fifty lb.per sq.ft., no additional reinforcement will be required.

e) When the finish used as a wearing surface is placed monolithically with the structural slab in buildings of the warehouse or industrial class, the thickness of the concrete over the fillers shall be ½ inch greater than the thickness used for design purpose.

f) Where the slab contains conduits or pipes, the thickness shall not be less than 1 inch plus the total over-hall depth of such conduits or pipes at any point. Such conduits or pipes shall be so located as not to impair the strength of the construction.

2.25 Floors with support on four Sides -

a) This construction, consisting of floors reinforced in two directions and supported on four sides, includes solid reinforced concrete slabs, concrete ribs with concrete hollow block fillers and top slabs placed monolithically with the ribs.

The supports for the floor slabs may be walls, reinforced concrete beams, or steel beams fully encased in concrete.

b) When a concrete top slab, placed monolithically with the ribs is used, it shall be not less in thickness than 1½ inches nor less than one-twelfth of the clear distances between ribs. It shall be reinforced for shrinkage as required in Section 4.

c) Where removable forms or fillers are used, the thickness of the concrete slab shall not be less than one-twelfth of the clear distance between ribs and in no case less than two inches. Such slab shall be reinforced to provide sufficient strength to carry the imposed loads.

2.26 Bending Moments -

Methods for the calculation of the bending moments in beams and slabs and investigations at supports of beams and slabs are fully dealt with in many text-books on reinforced concrete design to which the reader is referred for guidance.

2.27 Bending moment coefficients for slabs spanning in two directions -

The following table is recommended when computing bending moments in two way slabs.

$\frac{l_s}{l_l}$	B_s	B_l	$\frac{l_s}{l_l}$	B_s	B_l
0.40	0.951	0.013	0.72	0.650	0.118
0.42	0.941	0.015	0.74	0.625	0.130
0.44	0.930	0.018	0.76	0.600	0.143
0.46	0.918	0.022	0.78	0.574	0.156
0.48	0.904	0.026	0.80	0.549	0.170
0.50	0.888	0.030	0.82	0.525	0.184
0.52	0.872	0.035	0.84	0.500	0.200
0.54	0.854	0.040	0.86	0.477	0.215
0.56	0.836	0.046	0.88	0.454	0.230
0.58	0.815	0.053	0.90	0.432	0.247
0.60	0.794	0.061	0.92	0.411	0.263
0.62	0.772	0.069	0.94	0.390	0.281
0.64	0.749	0.077	0.96	0.376	0.298
0.66	0.725	0.087	0.98	0.351	0.315
0.68	0.701	0.097	1.00	0.333	0.333
0.70	0.675	0.107			

2.28 Loads on supporting beams -

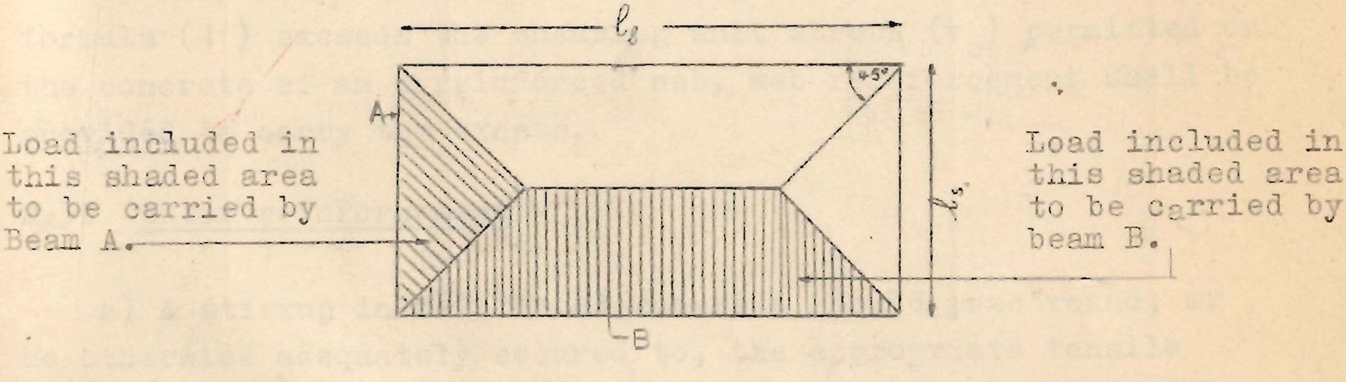
The loads on the supporting beams for a two-way rectangular slab may be assumed as the uniformly distributed load within the tributary areas of the slab bounded by the intersection of 45 degrees lines from the corners with the mediam line of the slab parallel to the long side, see Fig, below, short and long span beams due to one loaded slab are given by the following equations:

Load on short span beam,

i.e. $$W_s = \frac{w l_s^2}{4}$$

Load on long span beam,

i.e. $$W_l = \frac{w l_s l}{2} - W_s$$



2.29 Minimum Slab Thickness -

The slab thickness should not be less than 4 inches.

SECTION 2.3 - SHEAR & DIAGONAL TENSION

2.31 Shearing Unit Stress -

a) The sharing unit stress (v) in reinforced concrete beams shall be computed by formula (1) :

$$v = \frac{V}{bjd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

b) For beams of I or T section b' shall be substituted for b in formula (1).

c) In ribbed construction, where burned clay or concrete block are used, b' may be taken as a width equal to the thickness of the concrete web plus the thicknesses of the vertical shells of the concrete or burned clay block in contact with the joist.

d) When the value of the shearing unit stress computed by formula (1) exceeds the shearing unit stress (v_c) permitted on the concrete of an unreinforced web, web reinforcement shall be provided to carry the excess.

2.32 Shear reinforcement -

a) A stirrup in reinforced concrete should pass round, or be otherwise adequately secured to, the appropriate tensile reinforcement and such stirrup should have both its ends anchored properly.

b) Tensile reinforcement which is inclined and carried through a depth of beam equal to the arm of the resistance moment will also act as shear reinforcement provided it is anchored sufficiently.

c) Where more than one type of reinforcement is used to reinforce the same portion of the web, the total shearing resistance of this portion of the web shall be assumed as the sum of the shearing resistances computed for the various types separately.

In such computations the shearing resistance of the concrete shall be included only once, and no one type of reinforcement shall be assumed to resist more than $\frac{2V'}{3}$.

Where V' is the excess of the total shear over that permitted on the concrete.

2.33 Spacing Web Reinforcement -

a) Where web reinforcement is required it shall be so spaced that every 45 degree line (representing a potential crack) extending from the mid-depth of the beam to the longitudinal tension bars shall be crossed by at least one line of web reinforcement. If a shearing unit stress in excess of 0.06 f'c is used, every such line shall be crossed by at least two such lines of web reinforcement.

b) The pitch or spacing of stirrups should be calculated from the following equation :

$$S = \frac{A_v f_v \, jd}{V'} \quad \text{.....................} \quad (2)$$

where f_v is the permissible tensile stress in the shear reinforcement

A_v is the cross-sectional area of the stirrups

jd is the arm of the resistance moment.

V' is the resistance to shear.

Tests indicate that the most effective results are obtained when $S = \frac{1}{3}$ d.

SECTION 2·4 - BOND & ANCHORAGE

2.41 Length of embedment -

2.411 Bars in tension -

A bar in tension should extend from any section, on the side furthest from the point of maximum moment, for a distance such that the average bond stress does not exceed the appropriate permissible bond stress given in Section 1.

This condition will be satisfied if the length measured from such section is at least equal to m times the diameter of the bar, where :

$$m = \frac{\text{the tensile stress in the bar}}{\text{four times the permissible bond stress } u}$$

In no case should the value of m be less than 12, nor should the length of lap ever be less than 12 bar diameters.

2.412 Bars in compression -

The length of bar beyond any section should not be less than m times the diameter of the bar where :

$$m = \frac{\text{the compressive stress in the bar}}{\text{five times the permissible bond stress } u}$$

2.42 Computation of Bond stress in Beams -

a) In flexural members in which the tensile reinforcement is parallel to the compression face, the bond stress at any cross section shall be computed by formula (3)

$$u = \frac{V}{\sum_o jd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where V is the total shear across the section
jd is the arm of resistance moment
Σ_o is the sum of the perimeters of the bars in the tensile reinforcement.

In members of variable depth the effect of the change in depth should be taken into account in calculating the bond stress.

b) Adequate end anchorage shall be provided for the tensile reinforcement in all flexural members to which formula (3) does not apply, such as footings, brackets and other tapered or stepped beams in which the tensile reinforcement is not parallel to the compression face.

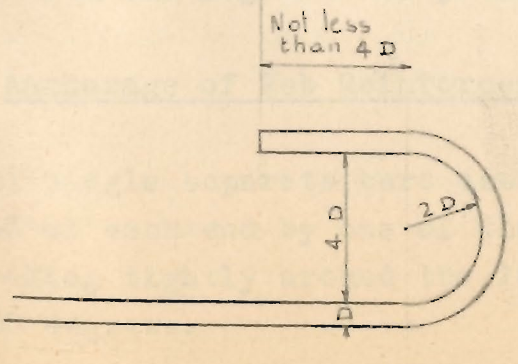
2.43 Hooks

2.43I Hooks and other anchorages -

Hooks and other anchorages of reinforcement in reinforced concrete should be of such form, dimensions and arrangement as will ensure their adequacy without overstressing the concrete or the steel.

2.432 Dimentions of hooks (U hooks)

A hook at the end of a bar should be of the form indicated in the figure below with an inner diameter of no less than four times the diameter of the bar, and a length of straight part beyond the end of the curve of at least four times the diameter of the bar, except that, when the hook fits over a main reinforcing or other adequate anchor bar, the diameter of the hook may be equal to the diameter of such bar.



2.44 Ordinary Anchorage requirements -

a) Tensile reinforcement in any span of a continuous restrained, or cantilever beam, or in any member of a rigid frame shall be adequately anchored.

Within any such span every reinforcing bar shall be extended at least 12 diameters beyond the point at which it is no longer needed to resist stress.

In cases where the length from the point of maximum tensile stress in the bar to the end of the bar is not sufficient to develop this maximum stress by bond, the bar shall extend into a region of compression and be anchored by means of a standard hook or it shall be bent across the web at an angle of not less than 15 degrees with the longitudinal portion of the bar and either made continuous with the positive reinforcement or anchored in a region of compression.

b) Of the compression reinforcement in continuous beams not less than one-fourth the area shall extend along the same face of the beam into thesupport a distance of ten or more bar diameters, or shall be extended as far as possible into the support and terminated in standard hooks.

2.45 Special anchorage requirements -

Where increased shearing or bond stresses are permitted because of the use of special anchorage every bar shall be terminated in a standard hook in a region of compression, or it shall be bent across the web at an angle of not less than 15 degrees with the longitudinal portion of the bar and made continuous with the negative or positive reinforcement.

2.46 Anchorage of Web Reinforcement -

a) Single separate bars used as web reinforcement shall be anchored at each end by one of the following methods :

1) Hooking tightly around the longitudinal reinforcement through 180 degrees.

2) Standard hook plus embedment in the compression area of the beam, which embedment exclusive of the hook shall be sufficient to develop by bond a stress of not less than 10,000 lb. per sq. in. at a bond stress of not more than .04 f'_c on plain bars nor .05 f'_c on deformed bars.

b) The loops or closed ends of such stirrups shall be anchored by bending around the longitudinal reinforcement through an angle of at least 90 degrees.

c) Hooking or bending stirrups or separate web reinforcement bars around the longitudinal reinforcement shall be considered effective only when these bars are perpendicular to the longitudinal reinforcement.

d) Longitudinal bars bent to act as web reinforcement shall, in a region of tension be continuous with the longitudinal reinforcement. The tensile stress in each bar shall be fully developed in both the upper and the lower half of the beam by one of the following methods :

1) As specified in Section 2.46 (a)

2) By bond at a unit bond stress not exceeding .04 f'_c on plain bars nor .05 f'_c on deformed bars, plus a bend of radius not less than two times the diameter of the bar, parallel to the upper or lower surface of the beam, plus an extension of the bar of not less than 12 diameters of the bar terminating in a standard hook. This short radius bend extension and hook shall together not be counted upon to develop a tensile unit stress in the bar of more than 10,000 lb. per sq. in.

3) By bond at a unit bond stress not exceeding .04 f'_c on plain bars nor .05 f'_c on deformed bars, plus a bend, of radius not less than 2 times the diameter of the bar, parallel to the upper or lower surface of the beam and continuous with the longitudinal reinforcement. The short radius bend and continuity shall together not be counted upon to develop a tensile unit stress in the bar of more than 10,000 lb. per sq. in.

e) In all cases web reinforcement shall be carried as close to the compression surface of the beam as fireproofing regulations and the proximity of other steel will permit.

2.47 Anchorage of Bars in Footing slabs -

All bars in footing slabs, except the longitudinal reinforcement between loads in continuous slab footings, shall be anchored by means of standard hooks. The outer faces of these hooks shall be not less than three inches nor more than six inches from the face of the footing.

2.48 Deformed bars -

In the case of deformed bars, the bond stresses u in Section 1, may be increased by 10 per cent.

For the purpose of this clause, a deformed bar is one for which it has been proved that the bond strength exceeds that of a plain round bar by 10 per cent or more.

SECTION 2.5 - C O L U M N S

2.51 General -

2.511 Limiting Dimensions -

The following sections on reinforced concrete and composite columns apply to a short column, for which the unsupported length is not greater than 10 times the least lateral dimension. When the unsuported length exceeds this value the design shall be modified as shown in Section 2.57. Principal columns in buildings shall have a minimum diameter or thickness of 10 inches and a minimum gross area of 120 sq. in. Posts that are not continuous from story to story shall have a minimum diameter or thickness of 6 inches.

2.512 Unsupported Length of Columns -

a) For purposed of determining the limiting dimensions of columns, the unsupported length of reinforced concrete columns shall be taken as the clear distance between floor slabs, except that

1) In beam and slab construction, it shall be the clear distance between the floor and the under side of the deeper beam framing into the column in each direction at the next higher floor level.

2) In columns restrained laterally by struts, it shall be the clear distance between consecutive struts in each vertical plane; provided that to be an adequate support, two such struts shall meet the column at approximately the same level, and the angle between vertical planes through the struts shall not vary more than 15 degrees from a right angle. Such struts shall be of adequate dimensions and anchorage to restrain the column against later deflection.

3) In columns restrained laterally by struts or beams, with brackets used at the junction, it shall be the clear distance

between the floor and the lower edge of the bracket, provided that the bracket width equals that of the beam or strut and is at least half that of the column.

b) For rectangular columns, that length shall be considered which produces the greatest ratio of length to depth of section.

2.52 Spirally Reinforced Columns -

2.521 Permissible Load -

The maximum permissible axial load, P, on columns with closely spaced spirals enclosing a circular concrete core reinforced with longitudinal bars shall be that given by Formula (4)

$$P = A_g \quad (0.22\ f'c \ + \ f_s p_g) \quad \ldots\ldots\ldots \quad (4)$$

Wherein A_g = the gross area of the column

$f'c$ = compressive strength of the concrete

f_s = nominal working stress in vertical column reinforcement, to be taken at 40 per cent of the minimum specification value of the yield point; viz., 16,000 lb. per sq. in. for intermediate grade steel.

p_g = ratio of the effective cross-sectional area of vertical reinforcement to the gross area, A_g.

2.522 Longitudinal reinforcement -

A reinforced concrete column should have longitudinal steel reinforcement, and the cross-sectional area of such reinforcement should not be less than 0.1 per cent nor more than 8 per cent of the gross cross-sectional area of the column required to transmit all the loading in accordance with this code.

The minimum number of bars shall be six and the minimum diameter shall be 5/8 in.

The center to center spacing of bars within the periphery of the column core shall not be less than $2\frac{1}{2}$ times the diameter for round bars or 3 times the side dimension for square bars. The clear spacing between bars shall not be less than $1\frac{1}{2}$ times the maximum size of the coarse aggregate used. These spacing rules also apply to adjacent bars at a lapped splice.

2.523 Splices in Vertical Reinforcement -

Where lapped splices in the column verticals are used, the minimum amount of lap shall be as follows :

1) For deformed bars - with concrete having a strength of 3000 lb. sq. in. or above 24 diameters of bar of intermediate grade steel and 30 diameter of bar of rail steel. For bars of higher yield point, the amount of lap shall be increased in Proportion to the nominal working stress. When the concrete strengths are less than 3000 lb. per sq. in. the amount of lap shall be one-third greater than the values given above.

2) For plain bars - the minimum amount of lap shall be 25 per cent greater than specified for deformed bars.

3) Welded splices or other positive connections may be used instead of lapped splices. Welded splices shall preferably be used in cases where the bar diameter exceeds $1\frac{1}{4}$ in. An approved welded splice shall be defined as one in which the bars are butted and welded and that will develop in tension at least the yield point stress of the reinforcing steel used.

2.524 Spiral Reinforcement -

The ratio of spiral reinforcement, (p') shall not be less than the value given by Formula (5), nor shall it be less in any case than 0.0112 for hot rolled spirals of intermediate grade or 0.0075 for cold drawn wire spirals.

$$p' = 0.45 \ (R - 1) \ \frac{f'c}{f's} \quad \ldots\ldots\ldots \quad (5)$$

Wherein p' = ratio of volume of spiral reinforcement to the volume of the concrete core (Out to out of spirals).

R = ratio of gross area to core area of column, A_g/A_c.

f'_s = useful limit stress of spiral reinforcement, to be taken as 40,000 lb. per sq. in. for hot rolled rods of intermediate grade and 60,000 lb. per sq. in. for cold drawn wire.

The spiral reinforcement shall consist of evenly spaced continuous spirals held firmly in place and true to line by at least three vertical spacer bars. Anchorage of spiral reinforcement shall be provided by 1½ extra turns of spiral rod or wire at each end of the spiral unit.

Splices, when necessary, shall be made in spiral rod or wire by welding or by a lap of 1½ turns. The center spacing of the spirals shall not exceed one-sixth of the core diameter. The clear spacing between spirals shall not exceed 3 in. nor be less than 1⅜ in. or 1½ times the maximum size of coarse aggregate used. The reinforcing spiral shall extend from the floor level in any story or from the top of the footing in the basement, to the level of the lowest horizontal reinforcement in the slab, or beam above. In a column with a capital it shall extend to the plane at which the diameter or width of the capital is twice that of the column.

2.525 <u>Protection of Reinforcement</u> -

The column reinforcement shall be protected everywhere by a covering of concrete cast monolithical with the core, for which the thickness shall not be less than 1½ in. nor less than 1½ times the maximum size of the coarse aggregate.

2.526 <u>Limits of Column Section</u> -

For columns built monolithically with concrete walls or piers the outer boundary of the column section shall be taken either as a circle $1\frac{1}{2}$ in. outside the column spiral or as a square or rectangle of which the sides are $1\frac{1}{2}$ in. outside the spiral. The value A_g thus defined shall be used in both Formulas (4) and (5). In any case it shall be permissible to design a circular column and to build it as a square column of the same least later dimension. In such case the permissible load, the gross area considered, and the required percentage of reinforcement must be taken as those of the circular column.

2.53 Tied Columns -

2.531 Permissible load -

The maximum permissible axial load on columns reinforced with longitudinal bars and separate lateral ties shall be 70 per cent of that given by Formula (4). The ratio (p_g), to be considered in tied columns shall not be less than 0.01 nor more than 0.04.

The longitudinal reinforcement shall consist of at least four bars, of minimum diameter of 5/8 inch.

Splices in reinforcing bars shall be made as described in Section 2.523.

2.532 Lateral ties -

Lateral ties shall be so disposed as to provide all necessary restraint against the buckling of each of the longitudinal reinforcements. Every bar in a column near the face should be properly linked. The ends of such transverse reinforcements should be properly anchored.

Lateral ties should not be less than onequarter the diameter of the main rods, and in no case less than $\frac{1}{4}$ in.

Lateral ties shall be spaced apart not more than the least of the three following distances :

1) the least lateral dimension of the column

2) twelve times the diameter of the smallest longitudinal reinforcement in the column

3) 12 in.

When there are more than four vertical bars, additional ties shall be provided so that every lingitudinal bar is held firmly in its designed position and has lateral support equivalent to that provided by a 90-degree corner of a tie.

2.533 Limits of Column Section -

In a tied column which for architectural reasons has a larger cross section that required by considerations of loading, a reduced effective are (A_g) not less than one-half of the total area may be used in applying the provisions of Section 2.531.

2.54 Composite Columns -

2.541 Permissible Load -

The permissible load on a composite column consisting of a structural steel or cast-iron column thoroughly encased in concrete reinforced with both longitudinal and spiral reinforcement, shall not exceed that given by Formula (6).

$$P = 0.22 A_c f'_c + f_s A_s + f_r A_r \quad \text{...............(6)}$$

Wherein A_c = net area of concrete section
$= A_g - A_s - A_r$.

A_s = cross sectional area of longitudinal bar reinforcement
A_r = cross sectional area of the steel or cast-iron core
f_r = permissible unit stress in metal core, not to exceed 16,000 lb. per sq. in. for a steel core; or 10,000 lb. per sq. in. for a cast-iron core.

The remaining notation is that of Section 2.52.

2.542 Details of Metal Core and Reinforcement -

The cross sectional area of the metal core shall not exceed 20 per cent of the gross area of the column. If a hollow metal core is used it shall be filled with concrete. The amounts of longitudinal and spiral reinforcement and the requirements as to spacing of bars, details of splices and thickness of protective shell outside the spiral that conform to the limiting values specified in Sections 2.522, 2.523 and 2.524. A clearance of at least 3 inches shall be maintained between the spiral and the metal core at all points except that when the core consists of a structural steel H-column, the minimum clearance may be reduced to 2 inches.

2.543 Splices and Connections of Metal Cores -

Metal cores in composite columns shall be accurately milled at splices and positive provision shall be made for alignment of onecore above another.

At the column base, provision shall be made to transfer the load to the footing at safe unit stresses in accordance with Section (1) of this code. The base of the metal section shall be designed to transfer the load from the entire composite column to thefooting, or it may be designed to transfer the load from the metal section only, provided it is so placed in the pier or pedestal as to leave ample section of concrete above the base for the transfer of load from reinforced concrete section of the column by means of bond on the vertical reinforcement and by direct compression on the concrete.

Transfer of loads to the metal core shall be provided for by the use of bearing members such as billets, brackets or other positive connections; these shall be provided at the top of the metal core and at intermediate floor levels where required.

The column as a whole shall satisfy the requirement of Formula (6) at any point; in addition to this, the reinforced concrete portion shall be designed to carry, in accordance with Formula (4), all floor loads brought into the column at levels between the metal brackets or connections. In applying Formula (4), the value of A_g shall be interpreted as the area of the concrete section outside the metal core, and the permissible load on the reinforced concrete section outside the metal core, and the permissible load on the reinforced concrete section shall be further limited to $0.35\ f'_c\ A_g$.

Ample section of concrete and continuity of reinforcement shall be provided at the junction with beams or girders.

2.544 Permissible Load on Metal core only -

The metal cores of composite columns shall be designed to carry safely any struction or other loads to be placed upon them prior to their encasement in concrete.

2.55 Combination Columns -

2.551 Steel Columns Encased in Concrete -

The permissible load on a structural steel column which is encased in concrete at least 2½ inches thick over all metal (except rivet heads) reinforced as hereinafter specified shall be computed by Formula (7).

$$P = A_r f'_r \left(1 + \frac{A_g}{100 A_r} \right) \ldots\ldots\ldots\ldots (7)$$

Wherein A_r = cross-sectional area of steel column.
f'_r = permissible stress of unencased steel column
A_g = total area of concrete section.

The concrete used shall develop a compressive strength, (f'_c) or at least 2000 lb. per sq. in. at 28 days.

The concrete shall be reinforced by welded wire mesh+ encircling the column being spaced not more than 4 inches apart and those parallel to the column axis not more than 8 inches apart. This mesh shall extend entirely around the column at a distance of one inch inside the outer concrete surface and shall be lap-spliced at least 40 wire diameters and wired at the splice.

Special brackets shall be used to receive the entire floor load at each floor level. The steel column shall be designed to

+ Wire mesh gage Number will be specified by the Engineer.

carry safely any construction or other loads to be placed upon it prior to its encasement in concrete.

2.552 Pipe Columns -

The permissible load on columns consisting of steel pipe filled with concrete shall be determined by Formula (8).

$$P = 0.22 f'_c A_c + f'_r A_r \quad \ldots\ldots\ldots\ldots\ldots\ldots (8).$$

The value of f'_r shall be that given by Formula (9).

$$f'_r = (18{,}000 - 70 \frac{h}{K}) F \quad \ldots\ldots\ldots\ldots\ldots (9).$$

Wherein f'_r = average unit stress in metal core

h = unsupported length of column

K = least radius of gyration of metal core section

$$F = \frac{\text{yield point of pipe}}{45{,}000}$$

If the yield point of the pipe is not known, the factor F shall be taken as 0.5.

2.56 Long Columns -

The maximum allowable load P' on axially loaded reinforced concrete or composite columns having a length, h, greater than 10 times the least lateral dimension, d, is given by Formula (10)

$$P' = P\ (1.3 - .03 \frac{h}{d}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

Wherein P = the allowable axial load on a short column as given by Formulas (4) and (6).

The maximum allowable load P' on eccentrically loaded columns in which h/d exceeds 10 is also given by Formula (10) in which P is the allowable eccentrically applied load on a short column as determined by the provisions of Sec. 2.58-2.59.

In long columns subjected to definite bending stresses, as determined in Sec. 2.57, the ratio h/d should not exceed 20.

2.57 Bending Moments in Columns -

The bending moments in the columns of all reinforced concrete structures shall be determined on the basis of loading conditions and restraint and shall be provided for in design.

When the stiffness and strength of the columns are utilized to reduce moments in beams, girders, or slabs, as in the case of rigid frames, or in other forms of continuous constructions wherein column moments are unavoidable, they shall be provided for in the design.

In building frames, particular attention shall be given to cases of unbalanced floor loads on both exterior and interior columns and of eccentric loading due to other causes.

Wall columns shall be designed to resist moments produced by

1) Loads on all floors of the buildings
2) Loads on single exterior bay at two adjacent floor levels, or
3) Loads on a single exterior bay at one floor level.

Resistance to bending moments at any floor level shall be provided by distributing the moment between the columns immediately above and below the given floor in proportion to their relative stiffness and conditions of restraint.

Bending moments in internal columns supporting an approximately symetrical arrangement of beams and loading need not be calculated except in the case of flat slab construction.

2.58 Combined Axial and Bending Stress -

In reinforced concrete columns subjected to bending moments, the recognized methods of analysis shall be followed in calculating the stresses due to combined axial load and bending. The maximum fiber stress in compression and (in the case of large eccentricities of loading) the tensile stress in the vertical bars will govern the design. The gross area of both spiral and tied columns shall be used in the computations[+].

2.59 Permissible Combined Compressive and Tensile Stress -

The maximum permissible compressive fiber stress, f_c, in eccentrically loaded columns shall be given by Formulas (11) and (12).

For spiral columns

$$f_c = \frac{0.22\, f'_c + f_s p_g}{1 + (n-1)\, p_g} \quad \frac{1 + \frac{ec}{R^2}}{1 + .8\frac{ec}{R^2}} \qquad \ldots\ldots\ldots\ldots (11)$$

For tied columns

$$f_c = \frac{0.154\, f'_c + 7\, f_s p_g}{1 + (n-1)\, p_g} \quad \frac{1 + \frac{ec}{R^2}}{1 + .8\frac{ec}{R^2}} \qquad \ldots\ldots\ldots\ldots (12)$$

The permissible tensile stress in the longitudinal reinforcement may equal that specified for flexural members, provided however that splices in the tensile steel at or near the section of maximum column moment are capable of developing fully the yield point strength of the reinforcement.

[+]For preliminary designs it will usually give satisfactory results to compute the combined fiber stress in compression on the basis of an uncracked section of the column, using Formula (13).

$$f_c = \frac{P}{A_g} \frac{\left(1 + \frac{ec}{R^2}\right)}{1 + (n-1)p_g} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13).$$

Wherein e = eccentricity of resultant load, measured from the gravity axis

c = distance from gravity axis to extreme fiber in compression.

R = radius of gyration of equivalent concrete section.

$n = \frac{30,000}{f'_c}$

(Foot note + cont'd)

This will result in a fairly accurate design if the eccentricity is less than ½ the over-all column depth and the value of $p_g n$ is 0.3 or more.

The term $\frac{ec}{R^2}$ may be replaced by the value $\frac{6e}{t}$ for rectangular columns and $\frac{8e}{t}$ for round columns without appreciable error (t = over-all depth of section). This design may then be analyzed by more accurate methods to insure that permissible stresses are not exceeded.

SECTION 3. FORMWORK.

SECTION 3 - FORMWORK

3.1 General -

Attention is drawn to the importance of the design of the formwork which can be an important factor in the economy and efficiency of reinforced concrete construction. The detailed design should preferably be undertaken by an expert and is considered to be outside the scope of the present code. The important qualities of good formwork relate to : rigidity and strength, economy of material, re-use, convenience of erection and striking, and good surface finish.

Forms shall conform to the shape, lines, grades, and dimensions of the concrete as called for on the drawings. Lumber used in forms for exposed surfaces shall be dressed to a uniform thickness, and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical where appearance of the finished surface is of importance. For unexposed surfaces and rough work, undressed lumber may be used. Lumber one used in forms shall have nails withdrawn, and surfaces to be in contact with concrete thoroughly cleaned before being used again.

3.2 Design -

Forms shall be sufficiently tight to prevent leakage of mortar. They shall be properly braced or tied together so as to maintain the desired position and shape during and after placing concrete. In the case of very long spans where no intermediate supports are possible, the probable deflection in the forms due to the weight of the fresh concrete shall be taken into account so that the finished members shall conform accurately to the desired line and grade. If adequate foundation for shores cannot be secured, trussed supports shall be provided.

Bolts and rods shall preferably be used for internal ties; they shall be so arranged that when the forms are removed no metal shall be within 1 inch of any surface. Shores supporting successive storeys shall be placed directly over those below, or so designed and placed that the load will be transmitted directly to them.

3,3 Pipes, Conduits, etc. Embedded in Concrete

Pipes which will contain liquid, gas or vapor at other than room temperature shall not be embedded in concrete necessary for structural stability or fire protection.

Electric conduits, sleeves and other pipes whose embedment is allowed shall not be of such size or in such location as unduly to impair the strength of the construction; such sleeves or pipes may be considered as replacing structurally the displaced concrete, provided they are not exposed to rusting or other deterioration.

Embedded pipes or conduits other than those merely passing through, shall not be larger in outside diameter than one-third the thickness of the slab, wall or beam in which they are embedded, nor so located as unduly to impair the strength of the construction.

3.4 Oiling -

The inside of forms shall be coated with nonstaining mineral oil or other approved meterial, or in case of wood forms they shall be thoroughly wetted (except in freezing weather). Where oil is used it shall be applied before the reinforcement is placed.

3.5 Camber -

It is generally desirable to give forms an upward camber to ensure that the beams will not have a sag when they have taken up their deflection, but this should not be done unless allowed for in the design calculations of the beams.

3.6 Inspection -

Temporaly openings shall be provided at the base of column and wall forms and at other points where necessary to facilitate cleaning and inspection immediately before depositing concrete.

3.7 Removal of forms -

The removal of forms shall not be started until the concrete has attained the necessary strength to support its own weight and any construction live loads.

All formwork should be removed without such shock or vibration as would damage the reinforced concrete.

Where the structure as a whole is supported on shores, the removable floor forms, beams and girder sides, column and similar vertical forms may be removed after 24 hours, providing the concrete is sufficiently hard not to be injured thereby.

Before the soffit and struts are removed the concrete surface should be exposed where necessary in order to ascertain that the concrete has sufficiently hardened. Proper precautions should be taken to allow for the decrease in rate of hardening that occurs with all cements in cold weather.

SECTION 4 STEEL REINFORCEMENT

SECTION 4 - STEEL REINFORCEMENT

4.1 Handling Metal Reinforcement -

4.11 Cleaning -

Metal reinforcement before being positioned shall be free from loose mill and rust scale and from coatings, including ice, that destroy or reduce the bond. Where there is delay in depositing concrete, reinforcement shall be reinspected and cleaned when necessary.

4.12 Fabrication -

Reinforcement shall be accurately formed to the dimensions indicated on the drawings. Stirrups and tie bars shall be bent around a pin having a diameter not less than 2 times the minimum thickness of the bar. Bends for other bars shall be made around a pin having a diameter not less than 6 times the minimum thickness except for bars larger than one inch in which case the bends shall be made around a pin of eight bar diameters. All bars shall be bent cold.

4.13 Straightening and Rebending -

Metal reinforcement shall not be straightened or rebent in a manner that will injure the material. Bars with kinks, or bends not shown on the drawing shall not be used. Heating of the reinforcement will be permitted only when the entire operation is approved by the Engineer.

4.14 Placing -

All reinforcement should be placed and maintained in the position shown on the drawings.

Metal reinforcement shall be accurately positioned and secured against displacement by using annealed iron wire ties or suitable clips at intersections.

Definite methods of ensuring the adequacy of cover should be sought by the contractor and the designer acting in conjunction.

4.15 Splicing of Reinforcement -

When it is necessary to splice reinforcement at points other than shown on the drawings, the character of the splice shall be determined by the Engineer.

In such splices the bars shall be placed in contact and wired. Splices in adjacent bars shall be staggered.

4.16 Future Bonding -

Exposed reinforcement intended for bonding with future extensions shall be effectively protected from corrosion.

4.17 Electric currents -

No part of the reinforcement should be used for conducting electric currents.

4.2 Cover -

Reinforcement should have concrete cover and the thickness of such cover (exclusive of plaster or other decorative finish) should be :

a) for each end of a reinforcing bar, not less than 1 in., nor less than twice the diameter of such rod or bar.

b) for a longitudinal reinforcing bar in a column, not less than 2 in., nor less than the diameter of such rod or bar.

c) for a longitudinal reinforcing bar in a beam, not less than $1\frac{1}{2}$ in., nor less than the diameter of such rod or bar.

d) for tensile, compressive, shear or other reinforcement in a slab, not less than $\frac{3}{4}$ in., nor less than the diameter of such reinforcement.

e) for any other reinforcement, not less than $\frac{3}{4}$ in., nor less than the diameter of such reinforcement.

f) At those surfaces of footings and other principal structural members in which the concrete is deposited directly against the ground, metal reinforcement shall have a minimum covering of 3 inches of concrete. At other surfaces of concrete exposed to the ground or to severe weathering conditions, metal reinforcement shall be protected by not less than 2 inches of concrete for bars over 5/8. in diameter, and $1\frac{1}{2}$ in. for bars 5/8 in. diameter or less. At underside of slabs exposed to weather one inch shall be provided.

In case of bars which are not round, and twin bars, the diameter should be taken as the diameter of a circle giving an equivalent area.

4.3 Distance between bars -

The distance between two parallel steel reinforcements in reinforced concrete should be not less than the greatest of the three following distances :

a) the diameter of either bar if the diameters be equal

b) the diameter of the larger bar if the diameters be unequal

c) $\frac{1}{4}$ in. more than the nominal maximum size of the coarse aggregate comprised in such concrete.

A greater distance should be provided when convenient.

The vertical distance between two horizontal main steel reinforcements, or the corresponding distance at right angles to two inclined main steel reinforcements, should be not less than $\frac{1}{2}$ in., except at a splice or lap and except where one of such reinforcements is transverse to the other.

The pitch of the main bars in a reinforced concrete solid slab should not be more than three times the effective depth of such slab.

The pitch of distributing bars in a reinforced concrete solid slab should not be more than four times the effective depth of such slab.

In the case of bars which are not round, the diameter should be taken, for the purpose of this clause, as the diameter of a circle giving an equivalent area.

4.4 Shrinkage and Temperature Reinforcement -

Reinforcement for shrinkage and temperature stresses normal to the principal reinforcement shall be provided in floor and roof slabs where the principal reinforcement extends in one direction only. Such reinforcement shall provide for the following minimum ratios of reinforcement area to concrete area (bd), but in no case shall such reinforcing bars be placed farther apart than five times the slab thickness nor more than 18 inches :

Floor slabs where plain bars are used 0.0025
Floor slabs where deformed bars are used 0.002

SECTION 5 CONTROL OF CONCRETE

SECTION 5.1 - M A T E R I A L S

5.11 Cement -

The cement used should be Chekka Portland Cement.

When European cement is used, the engineer should satisfy himself either by means of his own tests or by reference to reliable sources of information that the material which he proposes to use will adequately fulfill his special requirements.

5.12 Aggregates -

All aggregates should consist of inert materials that are clean, hard strong and durable. The particles should not be coated with clay or dirt.

5.121 Fine Aggregate -

a) General -

Fine aggregate shall consist of natural sand, sand prepared from the product obtained by crushing store, gravel; or, subject to the approval of the Engineer, other inert materials having similar characteristics. The particular type or types to be furnished shall be specified by the Engineer.

b) Uniformity -

Fine aggregate shall be well graded from coarse to fine and when tested by means of laboratory sieves shall conform to the following requirements :

$\frac{3}{8}$ " sieve	100 % passing
No. 4 (4760 micron)	95 to 100 % passing
No. 16 (1190 micron)	45 to 80 % passing
No. 50 (297 micron)	10 to 30 % passing
No. 100(149 micron)	2 to 10 % passing

at the approval of the engineer the above ranges may be varied to suit the job requirements.

However, in no case should a range in grading be specified more restrictive than indicated below :

No. 16 sieve	20 % passing
No. 50 sieve	15 % passing
No. 100 sieve	5 % passing

For the purpose of determining the degree of uniformity of a fine aggregate, a fineness modulus determination shall be made upon representative samples of fine aggregate from such sources as are proposed for use.

Fine aggregate from any one source having a variation in fineness modulus greater than plus or minus 0.20 from the fineness modulus of the representative sample submitted by the contractor shall either be rejected or may be accepted subject to such adjustment in proportions as may be necessary by reason of changes in grading of fine aggregate.

Fine aggregate from different sources of supply shall not be mixed or stored in the same pile nor used alternately in the same class of construction or mix, without permission from the engineer.

c) Organic Impurities -

All fine aggregate shall be free from injurious amounts of organic impurities.

5.122 Coarse Aggregate -

a) General -

Coarse aggregate shall consist of crushed stone, gravel, or other approved inert materials of similar characteristics, or combinations thereof, having hard, strong, durable pieces, free from adherent coatings and conforming to the requirements of these specifications.

b) Grading -

Coase aggregate should not be made up of particles of one size but should be graded from $\frac{1}{4}$ inch up to the maximum size.

The maximum size of the aggregate shall be not larger than one-fifth of the narrowest dimension between forms of the member for which the concrete is to be used nor larger than three-fourths of the minimum clear spacing between reinforcing bars.

5.13 Water -

Water used in mixing concrete shall be clean, and free from deleterious amounts of acids, alkalis, or organic materials.

Sea water should not be used for mixing concrete.

5.14 Metal Reinforcement -

a) General -

The principal requirements in the selection of metal reinforcement are the yield point, the bond value, and the ductility.

b) Quality -

The reinforcement should be rolled steel bars or such other reinforcement as may be suitable, having regard to the yield-points stress, ductility, ultimate resistance to tension and other essential properties of the completed reinforcement as produced in readiness for use in the reinforced concrete.

The engineer should satisfy himself either by means of his own tests or by reference to reliable sources of information that the reinforcement which he proposes to use will adequately fulfill his special requirements.

5.15 Storage of Materials -

Cement and aggregates shall be stored at the work in such a manner as to prevent deterioration or intrusion of foreign matter. Any material which has deteriorated or which has been damaged shall not be used for concrete.

SECTION 5.2 - PROPORTIONING

5.21 Basis for Specification -

a) There are two distinct views with respect to the function of the Constractor which cannot be reconciled in a single specification.

The author, therefore, presents alternate specifications covering the sections on proportioning and concrete quality.

b) Under Alternate A the Engineer establishes the general limitations of strength and water content within which the Contractor is permitted considerable latitude in the choice of materials and the methods of handling them. The Contractor is required to produce a plastic and workable concrete of the required strength and water content that can be placed without segregation or honeycomb. Under this Alternate the Contractor assumes the responsibility for the quality. If the concrete is lacking with respect to any of the above qualities, he must make good the deficiency at his own expense.

c) Under Alternate B the Engineer designates in detail the quantities of material to be used, the length of mixing time, amount of water, range in slump, etc., and to this extent is responsible for the quality of the concrete. Changes in quantities or types of materials can be made only on the order of the Engineer and then adjustment of compensation will be required under the clauses covering extra compensation or credit in the contract. The Engineer, on behalf of the owner, is responsible for the adequacy of the specification.

d) In using the accompanying specification, the Engineer must designate which of the Alternates is to be used, and fill in the necessary tables with the specific information required for the project.

5.22 Alternate A -

5.221 Concrete Quality -

It is the intent of this specification to secure, for every part of the work, concrete of homogeneous structure, which, when hardened, will have the required strength and resistance to weathering. To this end, the limiting strengths and water contents shown in Table (5.22 - A) are specified. The values given in Table (5.22 - A) are based on the use of Chekka Portland Cement, aggregates, and water which meet the requirements of this specification.

The strengths shall be determined in accordance with the requirements of Section 5.3. The maximum allowable net water content is the total water in the mixture at the time of mixing, no including the water absorbed by the aggregates.

5.222 Determination of Proportions -

The proportions of cement, aggregates, and water necessary to produce concrete conforming to the requirements of Table (5.22 - A) shall be determined by means of laboratory tests of concrete made with the cement and aggregates to be used on the work.

At least 35 days prior to the beginning of concrete work the Contractor shall submit, for approval, samples of the materials he proposes to use. Prior to the beginning of work he shall also submit a statement of the proportions proposed for the concrete mixtures. This shall be accompanied by a report in detail from an approved testing laboratory or inspection service showing for at least 3 different water contents the 7-day and 28-day concrete strengths obtained when using the materials proposed for the work.

The strength determinations shall be based on not less than 5 concrete test specimens for each age and for each water content. The strength tests shall be made in accordance with

TABLE 5.22 - A

Class	Minimum Allowable Strength, Compressive Flexural at 28 Days; p.s.i. *	Maximum Allowable Net Water Content Per Sack of Cement; gal.	Consistency, Range in Slump; in.	Maximum Size of Aggregate; in.
(1)	(2)	(3)	(4)	(5)

* The Engineer should fill in the details of TABLE (5.22-A) to indicate the characteristics of the concrete which are desired for each part of the work.

The Engineer should strike out one of the words "Flexural" or "Compressive" in column (2) as may be required.

Section 5.3.

The Engineer shall have the right to make check tests of concrete, using the same materials, and to order such changes as may be necessary to meet the requirements of the specifications.

The ratio between the 7-day and 28-day strengths established by the preliminary tests shall be used to determine the 7-day strengths necessary to satisfy the 28 days strength requirements of Table (5.22 - A). This ratio shall be modified as the work progresses as may be indicated by the tests results.

5.223 Workability of Concrete -

The concrete shall be of such consistency and composition that it can be worked readily into the corners and angles of the forms and around the reinforcement without permitting the materials to segregate or free water to collect on the surface.

Subject to the limiting requirements of Table (5.22 - A) the Contractor shall adjust the proportions of cement and aggregate as may be necessary to produce a mixture which will be easily placeable at all times, due consideration being given to the methods of placing and compacting used on the work.

5.224 Changes in Consistency for Mechanical Vibration -

When high frequency mechanical vibration is used for compacting concrete, the limiting consistencies in Table (5.22 - A) may be modified subject to the approval of the Engineer.

5.225 Changes in Proportions or Materials by the Engineer -

If, during the progress of the work, it is found impossible to secure concrete of the required workability and strength with the materials being furnished by the Contractor, the Engineer may order such changes in proportions or materials, or both, as may be necessary to secure the desired properties, subject to the limiting requirements shown in Table (5.22 - A).

Any changes so ordered shall be made at the Contractor's expense, and no extra compensation will be allowed by reason of such changes.

5.226 Changes in Materials by the Contractor -

If, during the progress of the work, the Contractor desires to use materials other than those originally approved, or if the materials from the sources originally approved change in characteristics, he shall submit, for approval, evidence satisfactory to the Engineer that the new combination of Materials will produce concrete meeting the requirement shown in Table (5.22 - A), and will not bring about objectionable changes in the color or appearance of the structure.

5.227 Changes in Requirements -

Regardless of the limitations of Table (5.22 - A), at any time during the progress of the work, the owner shall have the right to make such changes in the materials or proportions, or both as he may consider necessary to meet the requirement of the structure. In such case, the Contractor shall be compensated in accordance with the terms of the contract for the additional cost of materials or mixtures, or both, which are not covered by the specification requirements shown in Table (5.22 - A) for the respective portions of the work involved.

5.228 Concrete Made with High Early Strength Portland Cement -

When high early strength Portland Cement is used in lieu of normal Portland Cement, the requirements given in Table (5.22-A) shall apply except that the "Minimum allowable strength at 28 days" specified for normal Portland Cement shall be the minimum allowable strength at 7 days. The ages at time of test shall be 3 days and 7 days in lieu of the 7-day and 28-day ages specified for normal Portland Cement.

5.23 Alternate B -

5.231 Proportions -

All concrete shall be proportioned as indicated in Table (5.23 - B).

5.232 Cement factor -

The cement factor given in column 3 of Table (5.23 - B) indicates the weight of cement per cubic yard of concrete when the concrete is in a freshly mixed condition. The volume of the freshly mixed concrete shall be assumed to be the absolute volume of the cement, plus the volume of the mixing water, plus the displaced volumes of the satured, surface-dry aggregates. The quantity of mixing water to be used in this calculation shall not include water absorbed by the aggregates+.

5.233 Variations in Proportions -

In order to obtain proper workability and a smooth, dense, homogeneous, plastic mixture, free from segregation, the per cent of fine aggregate may be varied within the limits indicated with the approval of the Engineer. The estimated 28-day strengths indicated in column 2 of Table (5.23 - B) are the strengths used in the design calculations.

The Engineer will verify strengths by tests made during the progress of the work and in accordance with the requirements of Section 5.3.

+ Approximate absorption of aggregates

Average sand .... 1.0 % by weight
Pebbles & crushed limestone .... 1.0 % by weight
Very light & porous aggregate may be as high as 25 % by weight

TABLE 5.23 - B*

Class of Concrete	Estimated 28-Day Compressive Flexural Strength; p.s.i. *	Cement Factor; Sacks Cement (110 lb.) per cu. yd. Concrete	Max. Water per 110 lb. Cement; Gal.	Max. Size Agg.; In.	Fine Agg.; % Total Agg. by Weight (range)	Slump Range in.	Approx. Wts. Saturated Surface-Dry Agg. Per Sack (110 lb) of Cement (See note A below)	
							Fine Agg. lb	Coarse Agg. lb.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

* The Engineer should fill in the details of TABLE (5.23-B) to indicate the characteristics of the concrete which are desired for each part of the work.

The Engineer should strike out one of the words "Flexural" or "Compressive" in column (2) as may be required.

Note A. Chekka Cement weight 50 Kg (110 lb.) per Sack.

When a ratio between 7-day and 28-day strengths has been established by these tests or by preliminary tests, the 7-day strengths may be taken as a satisfactory indication of the 28-day strengths.

In the event that cement in excess of that indicated in Table (5.23 - B) is necessary to produce concrete of the indicated strength or workability the cement factor shall be increased as directed by the Engineer, and the Constractor shall receive extra compensation for the additional cement so used.

In the event that cement less than that indicated in Table (5.23 - B) is sufficient to produce concrete of the indicated strength or workability the Engineer may order a reduction in the cement factor, in which case there shall be an adjustment in contract price equal to the actual difference in cost to the Contractor of the required cement and aggregates.

5.234 Water content and slump range -

The maximum quantity of water per 110 lb. of cement specified in Table (5.23 -B) shall include the free water in the aggregates+;

\+

ASSUMED STRENGTH OF CONCRETE MIXTURES

Water content U.S. gal. per 110-lb. sack of cement	Assumed compressive strength at 28 days lb. per sq. in.
9	2,500
8¼	3,000
7	3,750

Note : In interpreting this table, surface water contained in the aggregate must be included as part of the mixing water in computing the water content.

APPROXIMATE QUANTITY OF SURFACE WATER CARRIED BY AVERAGE AGGREGATES.

Very wet sand	¾ to 1 gal. per cu.ft.
Moderately wet sand	about ½ gal. per cu.ft.
Moist sand	about ¼ gal. per cu.ft.
Moist gravel or crushed rock	about ¼ gal. per cu.ft.

however moisture absorbed by the aggregates shall not be included. The slump range indicated in Table (5.23 - B) is intended as a guide to the Contractor for the determination of placing and compacting procedures and equipment.

Within the range specified, the slump shall be as directed by the Engineer. If the concrete has a greater slump than the maximum indicated, the quantity of water shall be reduced to meet the slump requirements. If the concrete has a smaller slump than the minimum indicated, changes in the mixture shall be made as specified in Section 5.233.

5.235 Changes in Consistency for Mechanical vibration -

When high frequency mechanical vibration is used for compacting the concrete, the proportions and consistencies in Table (5.23 - B) shall be modified as required to produce the type of concrete specified in Sections 5.233 and 5.234.

5.236 Concrete made with high early strength portland Cement -

When high early strength portland Cement is used in lieu of normal Portland Cement, the requirements given in Table (5.23-B) shall apply except that the estimated 28-day strength indicated for normal portland cement concrete shall be the estimated 7-day strength when high early strength portland cement concrete is used. The ages at time of test specified in Section 5.233 shall be 3 days and 7 days respectively in lieu of the 7-day and 28-day ages specified for normal Portland Cement.

5.24 Measurements of Materials -

a) The fine aggregate and the coarse aggregate should be measured separately.

b) Materials shall be measured by weighing, except as otherwise specified or where other methods are specifically authorized by the Engineer.

The apparatus provided for weighing the aggregates and cement shall be suitably designed and constructed for this purpose.

Each size of aggregate and the cement shall be weighed separately. The accuracy of all weighing devices shall be such that successive quantities can be measured to within one per cent of the desired amount.

Cement in standard packages (sack) need not be weighed but bulk cement and fractional packages shall be weighed. The mixing water shall be measured by volume or by weight.

The water measuring device shall be susceptible of control accurate to plus or minus $\frac{1}{2}$ per cent of the capacity of the tank. All measuring devices shall be subject to approval.

c) Where volumetric measurement are authorized by the Engineer, the weight proportions shall be converted to equivalent volumetric proportions. In such case, suitable allowance shall be made for variations in the moisture condition of the aggregates, including the bulking effect in the fine aggregate.

SECTION 5.3 - TESTS

5.31 Field tests -

During the progress of construction the Engineer will have tests made to determine whether the concrete as being produced complies with the standards of quality specified in Section 5.2. The contractor shall cooperate in the making of such tests to the extend of allowing free access to the work for the selection of samples and storage of specimens, and in affording protection to the specimens against injury or loss through his operations.

5.32 Test pieces -

Three cylinders, beams or cubes will generally be made for each class of concrete used in any one day's operation.

In special cases the normal number of control specimens may be exceeded when in the opinion of the Engineer such additional tests are necessary.

5.33 Sampling and curing of test pieces -

Samples of concrete for test specimens shall be taken at the mixer.

When in the opinion of the Engineer, it is desirable to take samples elsewhere, they shall be taken as directed by him.

The test specimens shall be molded immediately after the sample is taken, placed in a protected spot and kept under moist curing conditions at approximately 70° F. for 24 hours, whereupon they shall be removed to the testing laboratory.

In the laboratory they shall be kept under standard moist curing conditions at 70° F. until time of test and shall be tested in the damp condition.

5.34 Age -

The standard age of test shall be 28 days, but 7-day tests may be used provided that the relation between the 7 and 28-day strengths of the concrete is established by test for the materials and proportions used.

The tests shall be made at the age of the concrete corresponding to that for which the strengths are specified in Tables (5.22 - A) or (5.23 - B).

5.35 Compression and Flexure tests -

Compression and flexure tests shall be carried in accordance with standard methods of tests.

If the average strength of the laboratory control cylinders for any portion of the structure falls below the compressive strength called for on the plans, the architect or engineer shall have the right to order a change in the proportions or the water content for the remaining portion of the structure. If the average strength of the job-cured cylinders falls below the required strength, the architect or engineer shall have the right to require conditions of temperature and moisture necessary to secure the required strength.

In the event that the architect or engineer changes the water content specified, adjustment covering amount of cement and aggregates affected, will be made as an extra or a credit under the provisions of the contract.

5.36 Slump Tests - (Consistency)

The slump test for consistency of concrete should be made in accordance with the Standard method of slump tests for consistency. It is required that the slump cone be filled in three layers of approximately equal volume. Because of the larger diameter at the bottom, the first layer of the cone should be filled to about one-fourth its height.

A 6-in. slump should be regarded as the maximum to be permitted. Usually the most satisfactory work is obtained with concrete having a slump ranging from 2-in. to 4-in.

SECTION 5.4 - PREPARATION OF EQUIPMENT

5.41 Equipment and place of deposit -

a) Before placing concrete all equipment for mixing and transporting the concrete shall be cleaned, all debris and ice shall be removed from the place to be occupied by concrete. Masonry that will be in contact with concrete shall be well drenched (except in freezing weather).

b) The mixing equipment shall be capable of combining the aggregates, cement and water within the specified time into a thoroughly mixed and uniform mass, and of discharging the mixure without segregation.

c) Water shall be removed from place of deposit before concrete is placed.

5.42 Cleaning and treatment of forms.

All rubbish, particularly chippings, shavings and sawdust, should be removed from the interior of the forms before the concrete is placed and the formwork in contact with the concrete should be cleaned and thoroughly wetted (except in freezing weather) or treated with an approved composition. Care should be taken that such approved composition is kept out of contact with the reinforcement.

SECTION 5.5 - M I X I N G

5.51 Hand mixing -

Hand mixing shall be allowed only when concrete is required in small quantities at a time.

Hand mixing shall be done on a watertight platform and in such a manner as to insure a uniform distribution of the materials throughout the mass.

Mixing shall be continued until a homogeneous mixture of the required consistency is obtained.

5.52 Machine mixing -

The concrete shall be mixed in batch mixers of approved type. The effective time of mixing shall not be less than one minute.

The concrete shall be mixed until there is a uniform distribution of the materials and shall be discharged completely before the mixer is recharged.

The mixer shall be rotated at a speed recomended by the manufacturer and should never be overloaded above the rated capacity.

The addition of water to make the mixture more workable should not be allowed.

5.53 Retempering -

The retempering of concrete or mortar which has partially hardened, that is, mixing with or without additional cement aggregate or water, will not be permitted.

SECTION 5.6 - TRANSPORTING & CHUTING

5.61 <u>Transporting</u> -

Concrete should be handled from the place of mixing to the place of final deposit as rapidly as practicable by methods which will prevent the segregation or loss of the ingredients.

It should be deposited as nearly as practicable in its final position to avoid rehandling or flowing.

5.62 <u>Chuting</u> -

Equipment for chuting and conveying concrete shall be of such size and design as to insure a practically continuous flow of concrete at the delivery end without separation of the materials.

The chute shall be of metal, and shall be thouroughly cleaned before and after each run.

The workability of the concrete, the character of the materials used, and the design of the chutes will determine the slope of chutes that will be required. Slopes not flatter than 1 to 3 nor steeper than 1 to 2 are allowable.

The mix should be designed so that the concrete will travel fast enough to keep the chutes clean.

When long chutes are used the concrete should be delivered into a hopper of the bottom gate type before it is deposited into the forms.

The cycle of operations should be so timed that a nearly continuous flow of concrete is obtained at the discharge end of the chute.

SECTION 5.7 - P L A C I N G

5.71 General -

a) Concrete should be placed before setting has commenced and shall be deposited in such a manner as to prevent segregation of the ingredients.

b) All concrete shall be thoroughly compacted by suitable means during the operation of placing and shall be thoroughly worked around reinforcement and into the corners of the forms.

c) The concreting shall be carried out at such a rate that the concrete is at all times plastic and flows readily into the spaces between the bars.

d) The top surface of the placed concrete shall be generally level.

e) The concrete should not be allowed to drop freely more than 3 or 4 ft.Proper precautions should be taken to prevent segregation when placing concrete in tall and narrow forms.

5.72 Mechanical vibration -

The use of mechanical vibrators for compacting concrete is strongly recommended, provided that the reduced water/cement ratios recommended in Section 5.2 are adopted. It is also recommended that where it is to be adopted, the reinforced concrete designer should include a specification for this.

5.73 Construction joints -

Concreting should be carried out continuously up to construction joints, the position and arrangement of which should be predetermined by the designer.

When work has to be resumed on a surface which has hardened, such surface should be removed by hacking. The surface should then be swept clean, thoroughly wetted, and covered with $\frac{1}{2}$ in. layer of mortar composed of cement and sand in the same ratio as the cement and sand in the concrete mixture. This $\frac{1}{2}$ in. layer of mortar should be freshly mixed and placed immediately before the placing of the concrete.

SECTION 5.8 - C U R I N G

Concrete shall be maintained in a moist condition for at least 7 days after placement and for a longer period when practicable.

Fresh concrete should be covered with canvas or similar absorbent material. The covering should be placed as soon as it can be done without marring the surface of the concrete and care should be taken to keep the covering continuously wet by frequent sprinkling.

Ponding is strongly recommended as a method of curing for flat horizontal surfaces.

When wood forms are left in place during the curing period they shall be kept sufficiently damp at all times to prevent openings at the joints and drying of the concrete.

Inspection shall be made of all exposed surfaces at intervals as directed by the Engineer, and job records shall be kept indicating whether surfaces were wet at times of inspection, and if not wet, stating reasons why.

SECTION 5.9 - COLD WEATHER REQUIREMENTS

a) Adequate equipment shall be provided for heating the concrete materials and protecting the concrete during freezing or near-freezing weather. No frozen materials or materials containing ice shall be used.

b) All concrete materials and all reinforcement, forms, fillers and ground with which the concrete is to come in contact shall be free from frost.

Whenever the temperature of the surrounding air is below 40° F. all concrete placed in the forms shall have a temperature of between 70° F. and 80° F., and adequate means shall be provided for maintaining a temperature of not less than 70° F. for 3 days or 50° F. for 5 days except when high-early strength concrete is used the temperature shall be maintained at not less than 70° F. for 2 days or 50° F. for 3 days or for as much more time as is necessary to insure proper curing of the concrete.

No dependence shall be placed on salt or other chemicals for the prevention of freezing. Manure, when used for protection, shall not be applied directly to concrete.

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BIBLIOGRAPHY

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