Chapter Ind 53

STRUCTURAL REQUIREMENTS

Ind 53.001 Floor, roof and sidewalk loads. (1) DEAD LOADS. All buildings and structures, and parts thereof, shall be designed and constructed to support in addition to the minimum superimposed live loads specified in this section, the actual dead weight of all component members; and in addition thereto, an allowance for the weight of partitions, ceiling and floor finish, and concentrated loads such as safes, mechanical apparatus and similar equipment.

(2) LIVE LOADS. All buildings and structures, and parts thereof, shall be designed and constructed to support the following minimum superimposed live loads uniformly distributed in pounds per square foot of horizontal area in addition to the dead load:

(a) *Theaters and assembly halls with fixed seats:*

1. Auditorium	50
2. Lobbies, corridors and passageways	80
3. Stairways	80

(b) *Assembly halls without fixed seats:*

1. Auditorium	100
2. Lobbies, corridors and passageways	80
3. Stairways	80

(c) *School, library, museum classification:*

1. Instruction rooms, study rooms, reading rooms, exhibition rooms, art display rooms, laboratories	50
2. Vocational rooms	100
3. Library book stacks	100
4. Lobbies, corridors and passageways	80
5. Stairways	80

(d) *Apartment, hotel, place of detention classification:*

1. Living rooms, sleeping rooms	40
2. Lobbies, corridors, passageways	80
3. Offices and similar areas	60
4. Stairways	80
5. Dining rooms	100

(e) *Office buildings:*

1. Offices	50
2. Commercial	100
3. Stairways	80

(f) *Mercantile establishments:*

1. All floor areas and stairways	100

(g) *Factories and workshops:*

1. All floor areas and stairways	100

(h) *Garages:*

1. All floor areas ——8000 pound axle load in any possible position or 80 pounds per square foot. (Whichever produces the greater stress.)

(i) *Grandstands, reviewing stands, bleachers:*

1. All areas	100

(j) *Stages, in theaters and assembly halls*	150
(k) *Roofs*	30
(l) *Sidewalks*	250

(3) The above live load requirements shall be considered only as a minimum. In every case where the loading is greater than this minimum, the design of the building or structure, or part thereof, shall be for the actual load and loading conditions.

(4) The following reductions in assumed live loads shall be permitted in designing girders, columns, piers and walls in fire-resistive buildings.

(a) No reduction of the assumed live load shall be allowed in the design of any slabs, joints or beams.

(b) A reduction of one per cent of the total live load used in the design of girders shall be allowed for each 20 square feet of tributary floor area, with a maximum allowable reduction of 15%. This reduction shall not be carried into the columns nor shall such reduction be used in the design of buildings to be used or occupied as warehouses or for storage purposes.

(c) For determining the total live loads carried by columns, piers and walls, the following reductions shall be permitted, based on the assumed live loads applied to the entire tributary floor area.

1. Warehouses and Storage Buildings

a. Carrying the roof	0%
b. Carrying 1 floor and roof	0%
c. Carrying 2 floors and roof	5%
d. Carrying 3 floors and roof	10%
e. Carrying 4 floors and roof	15%
f. Carrying 5 or more floors and roof	20%

2. Manufacturing Buildings, Stores and Garages
   a. Carrying the roof ---------- 0%
   b. Carrying 1 floor and roof ---------- 0%
   c. Carrying 2 floors and roof ---------- 10%
   d. Carrying 3 floors and roof ---------- 20%
   e. Carrying 4 or more floors and roof ---------- 30%
3. All Other Buildings
   a. Carrying the roof ---------- 0%
   b. Carrying 1 floor and roof ---------- 0%
   c. Carrying 2 floors and roof ---------- 10%
   d. Carrying 3 floors and roof ---------- 20%
   e. Carrying 4 floors and roof ---------- 30%
   f. Carrying 5 floors and roof ---------- 40%
   g. Carrying 6 floors and roof ---------- 45%
   h. Carrying 7 or more floors and roof ---------- 50%

(5) The following reductions in assumed live loads shall be permitted in designing columns, piers and walls in buildings of mill and ordinary construction.

(a) *Warehouses and storage buildings*
   1. Carrying the roof ---------- 0%
   2. Carrying 1 floor and roof ---------- 0%
   3. Carrying 2 floors and roof ---------- 5%
   4. Carrying 3 or more floors and roof ---------- 10%

(b) *Manufacturing buildings, stores and garages*
   1. Carrying the roof ---------- 0%
   2. Carrying 1 floor and roof---------- 0%
   3. Carrying 2 floors and roof ---------- 10%
   4. Carrying 3 or more floors and roof ---------- 20%

(c) *All other buildings*
   1. Carrying the roof ---------- 0%
   2. Carrying 1 floor and roof ---------- 0%
   3. Carrying 2 floors and roof ---------- 10%
   4. Carrying 3 floors and roof ---------- 20%
   5. Carrying 4 or more floors and roof ---------- 30%

Ind 53.01 Wind pressure. (1) Every building shall be designed to resist a horizontal wind pressure of not less than 20 pounds for every square foot of exposed surface, in addition to the dead loads and the live loads specified above, except as provided in Wis. Adm. Code subsection Ind 55.68 (4) and section Ind 52.22.

(2) If the overturning moment due to wind pressure exceeds 75% of the moment of stability of the structure due to dead load only, the structure shall be anchored to its foundations, which shall be of sufficient weight to insure the stability of the structure; and sufficient diagonal bracing or rigid connections between uprights and horizontal members shall be provided to resist distortion.

(3) The overturning moment may be disregarded in a structure less than 100 feet in height if the height does not exceed twice the width.

(4) Members subject to stresses produced by a combination of wind and other loads may be proportioned for unit stresses 33⅓% greater than those specified for dead and live load stresses, provided the section thus required is not less than that required for the combination of dead load, live load and impact (if any).

Ind 53.02 Foundations. (1) The permissible loads on natural earth shall not be more than the following, in tons per square foot:

(a) Quick sand and alluvial soils ---------------------------- ½
(b) Soft clay -- 1
(c) Ordinary clay and sand together in layers, wet and spongy 2
(d) Clay or fine sand, firm and dry ------------------------ 3
(e) Sand, compact and well cemented ---------------------- 4
(f) Gravel and coarse sand, well packed ------------------- 5
(g) Hard pan or shale ------------------------------------ 6
(h) Rock -----------------Not more than 20% of the ultimate crushing strength of such rock.

(2) Where material at footing excavation level is such as to permit loads in excess of 2 tons per square foot, and the design is for loading in excess of 2 tons per square foot, 2 inch hand auger test holes shall be bored at intervals not exceeding 30 feet in any direction within the building area to a depth of at least 5 feet below the base of the footings, to determine the character of the underlying material. Allowable loading shall be in accordance with the above table for the material encountered.

(3) The maximum, or safe working load for piles shall be determined by the following formula:

$$L = \frac{2WH}{S + 0.1} \text{ for steam hammer}$$

$$L = \frac{2WH}{S + 1} \text{ for drop hammer}$$

in which formula

L = safe load in pounds
W = weight of hammer in pounds
H = fall of hammer in feet
S = penetration or sinking of the pile under the last blow, in inches.

(4) In no case shall the maximum load on a timber pile exceed 500 pounds per square inch of the section of the pile at mid-length.

Ind 53.03 Masonry construction; general requirement. The requirements of Wis. Adm. Code sections Ind 53.03 to Ind 53.13, inclusive, herein shall apply to the construction of all masonry footings, foundations, walls, columns, piers and similar work under this code.

Ind 53.04 Natural building stone and cast stone. (1) RUBBLE MASONRY. The stresses in rubble stone masonry, due to all dead and live loads, shall not exceed 100 pounds per square inch when laid in lime-cement mortar, or 140 pounds per square inch when laid in Portland cement mortar.

(2) ASHLAR MASONRY. The stresses in ashlar or carefully coursed masonry, due to all dead and live loads shall not exceed the following at any point:

Kind of Stone	Laid in Lime-Cement Mortar	Laid in Cement Mortar
	(Pounds per Square Inch)	
Granite	640	800
Limestone	400	500
Marble	400	500
Cast Stone	400	500
Sandstone	320	400

(3) WEATHER RESISTANCE OF STONE. All natural building stone to be used in masonry exposed to the weather or frost action shall be such that the strength and structure of the stone will not be affected by the weathering or frost action.

Note: Where the weather resistance of a stone is questioned this will require freezing and thawing tests as prescribed under the specification of the American Society for Testing Materials.

(4) All cast stone shall be branded with a permanent identification mark of the manufacturer which shall be registered with the industrial commission.

(5) The average compressive strength of cast stone taken on four representative samples at the age of 28 days or when delivered on the job shall be not less than 5000 pounds per square inch with an individual minimum of 4500 pounds per square inch, and the average absorption of such samples shall be not more than 7% of their dry weight, with an individual maximum of 8%.

(6) Tests of cast stone specimens shall be made in accordance with the "Tentative Specifications for Cast Stone" (Serial Designation P-3-A29T) of the American Concrete Institute.

Ind 53.05 Building brick. (1) DEFINITION. By *building brick* is meant a structural unit of burned clay or shale, sand lime or concrete, usually solid and about 8 inches by 3¾ inches by 2¼ inches in size.

(2) STRUCTURE. All building brick shall be rectangular in form, free from cracks, laminations and other defects which may interfere with proper laying of the brick or impair the strength or permanence of the structure.

(3) MANUFACTURE. Concrete building brick shall be manufactured from a mixture of Portland cement and approved aggregates, such as sand, gravel, crushed stone, bituminous or anthracite cinders, burned clay or shale, or blast furnace slag.

(4) IDENTIFICATION. All building brick shall be of distinctive design or appearance, or marked so that the identity of the manufacturer may be known at any time.

(5) STRENGTH AND ABSORPTION. (a) The strength and absorption of all building brick manufactured from burned clay or shale shall conform to the following minimum requirements:

	Compressive Strength (bricks flatwise) lbs. per square inch Average Gross Area		Water Absorption by 5 hour boiling per cent		C/B Ratio	
Grade	Average of 5 bricks	Individual Minimum	Average of 5 bricks	Individual Maximum	Average of 5 bricks	Individual Maximum
S.W.	3000	2500	17.0	20.0	0.78	0.80
M.W.	2500	2200	22.0	25.0	0.88	0.90
N.W.	1500	1250	No Limit	No Limit	No Limit	No Limit

1. The ratio C/B is the ratio of absorption by 24-hour submersion in water at room temperature to that after 5-hour submersion in boiling water.

(b) If the average compressive strength is greater than 8000 pounds per square inch and the average water absorption is less than 8% by weight after 24 hours submersion in cold water, the C/B ratio shall be waived.

(6) S. W. BRICK. Grade S. W. brick shall be used in exterior and exposed locations where a high degree of resistance to frost action is desired and the exposure is such that the brick may be frozen when permeated with water.

(a) Brick used for foundation courses, retaining walls, parapet walls and similar locations shall conform to this grade.

(7) M. W. BRICK. Grade M. W. brick may be used where exposed to temperatures below freezing but where brick are not likely to be permeated with water or where a moderate degree of resistance to frost action is permissible.

(a) Brick conforming to this grade may be used in the face of a wall above grade.

(8) N. W. BRICK. Grade N. W. brick may be used for backup or for interior construction or if exposed for use where no frost action occurs.

(9) CONCRETE AND SAND LIME BRICK. The strength of all concrete and sand lime brick used in masonry construction shall conform to the following minimum requirements:

Compressive Strength (bricks flatwise) Pounds Per Square Inch Average Gross Area		Modulus of Rupture (bricks flatwise) Pounds Per Square Inch	
Average of 5 Tests	Individual Minimum	Average of 5 Tests	Individual Minimum
2500	2000	450	300

(10) TESTS. Typical specimens of all types of building brick shall be tested originally to prove compliance with the provisions of this code, and all concrete and sand-lime brick shall be retested at intervals of not more than one year. Further tests may be demanded at any time there is reasonable suspicion of non-conformance to the requirements of this code.

(11) STANDARDS. The testing of all brick shall be in accordance with the Standard Methods of Testing Brick (A. S. T. M. Designation C 67) of the American Society for Testing Materials.

Ind 53.06 Hollow building units. (1) DEFINITIONS. (a) Hollow tile are the products of surface clay, shale, fireclay, or admixtures thereof, moulded to permanent hollow form for use as masonry units in building construction.

(b) Hollow concrete masonry units are the products of Portland cement and suitable aggregates such as sand, gravel, crushed stone, bituminous or anthracite cinders, burned clay or shale or blast furnace slag, moulded to permanent form for use as masonry units in building construction. Hollow concrete masonry units with applied facings of any type shall conform to the requirements of this code.

(2) HOLLOW TILE USED IN BEARING AND EXTERIOR WALLS. (a) *Strength and absorption.* All hollow tile used in bearing and exterior walls shall conform to the following minimum requirements for strength absorption:

Compressive Strength (Based on Gross Area) Pounds per Square Inch				Absorption Per cent		
End Construction Tile		Side Construction Tile				
Average of 5 Tests	Individual Minimum	Average of 5 Tests	Individual Minimum	Average of 5 Tests	Individual Maximum	Individual Minimum
1400	1000	1000	900	5 to 16	19	4

(3) NUMBER OF CELLS. Load bearing tile shall conform to the following requirements as to the minimum number of cells per unit in the direction of wall thickness:

Nominal Horizontal Thickness of Tile as Laid in Wall, in inches	Minimum Number of Cells in Direction of Wall Thickness
4	1
6	2
8	2
10	2
12	3

Note: Cells, as used herein, are hollow spaces enclosed within the perimeter of the exterior shells, and having a minimum dimension of not less than ½ inch and a cross sectional area of not less than one square inch.

(4) DOUBLE-SHELL TILE. In double-shell tile the 2 voids between exterior and interior shells on either side of the tile shall be considered as one cell in thickness of wall when their combined width is not less than ½ inch, provided the short webs between the inner and outer shells are not greater in number and thickness than the long transverse webs holding the inner shells.

(5) SHELL AND WEB THICKNESS. The average over-all thickness of the shells, measured between the inner and extreme outer surfaces of end-construction hollow tile, shall be not less than ¾ inch, except that in double-shell tile the combined average over-all thickness of the inner and outer shell shall be not less than ¾ inch. The thickness of the webs shall be not less than ½ inch.

(6) AVERAGE THICKNESS. The average over-all thickness of the shells, measured between the inner and extreme outer surfaces of side-construction hollow tile, shall be not less than ⅝ inch, except that in double-shell tile the combined average over-all thickness of the inner and outer shell shall be not less than ¾ inch. The thickness of the webs shall be not less than ½ inch.

(7) BRANDING. All clay tile shall be branded with a distinctive indentation on the shell. Clay tile which comply with all requirements for exterior construction and bearing walls shall have the word BEARING impressed on them. All clay tile shall bear the name, initials or trade-mark of the manufacturer.

(8) TESTS. Typical specimens of all sizes and designs of hollow tile used in exterior or bearing walls shall be tested originally to prove compliance with this code, and thereafter as directed by the industrial commission. Tile shall be sampled and tested in accordance with the standard methods of sampling and testing structural clay tile.

Note: It will be the policy of the industrial commission to accept methods of sampling and testing structural clay tile as specified by the American Society of Testing Materials. (A.S.T.M. Designation C–112)

(9) HOLLOW CONCRETE MASONRY UNITS. (a) *Compressive strength.* All hollow concrete masonry units shall have a compressive strength of not less than 1000 pounds per square inch gross area as laid in the wall.

1. The average strength of any group of test specimens of hollow concrete masonry units shall not be less than the above requirement. The strength of any individual test specimen shall not be less than 900 pounds per square inch gross area.

(b) *Absorption.* Hollow concrete masonry units shall not absorb more than 14 pounds of water per cubic foot of concrete actually contained.

(c) *Branding.* At least one-third of all hollow concrete masonry units shall be branded with a distinctive indentation or waterproof stencilled mark, which shall bear the name, initials, or trade-mark of the manufacturer. All cubes or piles of block on the job shall be easily identified by branded block which are visible. Producers having more than one plant shall register and use a separate, distinctive brand for each plant. A facsimile of each individual brand shall be filed with the industrial commission.

(d) *Tests.* Typical specimens of all sizes and designs of hollow concrete masonry units shall be tested in an approved manner, originally to prove compliance with the requirements of this code, and thereafter as required by the industrial commission or its authorized agents.

Note: It will be the policy of the industrial commission to accept the method of testing as described in A.S.T.M. Designation C–140 "Methods of Sampling and Testing Concrete Masonry Units".

(e) Sampling of hollow concrete masonry units shall be done only by the industrial commission or their authorized agents. The time and place of sampling shall be at the discretion of the industrial commission or their authorized agents. It is intended that such tests will be made at intervals not to exceed one year.

1. At the time of the sampling, the producer or purchaser shall inform the sampling agent of the name and location of the approved testing laboratory to which the samples will be sent for testing. The sampling agent shall notify the industrial commission of the date, number, size, type and seal numbers of the samples selected. Compression tests shall be completed not later than 7 days after sealing. To validate the test, all seals must be accounted for in the laboratory report.

2. Producers having more than one plant will be considered as separate plants with separate samplings and tests for each plant.

(f) Approvals following original tests will remain in effect until later tests show non-conformance with the requirements of this code. To verify compliance with these requirements, the industrial commission may require that tests be made at its designated laboratory.

(g) Non-conformance with the requirements of Wis. Adm. Code section Ind 53.06 shall be determined by the failure of 3 complete tests on a particular job, as tested in an approved manner. In the event of job non-conformance, the necessary structural correction shall be made and the producer shall be barred from supplying any more units on that project.

(h) Testing laboratories must apply annually for certification by the industrial commission. Such certification shall be based on standards established by the industrial commission. Only those tests that are made by a certified laboratory will be accepted. To verify compliance with these standards the industrial commission may require that tests be made at its designated laboratory.

1. The owner or supplier shall have the choice of selecting a certified testing laboratory for any tests at his expense.

(10) CLAY TILE USED IN NON-BEARING PARTITIONS.

(a) *Weight.* The weight of hollow clay tile used in non-bearing partitions shall be not less than the following:

Dimension	Minimum No. of cells in unit	Minimum No. of cells in direction of wall thickness	Minimum average weight, lb. per sq. ft. of tile	Individual minimum weight, lb. per sq. ft. of tile
2x12x12	3	1	14	13
3x12x12	3	1	15	14
4x12x12	3	1	16	15
6x12x12	3	1	22	21
6x12x12	4	2	25	24
8x12x12	4	2	30	28
10x12x12	4	2	35	33
12x12x12	4	2	40	38

1. The weights above are for scored tile. If any of the faces are unscored, the weights shall be increased 0.5 lb. per square foot of unscored area.

2. No dimension shall vary more than 3% from the specified dimensions for any form of tile.

3. The requirements for minimum weights of hollow clay tile used in non-bearing partitions shall be waived if the over-all thickness of the shells, measured between the inner and extreme outer surfaces, is not less than ⅝ inch and the thickness of webs is not less than ½ inch.

(b) *Shape and structure.* All hollow clay tile used in non-bearing partitions shall be reasonably free from laminations and from such cracks, blisters, surface roughness and other defects which would interfere with the proper setting of the tile, or impair the strength, permanence or fire protection value of the construction.

1. The depth of curvature or warpage of any face, shall not exceed 3% of the greatest dimension of such face, but in no case more than ¼ inch.

2. Surfaces of all tile intended for the direct application of plaster or stucco shall be scratched or scored. When scored, each groove shall

be not less than ⅛ inch nor more than 3/16 inch in depth, nor more than 1 inch in width. The area covered by the grooves shall not exceed 50% of the area of the scored faces.

(c) *Branding.* All hollow clay tile used in non-bearing partitions shall be branded with a distinctive indentation. All hollow clay tile not suitable for use in bearing and exterior walls but used in non-bearing partitions shall have the word PARTITION impressed on them.

1. All hollow clay tile used in partition work shall bear the name, initials or trade-mark of the manufacturer.

(11) HOLLOW CONCRETE MASONRY UNITS USED IN NON-BEARING PARTITIONS. All hollow concrete masonry units used in non-bearing partitions shall comply with the requirements of Wis. Adm. Code subsection Ind 53.06 (9).

(12) CLAY TILE AND HOLLOW CONCRETE MASONRY UNITS USED IN FLOOR CONSTRUCTION. (a) *General requirements.* Where hollow clay tile are used in concrete floor construction in a way that the whole or any portion of a tile is subjected to a load, the requirements which apply to tile used in exterior and bearing construction shall be complied with. Where hollow concrete masonry units are used in floor construction in a way that the whole or any portion of a block is subjected to a load, the block shall comply with the requirements of Wis. Adm. Code subsection Ind 53.06 (9).

(b) *Tile and masonry floor units.* Where hollow clay tile or hollow concrete masonry units are used in concrete floor construction in a way that no portion of a tile or block is subjected to a load, the requirements which apply to tile or block used in partitions shall apply.

(c) *Branding.* All clay tile or concrete masonry units used in floor construction shall conform to the branding requirements of subsection (9) (c).

History: 1-2-56; am. Register, December, 1962, No. 84, eff. 1-1-63.

Ind 53.07 Allowable unit stresses in masonry. (1) The compressive stresses in masonry walls, partitions, piers and similar bearing masonry shall not exceed the following in pounds per square inch:

Kind of Masonry	Kind of Mortar		
	Lime	Lime-Portland Cement	Portland Cement
Brick	90	140	175
Hollow Concrete Masonry Units	----------	85	100
Hollow Clay Tile	----------	85	100

(2) Where a combination of 2 or more building units is used, the minimum requirements shall apply to the masonry.

Ind 53.08 Mortar. (1) All cement used in the making of mortar for embedding masonry and for other structural purposes under this code shall conform to the requirements of the standard specifications for these materials issued by the American Society for Testing Materials having designation listed as follows:

Specifications for Portland Cement—C 150-41.

(2) Lime putty for mortar shall be made by slaking quicklime to a smooth paste, and shall be stored and protected for a period of not less than 10 days before being used in the making of mortar. Where pulverized quicklime is used, the storing period may be reduced to 48 hours.

(a) Hydrated lime shall be considered the equivalent of lime putty for all uses hereunder.

(3) Lime mortar shall consist of one part lime putty, or dry hydrated lime, to not more than 3 parts of approved sand, all measurements by volume.

(4) Lime-cement mortar shall consist of one part of lime putty, or dry hydrated lime, and one part of Portland cement added to not more than 6 parts of approved sand, all measurements by volume.

(a) In lime or lime-cement mortars any desired part of the lime may be replaced with an equal volume of Portland cement.

(5) Cement mortar shall consist of one part of Portland cement and not more than 3 parts of approved sand, except that lime putty, or dry hydrated lime, in volume equal to not more than 15% of the volume of Portland cement may be added to the mortar.

Note: Approved sand for mortar shall conform to the Tentative Specifications for Concrete Aggregates (A.S.T.M. Designation C33—40) of the American Society for Testing Materials.

Ind 53.09 Bearing masonry walls, bearing partitions and piers. (1) GENERAL REQUIREMENTS. All masonry units used in the construction of bearing walls, bearing partitions and piers shall conform in all respects to the requirements for bearing units.

(2) UNIT STRESSES. The unit stresses in bearing masonry walls, partitions and piers shall not exceed those specified in Wis. Adm. Code sections Ind 53.04 and Ind 53.07.

(3) MORTARS. Cement mortar shall be used for all masonry which will have one or more faces in contact with soil. Lime-cement mortar or cement mortar shall be used for all masonry in isolated piers, parapet walls, chimneys where exposed to the weather, and for all hollow masonry units. All other masonry may be laid in cement mortar, lime-cement mortar or lime mortar.

(4) MASONRY BOND. In brick masonry, or in combination brick and other masonry units, the bonding of each tier of units to that adjoining shall be secured by means of a full header course of brick every sixth course of brick, or equivalent. The use of metal ties for bonding masonry is not approved.

(a) By equivalent, is meant that 1/6 of the surface of a wall shall be header, or bond, units.

(b) Where masonry units are larger or smaller than brick, the bond courses shall be placed at intervals not exceeding 16 inches.

(c) Stack bond. Stack bonded masonry units used in the construction of bearing walls and partitions shall be bonded with 3/16 inch diameter steel rods or metal ties of equivalent stiffness embedded in the mortar joints. The vertical distance between ties shall not exceed 16 inches.

(5) USE OF HOLLOW CLAY TILE AND HOLLOW CONCRETE MASONRY UNITS. Approved clay tile and concrete masonry units may be used in

bearing and exterior walls of buildings not more than 3 stories, or 45 feet in height, or in panel walls in buildings of any height. In determining this height, the basement or foundation wall shall be considered a story if constructed of clay tile or concrete masonry units.

(6) LOADING. Concentrated loads shall be transmitted to hollow clay tile or hollow concrete block masonry by at least 3 courses of brick or equivalent concrete or by a metal plate of sufficient thickness and size to distribute the load to the webs and shells in such a manner as not to exceed the unit allowable stress.

(7) PARTY WALL CONSTRUCTION. Where hollow clay tile or hollow concrete masonry units are used in party walls, there shall be not less than 2 such units, each 8 inches in thickness as a minimum, used in making up the thickness of the wall unless solid masonry is used for building all chases, recesses, framing of all openings, and for the support, anchorage, and protection of all joists and beams carried into such wall.

(8) WALL CONSTRUCTION. Clay tile and concrete masonry units used in bearing walls shall be well bedded in mortar. The net bearing area of all clay tile and concrete masonry units as laid in the wall shall be such that the allowable unit stress in the mortar is not exceeded.

(9) SAME. All clay tile laid with cells vertical shall be laid in Portland cement mortar. All clay tile laid with cells horizontal and all concrete masonry units shall be laid in cement-lime mortar, or better.

(10) HEIGHT AND THICKNESS. All bearing walls, party walls and standard division walls, except as hereinafter provided, shall be not less than 12 inches thick in the upper 3 stories, increasing 4 inches in thickness for each 3 stories, or fraction, below. No such 3 story height shall exceed 40 feet.

(11) WALL THICKNESS. A building not more than 3 stories in height may have 8 inch bearing walls in the upper story, provided such story is not more than 10 feet high in the clear, and the span is not more than 20 feet, and the wall is not more than 30 feet long between cross walls, offsets or pilasters.

(12) SAME. A building not more than one story in height may have 8 inch bearing walls, provided the clearstory height is not more than 12 feet, the roof span is not more than 25 feet, and the distance between cross walls, offsets or pilasters is not more than 20 feet.

(a) A building not more than one story in height may have 6-inch bearing walls provided the clearstory height is not more than 9 feet, the roof span is not more than 18 feet and the distance between cross walls, offsets, or pilasters is not more than 15 feet. All other 1-story buildings shall have all bearing walls not less than 12 inches thick.

(13) LATERAL SUPPORT. All bearing masonry walls shall have substantial lateral support at right angles to the wall face at intervals, measured either vertically or horizontally, not exceeding 18 times the wall thickness. Such lateral support shall be obtained by masonry cross walls, piers or buttresses when the limiting distance is measured horizontally, or by floors or roof when the limiting distance is measured vertically.

(14) WALLS BELOW GRADE. Masonry walls which are in contact with the soil in any story shall be increased 4 inches in thickness in that story, except that for places of abode as specified in Wis. Adm. Code section Ind 57.001, not over 2 stories in height, 12 inch walls will be accepted if substantial lateral supports consisting of masonry walls, offsets or pilasters are provided at intervals not to exceed 20 feet.

(15) STONE WALLS. Rubble and rough cut stone walls shall be 4 inches thicker than required for walls of artificially formed units or of ashlar masonry.

(16) SAME. Stone and similar solid facing not less than 4 inches thick may be considered as part of the required thickness of a wall if bonded to the backing as required for brickwork. No such wall shall be less than 12 inches thick.

(17) PIERS. In all buildings, the section of masonry supporting trusses or girders shall be considered as isolated piers, the least dimension of which, in inches, shall be not less than 1/30 of the span of the truss, or girder, in inches, and the height shall not exceed 12 times the minimum horizontal dimension.

(a) The height of masonry piers which are not built into, and as a part of bearing walls, shall be not more than 10 times the minimum horizontal dimension.

(b) Support for long span joist. Where long span steel joist or laminated structural wood members or precast concrete members are used on spans of more than 40 feet, and the spacing exceeds 4 feet, pilasters shall be provided to support each joist or spandrel beam supported on pilasters, or steel columns shall be provided to support the joist.

(18) CHASES, RECESSES AND OPENINGS. There shall be no chases in 8 inch walls or in any pier. No chase in any wall shall be deeper than ⅓ the wall thickness. No horizontal chase shall exceed 4 feet in length nor shall the horizontal projection of any diagonal chase exceed 4 feet. No vertical chase shall be closer than 2 feet to any pilaster, cross wall, end wall or other stiffener.

(a) The aggregate area of recesses and chases in the wall of any one story shall not exceed ¼ the whole area of the face of the wall in that story. No chases or recesses shall be permitted in any wall which will reduce the fire resistance of such wall below the minimum required by this code.

(b) The maximum percentage of openings in the horizontal cross section of any wall shall not exceed 50%, unless the wall is increased 4 inches in thickness, or such portions of the wall between openings shall be as required for piers for the entire wall height.

History: 1-2-56; am. (12) (a), Register, June, 1956, No. 6, eff. 7-1-56; am. (4) (b), Register, August, 1957, No. 20, eff. 9-1-57; r. and recr. Register, September, 1959, No. 45, eff. 10-1-59.

Ind 53.10 Non-bearing masonry walls. (1) GENERAL REQUIREMENTS. All exterior non-bearing masonry walls if constructed with one course of brick to the weather may be backed with common brick, concrete masonry units, or non-bearing clay tile, conforming to the requirements of Wis. Adm. Code sections Ind 53.05 and Ind 53.06. If walls are built of concrete masonry units or clay tile, with or without exterior stucco, such walls shall be constructed of concrete masonry units or clay tile conforming to the requirements of Wis. Adm. Code section Ind 53.06.

(2) INTERIOR NON-BEARING WALLS. Interior non-bearing partition walls may be built of materials conforming to the requirements of Wis. Adm. Code sections Ind 53.05 and Ind 53.06, or of gypsum block or other approved materials.

(3) TYPE OF MORTAR. Lime, lime-cement or cement mortar shall be used for all non-bearing masonry, except as follows:

(a) Lime mortar shall not be used in normally wet or damp locations.

(b) Gypsum shall be used for gypsum masonry.

(c) Gypsum may be used for interior clay tile masonry.

(4) MASONRY BOND AND ANCHORAGE. In non-load bearing brick masonry or in combinations of brick and other masonry units, the bonding of each tier of units to that adjoining, shall be secured by means of a full header course of brick or other units placed at intervals not exceeding 32 inches. The height of such bond course shall not exceed 5 inches and the width of bed joint used to effect the masonry bond shall be at least 4 inches.

(a) All exterior and interior non-bearing walls and partitions shall be securely anchored to supporting members by means of corrosion resistant ties of at least No. 13 U.S. Standard Gauge metal spaced not more than 18 inches center to center.

(b) Stack bond. Stack bonded masonry units used in the construction of non-load bearing walls and partitions shall be bonded with 3/16 inch steel rods or metal ties of equivalent stiffness embedded in the mortar joint. The vertical distance between ties shall not exceed 32 inches.

(c) Masonry veneer on frame structures shall be securely anchored to the structure with corrosion resistant ties of at least No. 13 U.S. Standard Gauge metal or equal. The maximum vertical distance between ties shall not exceed 18 inches and the maximum horizontal distance shall not exceed 36 inches and the ties in alternate courses shall be staggered.

(5) HEIGHT AND THICKNESS. Interior non-bearing masonry walls which are supported by fire-resistive construction and have tight contact with not less than 2-hour fire-resistive construction at the top, shall be not more than 36 times their thickness in clear height. Similar non-bearing walls which contact less than 2-hour fire-resistive support at the top shall be not more than 24 times their thickness in clear height. Plastering shall be included in computing the thickness.

(6) THICKNESS OF EXTERIOR NON-BEARING WALLS. The thickness of exterior non-bearing walls shall be not less than 1/24 of the clear height and not less than 1/30 of the horizontal distance between vertical supports, but in no case less than 8 inches.

History: 1–2–56; r. and recr. Register, September, 1959, No. 45, eff. 10–1–59.

Ind 53.11 Cavity walls. (1) Exterior non-bearing walls may be built with a facing of 4 inches of building brick complying with the requirements of Wis. Adm. Code section Ind 53.05, and a backing of either building brick complying with the requirements of Wis. Adm. Code section Ind 53.05, or hollow building units complying with the requirements of Wis. Adm. Code section Ind 53.06. Such walls shall have an air space between the facing and backing of not less than 2 inches nor more than 2½ inches, and shall be bonded to each other with galvanized metal ties at least ¼ inch thick every 16 inches in height and 24 inches in width. The maximum height between supports shall be 10 feet. For heights greater than 10 feet between supports, the thickness of the backing shall be increased 2 inches for each 5 feet, or fraction thereof. The wall shall be anchored to the supporting framework with metal ties at least ⅛ inch thick, spaced not more than 24 inches center to center.

(2) A waterproofing membrane shall be installed at the bottom of the wall cavity. It shall pass through both the exterior facing course and the backing in such a manner as to drain outward the water which might penetrate the facing. Open vertical joints, or weep holes, shall be provided every 3 feet horizontally in the facing above the membrane.

Ind 53.12 Bonding and anchoring stone and cast stone veneers. (1) For bearing walls, stone shall be bonded to the backing every 16 inches of wall height with bond courses at least 4 inches in height, and the width of bed joint used to effect the masonry bond shall be at least 4 inches.

(2) For non-bearing walls, individual stones shall be anchored to the supporting framework and dowelled to each other at all horizontal joints, and anchored to the backing at all horizontal joints and at vertical joints so that one anchor is provided for every 6 square feet of wall surface. All anchors shall be not less than ¼ square inch in cross section and made of wrought iron galvanized after forming, or of commercial bronze.

(3) The backing of all stone or cast stone bearing or non-bearing walls shall be of brick conforming to the requirements of section Ind 53.05 or other solid material weighing at least 130 pounds per cubic foot except where the stone facing is not more than 4 inches in thickness, the backing may be of hollow masonry units conforming to the requirements of section Ind 53.06, or other similar non-corrosive material.

History: 1–2–56; r. and recr. Register, September, 1959, No. 45, eff. 10–1–59.

Ind 53.13 Parapet walls. (1) Parapet walls not less than 8 inches in thickness and 2 feet in height shall be provided on all exterior walls of masonry or concrete, where such walls connect with roofs other than roofs that are of incombustible construction throughout; but this section shall not apply:

(a) To buildings where frame construction would be permitted under the provisions of this code.

(b) To walls which face streets, or alleys.

(c) To walls where not less than 10 feet of vacant space is maintained between the wall and the boundary line between premises.

(d) To walls which are not less than 10 feet from other buildings on the same premises.

(2) All parapet walls shall be properly coped with incombustible, weatherproof material.

(3) Parapet walls not less than 8 inches in thickness and 3 feet in height shall be provided on all division and party walls of masonry or concrete where such walls connect with roofs of other than 2-hour fire-resistive construction, or better.

History: 1–2–56; am. Register, December, 1962, No. 84, eff. 1–1–63.

Ind 53.14 Concrete materials. (1) PORTLAND CEMENT. Portland cement shall conform to the "Standard Specifications for Portland Cement" (A.S.T.M. Serial Designation: C–150–49).

(2) CONCRETE AGGREGATES. Concrete aggregates, except lightweight aggregates, shall conform to the "Standard Specifications for Concrete Aggregates" (A.S.T.M. Designation C–33–49) including the method of sampling and testing.

(3) LIGHTWEIGHT AGGREGATES. Lightweight aggregates for concrete shall conform to the "Standard Specifications for Lightweight Aggregates for Concrete" (A.S.T.M. Designation C–130–42) including the methods of sampling and testing.

(a) The maximum size of the aggregate shall not be larger than 1/5 of the narrowest dimension between sides of the forms of the member for which the concrete is to be used nor larger than 3/4 of the minimum clear spacing between reinforcing bars.

(4) WATER. Water used in mixing concrete shall be clean, and free from injurious amounts of oil, acid, alkali, organic matter, or other harmful substances.

(5) METAL REINFORCEMENT. Metal reinforcement shall conform to the requirements of the "Standard Specifications for Billet-Steel Bars for Concrete Reinforcement" (A.S.T.M. Serial Designation: A15–50T) or for "Rail Steel Bars for Concrete Reinforcement" (A.S.T.M. Serial Designation: A16–50T) or for "Welded Steel Wire Fabric for Concrete Reinforcement" (A.S.T.M. Serial Designation A–185–37).

(a) *Deformed bars.* Deformed reinforcing bars shall conform to the "Standard Specifications for Minimum Requirements for the Deformations of Deformed Steel Bars for Concrete Reinforcement" (A.S.T.M. Serial Designation: A–305–50T). Bars not conforming to these specifications shall be classed as plain bars.

(b) *Wire mesh.* Wire mesh with welded intersections not further apart than 6 inches in the direction of the principal reinforcement and with cross wires not smaller than No. 10 W and M gauge may be rated as deformed bars.

(c) *Placing metal reinforcement.* Metal reinforcement shall be accurately placed and adequately secured in position by concrete or metal chairs or spacers. The minimum clear distance between parallel bars, except in columns, shall be equal to the nominal diameter of the bars. In no case shall the clear distance between the bars be less than one inch, nor less than one and one-third the maximum size of the coarse aggregate. Where reinforcement in beams or girders is placed in 2 or more layers, the clear distance between layers shall not be less than one inch and the bars in the upper layers shall be placed directly above those in the bottom layer.

(6) STORAGE OF MATERIALS. Cement and aggregates shall be stored in such a manner as to prevent deterioration or the intrusion of foreign matter. Any material which has deteriorated or which has been damaged shall be removed completely from the premises.

Ind 53.15 Concrete proportions, mixing and strength. (1) PROPORTIONS. The proportions of aggregate to cement for any concrete shall be such as to produce a mixture which will work readily into the corners and angles of the forms and around reinforcement with the method of placing employed on the work, but without permitting the materials to segregate or excess free water to collect on the surface.

(a) The methods of measuring concrete materials shall be such that the proportions can be controlled accurately and checked easily at any time during the work. Wherever practicable, such measurement shall be by weight rather than by volume.

(2) MIXING. The concrete shall be mixed until there is a uniform distribution of the materials and the mass is uniform in color and homogeneous. In machine mixing, only batchmixers shall be used. Each batch shall be mixed not less than one minute after all the materials are in the mixer and must be discharged completely before the mixer is recharged. Machine mixers shall have a peripheral speed of approximately 200 feet per minute.

(a) Ready-mixed concrete shall be mixed and delivered in accordance with the requirements set forth in the "Standard Specifications for Ready-mixed Concrete" (A.S.T.M. Serial Designation C94–48).

(3) STRENGTH. For the design of reinforced concrete structures, the value of f'_c used for determining the working stresses as stipulated in Wis. Adm. Code subsection Ind 53.22 (3) shall be based on the specified minimum 28-day compressive strength of the concrete, or on the specified minimum compressive strength at the earlier age at which the concrete may be expected to receive its full load. All plans, submitted for approval or used on the job, shall show clearly the assumed strength of concrete at the specified age for which all parts of the structure were designed.

(a) All concrete exposed to the action of the weather shall have a water-content of not to exceed 6 gallons per sack of cement.

(b) When average aggregates are to be used and no preliminary tests are to be made, the water content to be used for various desired strengths of concrete shall be as indicated in the following table:

Water-Content, U. S. Gallons per 94 lb. Sack of Cement	7½	6¾	6
Assumed Compressive Strength at 28 Days, lb. per sq. in.	2000	2500	3000

(c) In computing the water-content, surface water carried by the aggregates must be included. Water-content other than shown in the above table may be used, provided that the strength-quality of the concrete proposed for use in the structure shall be established by tests made in advance of the start of the work, using suitable consistencies and in accordance with the "Standard Method of Making Compression Tests of Concrete" (A.S.T.M. Serial Designation: C39–49).

(d) A curve representing the relation between the water-content and the average 28-day compressive strength or earlier strength at which the concrete is to receive its full working load, shall be established for a range of values including all the compressive strengths indicated on the plans.

(e) The curve shall be established by at least 3 points, each point representing average values from at least 4 test specimens. The maximum allowable water-content for the concrete for the structure shall be as determined from this curve and shall correspond to a strength which is 15% greater than that indicated on the plans. No substitutions shall be made in the materials used on the work without additional tests in accordance herewith to show that the quality of the concrete is satisfactory.

(4) CURING AND PROTECTION AGAINST COLD WEATHER. In all concrete structures, concrete made with normal Portland cement shall be maintained in a moist condition for at least the first 7 days after placing, and high-early-strength concrete shall be so maintained for at least the first 3 days.

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

(b) All concrete materials and all reinforcements, 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 degrees Fahrenheit, all concrete when placed in the forms shall have a temperature of between 60 and 90 degrees Fahrenheit and shall be maintained at a temperature of not less than 50 degrees Fahrenheit for at least 72 hours for normal concrete or 24 hours for high-early-strength concrete, or for as much more time as is necessary to insure proper rate of curing of the concrete. The housing, covering or other protection used in connection with curing shall remain in place and intact at least 24 hours after the artificial heating is discontinued. No dependence shall be placed on salt or other chemicals for the prevention of freezing.

(5) FORMS AND SHORING FOR CONCRETE STRUCTURES. Forms shall be substantially constructed to carry dead and live loads and impact imposed during pouring operations. Forms shall conform to the shape, lines, and dimensions of the members as called for on the plans, and shall be sufficiently tight to prevent leakage of mortar. They shall be properly braced or tied together so as to maintain position and shape.

(a) Forms shall be removed in such manner as to insure the complete safety of the structure. Where the structure as a whole is supported on shores, the removable floor forms, beam and girder sides, column and similar vertical forms may be removed after 24 hours, provided the concrete is sufficiently hard not to be injured thereby. In no case shall the supporting forms or shoring be removed until the members have acquired sufficient strength to support safely their weight and the load thereon. The results of suitable control tests may be used as evidence that the concrete has attained such sufficient strength.

Ind 53.16 Flexure of beams, frames, and slabs. (1) CONDITION OF DESIGN. All members of frames or continuous construction shall be designed to resist at all sections the maximum moments and shears produced by dead load, live load and wind load, as determined by some one of the approximate methods of elastic frame analysis. Any reasonable assumptions may be adopted as to relative stiffness of columns and floor members. The assumptions made should be consistent throughout the analysis. The following will serve as a guide to satisfactory design.

(a) The stiffness, K, of a member is defined as EI divided by l or h. The modulus of elasticity for concrete shall be assumed as 1000 f'_c, and that for steel as 30,000,000 lbs. per sq. in. In the analysis of continuous frames, center to center distances, l and h, shall be used in the determination of moments.

(b) In computing the value of I of slabs, beams, girders, and columns, the reinforcement may be neglected. In T-shaped sections allowance shall be made for the effect of the flange. The additional width of haunched floor members near supports may be neglected in computing moments, but may be considered to resist moment and shear. The additional depth of haunched floor members may be considered as resisting moment only when a complete analysis is made taking into account the variation in depth. Otherwise the minimum depth should be used to find moment and to resist the resulting moment. However, in any case, the actual depth may be assumed to resist shear.

(c) Moments at faces of supports may be used for design of beams and girders. Solid or ribbed slabs with clear spans of not more than 10 feet that are built integrally with their supports may be designed as continuous slabs on knife edge supports with spans equal to the clear spans of the slab and the width of beams otherwise neglected. The span length of members that are not built integrally with their supports shall be the clear span plus the depth of the beam or slab but shall not exceed the distance between centers of supports.

(d) The clear distance between lateral supports of a beam shall not exceed 32 times the least width of compression flange.

(2) REQUIREMENTS FOR T-BEAMS. In T-beam construction, the slab and beam shall be built integrally or otherwise effectively bonded together. The effective flange width to be used in the design of symmetrical T-beams shall not exceed ¼ of the span length of the beam, and its overhanging width on either side of the web shall not exceed 8 times the thickness of the slab nor ½ the clear distance of the next beam.

(a) For beams having a flange on one side only, the effective overhanging flange width shall not exceed $\frac{1}{12}$ of the span length of the beam, nor 6 times the thickness of the slab, nor ½ the clear distance to the next beam.

(b) Where the principal reinforcement in a slab which is considered as the flange of a T-beam (not a joist in concrete joist 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 5 times the thickness of the flange, nor in any case 18 inches.

(c) Provision shall be made for the compressive stress at the support in continuous T-beam construction, care being taken that the provisions relating to the spacing of bars, and the placing of concrete shall be fully met.

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

(e) Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness of not less than ½ the width of the web and a total flange width not more than 4 times the web thickness.

(3) COMPRESSION STEEL IN FLEXURAL MEMBERS. Compression steel in beams, girders, or slabs shall be anchored by ties or stirrups not less than ¼ inch in diameter spaced not farther apart than 16 bar diameters, or 48 tie diameters. Such stirrups or ties shall be used throughout the distance where the compression steel is required.

(4) CONCRETE JOIST FLOOR CONSTRUCTION. Concrete joist floor construction consists of concrete joists and slabs placed monolithically with or without burned clay or concrete tile fillers. The joists shall not be farther apart than 30 inches face to face. The joists shall be not less than 4 inches wide, nor of a depth more than 3 times the width.

(a) When burned clay or concrete tile fillers, of material having a unit compressive strength at least equal to that of the designed strength of the concrete in the joists are used, and the fillers are so placed that the joints in alternate rows are staggered, the vertical shells of the fillers in contact with the joists 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.

(b) The concrete slab over the fillers shall be not less than one and one-half inches in thickness, nor less in thickness than $\frac{1}{12}$ of the clear distance between joists.

(c) Where removable forms or fillers are used, the thickness of the concrete slab shall not be less than $\frac{1}{12}$ of the clear distance between joists and in no case less than 2 inches. Such slab shall be reinforced at right angles to the joists 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 50 lbs. per sq. ft., no additional reinforcements shall be required.

(d) 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 purposes.

(e) Where the slab contains conduits or pipes, the thickness shall not be less than ½ inch plus the total over-all 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.

(5) FLAT SLABS AND TWO-WAY SLABS WITH SUPPORTS ON 4 SIDES. Structures of these types shall be designed in accordance with the provisions of the 1940 Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, or the building regulations for reinforced concrete of the American Concrete Institute (A.C.I. 318–56).

Ind 53.17 Shear and diagonal tension. (1) GENERAL. Due to the composite character of reinforced concrete beams, the action of reinforcement in resisting diagonal tension is not susceptible of exact analysis. Hence, the design of web reinforcement is based on empirical or modified rational methods which have been developed from tests and the observations of existing structures.

(a) Vertical stirrups, bent-up longitudinal bars or both, add greatly to the resistance to shear or diagonal tension. This is especially true if adequate bond resistance is provided, either in the form of low bond stress or effective anchorage of the reinforcement. The importance of bond resistance is such that high working stresses are permitted only when all of the reinforcement is anchored properly. Therefore, the requirements of Wis. Adm. Code section Ind 53.18 on bond and anchorage are intimately related to the provisions of this section.

(2) UNIT SHEARING STRESS. The shearing unit stress used as a measure of diagonal tension shall be computed by the formula $v = \frac{V}{bjd}$. For beams of I or T section, the width of the concrete web or stem shall be used.

(a) In concrete joist floor construction where burned clay or concrete tile are used, the shells of the tile in contact with the joists may be used in computing the shearing stress provided that the net compressive strength of the shells of tile equals that of the concrete in the joists and provided that the joints in alternate rows of tile are staggered.

(3) USE OF WEB REINFORCEMENT. Where the shearing unit stress in a beam or joist exceeds $0.03 f'_c$, web reinforcement shall be provided at all sections for the shear in excess of this amount.

(a) Web reinforcement may consist of vertical or inclined stirrups or bent-up longitudinal reinforcement or a combination thereof. Bars inclined at an angle less than 15 degrees with the axis of the beam shall not be considered as web reinforcement.

(b) Stirrups or bent-up longitudinal bars to be considered effective as web reinforcement shall be anchored at both ends in accordance with the requirements of Wis. Adm. Code section Ind 53.18.

(4) SPACING OF WEB REINFORCEMENT. 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 2 such lines of web reinforcement.

Ind 53.18 Bond and anchorage. (1) UNIT BOND STRESS. 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 the formula $u = \frac{V}{\Sigma o\, jd}$. In beams of variable depth to which this formula does not apply, special provision must be made for the end anchorage of all tensile reinforcement.

(2) ANCHORAGE FOR LONGITUDINAL STEEL AND WEB REINFORCEMENT. Tensile negative reinforcement in any span of a continuous restrained or cantilever beam, or in any member of a rigid frame shall be ade-

quately anchored by bond, hooks or mechanical anchors in or through the supporting member. Within any such span, every reinforcing bar, whether required for positive or negative reinforcement, shall be extended at least 12 diameters beyond the point at which it is no longer needed to resist stress. The maximum tension in any bar must be developed by bond on a sufficient straight or bent embedment or by other anchorage. If preferred, the bar may 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 reinforcement which resists moment of opposite sign.

(a) Of the positive reinforcement in continuous beams not less than ¼ of the area shall extend along the same face of the beam into the support a distance of 6 inches.

(b) In simple beams, or at the freely supported end of continuous beams, at least ⅓ the required positive reinforcement shall extend along the same face of the beam into the support a distance of 6 inches.

(c) Plain bars in tension shall terminate in standard hooks except that hooks shall not be required on the positive reinforcement at interior supports of continuous members.

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

1. By welding to longitudinal reinforcement.

2. By hooking tightly around the longitudinal reinforcement through 180 degrees.

3. The extreme ends of bars forming simple U or multiple stirrups shall be anchored as specified in 1 or 2 or shall be bent through an angle of 90 degrees tightly around a longitudinal reinforcing bar not less in diameter than the stirrup bar and shall project beyond the bend at least 12 diameters of the stirrup bar.

4. In all cases, web reinforcements shall be carried as close to the compression surface of the beam as fire and rust protection regulations and the proximity of other steel will permit.

Ind 53.19 Columns. (1) LIMITING DIMENSIONS. The following sections apply to a short column, for which the unsupported height is not greater than 10 times the least lateral dimension. When the unsupported height exceeds this value, the design shall be modified as shown in Wis. Adm. Code section Ind 53.19. The unsupported height may be defined as the distance from the bottom of a slab, column capital, or beam to the top of the floor below.

Principal columns in buildings shall have a minimum diameter of 10 inches. Rectangular columns shall have a minimum thickness of 8 inches and a minimum gross area of 120 square inches.

Posts, bearing walls, piers, or mullions that are not continuous from story to story shall have a minimum diameter or thickness of 6 inches.

(2) SPIRAL COLUMNS. The maximum allowable axial load on columns reinforced with longitudinal bars and closely spaced spirals enclosing a circular core shall be as follows:

$$P = A_g\ (0.225\ f^1_c + f_s p_g)$$

Wherein

A_g = The gross area of the column.

f^1_c = Compressive strength of the concrete.

f_s = Nominal allowable stress in vertical column reinforcement to be taken at 40% of the minimum specification value of the yield point; namely, for rail or hard grade steel—20,000#; for intermediate grade steel—16,000#.

p_g = Ratio of the effective cross sectional area of vertical reinforcement to the gross area A_g. The ratio p_g shall not be less than 0.01 nor more than 0.08.

(a) *Vertical bars.* The minimum number of vertical bars shall be 6, and the minimum diameter of bar shall be ⅝ inch. Spirals shall be at least ¼ inch in diameter and shall not be spaced less than 1½ inches nor more than 3 inches apart.

(b) *Spiral reinforcement.* The ratio of spiral reinforcement p^1 shall not be less than the value given by the following formula:

$$p^1 = 0.45 \left(\frac{A_g}{A_c} - 1 \right) \frac{f^1_c}{f^1_s}$$

Wherein

p^1 = Ratio of volume of spiral reinforcement to the volume of the concrete core (out to out of spirals).

f^1_s = Useful limit stress of spiral reinforcement to be taken as 40,000# per sq. in. for hot rolled rods of intermediate grade, 50,000# per sq. in. for rods of hard grade, and 60,000# per sq. in. for cold drawn wire.

(3) TIED COLUMNS. The maximum allowable axial load on columns reinforced with longitudinal bars and separate lateral ties shall be 80% of that given by the formula for spirally reinforced columns.

(a) The minimum number of vertical bars shall be 4, and the minimum diameter of bar shall be ⅝ inch. Lateral ties shall be at least ¼ inch in diameter and shall be spaced apart not over 16 bar diameters, 48 tie diameters, or the least dimension of the column. When there are more than 4 vertical bars, additional ties shall be provided so that every longitudinal bar is held firmly in its designed position.

(4) LONG COLUMNS. The maximum allowable load P^1 on an axially loaded reinforced concrete column having a height, h, greater than 10 times its least lateral dimension, d, is given by the formula:

$$P^1 = P \left[1.3 - .03\frac{h}{d} \right]$$

in which P = the allowable axial load on a normal short column.

(5) BENDING MOMENTS IN COLUMNS. Columns in building frames shall be designed to resist the maximum moments and shears produced by dead load, live load, and wind load, as determined by some approximate method of elastic frame analysis. Assumptions as to relative rigidity of columns and floor members shall be consistent throughout and agree with the methods used in the analysis of floor members. Recognized methods of analysis shall be followed in calculating the stresses due to combined axial load and bending. The gross area of both spiral and tied columns may be used in these computations.

(a) 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 3,000# per sq. in. or above, 20 diameters of bar of intermediate or hard grade steel. For bars of higher yield point, the amount of lap shall be increased one diameter for each 1,000# per sq. in. by which the allowable stress exceeds 20,000# per sq. in. When the concrete strengths are less than 3,000# per sq. in., the amount of lap shall be ⅓ greater than the values given above.

2. For plain bars, the minimum amount of lap shall be twice that 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 1¼ inches. 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.

History: 1–2–56; am. Register, December, 1962, No. 84, eff. 1–1–63.

Ind 53.20 Plain and reinforced concrete walls and piers. (1) Definitions. Plain concrete walls shall be defined as concrete walls where the area of the horizontal reinforcement is less than 0.0025 and the area of the vertical reinforcement is less than 0.0015 times the cross sectional area of the wall where bars are used and not less than ¾ this amount where welded wire fabric of not less than No. 10 A. S. & W. gauge is used.

(2) Thickness. The thickness of reinforced concrete bearing walls shall not be less than 6 inches for the upper 15 feet of their height, and for each successive 25 feet downward, the minimum thickness shall be increased 1 inch.

(a) Reinforced concrete bearing walls shall have a thickness of not less than 1/25 of the unsupported height or width, whichever is the shorter.

(b) Exterior basement walls, foundation walls, and party walls of either plain or reinforced concrete shall be not less than 8 inches thick.

(c) The limit of thickness and quantity of reinforcement may be waived when structural analysis shows adequate strength and stability, if approved by the industrial commission.

(3) Working stresses. The allowable working stresses in reinforced concrete bearing walls with minimum reinforcement specified above shall be 0.25 f'_c for walls having a ratio of height to thickness of 10 or less and shall be reduced proportionally to 0.15 f'_c for walls having a ratio of height to thickness of 25. When the reinforcement in bearing walls is designed, placed, and anchored in position as for tied columns, the allowable working stresses for tied columns may be used. The length of wall to be considered effective for each concentrated load shall not exceed the width of the bearing plus 4 times the wall thickness, nor shall it exceed the center to center distance between loads. The ratio p'_g shall not exceed 0.04.

(4) Non-bearing walls. Non-bearing panel and enclosure walls of reinforced concrete shall have a thickness of not less than 4 inches and not less than 1/30 the distance between supporting or enclosing members.

History: 1–2–56; r. and recr. Register, August, 1957, No. 20, eff. 9–1–57.

Ind 53.21 Footings. (1) BENDING MOMENT. The external moment on any section shall be determined by passing through the section a vertical plane which extends completely across the footing, and computing the moment of the forces acting over the entire area of the footing on one side of said plane.

(a) The greatest bending moment to be used in the design of an isolated footing shall be the moment computed in the manner just described at sections located as follows:

1. At the face of the column, pedestal or wall, for footings supporting a concrete column, pedestal or wall.

2. Halfway between the middle and the edge of the wall, for footings under masonry walls.

3. Halfway between the face of the column or pedestal and the edge of the metallic base, for footings under metallic bases.

4. The width resisting compression at any section shall be assumed as the entire width of the top of the footing at the section under consideration.

(b) In one-way reinforced footings, the total tensile reinforcement at any section shall provide a moment of resistance at least equal to the bending moment and the reinforcement thus determined shall be distributed uniformly across the full width of the section.

(c) In two-way reinforced footings, the total tensile reinforcement at any section shall provide a moment of resistance at least equal to 85% of the bending moment.

(d) In two-way square footings, the reinforcement extending in each direction shall be distributed uniformly across the full width of the footing.

(e) In two-way rectangular footings, the reinforcement in the long direction shall be distributed uniformly across the full width of the footing. In the case of the reinforcement in the short direction, that portion determined by the following formula shall be uniformly distributed across a band-width (B) centered with respect to the center line of the column or pedestal and having a width equal to the length of the short side of the footing. The remainder of the reinforcement shall be uniformly distributed in the outer portions of the footing.

$$\frac{\text{Reinforcement in band-width (B)}}{\text{Total reinforcement in short dimension}} = \frac{2}{(S + 1)}$$

In this formula, "S" is the ratio of the long side to the short side of the footing.

(2) ANCHORAGE OF BARS IN FOOTING SLABS. Plain bars in footing slabs shall be anchored by means of standard hooks. The outer faces of these hooks and the ends of deformed bars shall not be less than 3 inches nor more than 6 inches from the face of the footing.

(3) SHEAR AND BOND. The critical section for shear to be used as a measure of diagonal tension shall be assumed as a vertical section obtained by passing a series of vertical planes through the footing,

each of which is parallel to a corresponding face of the column, pedestal, or wall and located a distance therefrom equal to the effective depth for footings on soil, and ½ the effective depth for footings on piles.

(a) Each face of the critical section as defined above shall be considered as resisting an external shear equal to the load on an area bounded by said face of the critical section for shear, 2 diagonal lines drawn from the column or pedestal corners and making 45 degree angles with the principal axes of the footing, and that portion of the corresponding edge or edges of the footing intercepted between the 2 diagonals.

(b) Critical sections for bond shall be assumed at the same planes as those prescribed for bending moment; also at all other vertical planes where changes of section or of reinforcement occur.

(c) Computations for shear to be used as a measure of bond shall be based on the same section and loading as prescribed for bending moment.

(d) The total tensile reinforcement at any section shall provide a bond resistance at least equal to the bond requirement as computed from the following percentages of the external shear at the section:

1. In one-way reinforced footings, 100%.
2. In two-way reinforced footings, 85%.

(e) In computing the external shear on any section through a footing supported on piles, the entire reaction from any pile whose center is located 6 inches or more outside the section shall be assumed as producing shear on the section; the reaction from any pile whose center is located 6 inches or more inside the section shall be assumed as producing no shear on the section. For intermediate positions of the pile center, the portion of the pile reaction to be assumed as producing shear on the section shall be based on straightline interpolation between full value at 6 inches outside the section and zero value of 6 inches inside the section.

(4) TRANSFER OF STRESS AT BASE OF COLUMN. The stress in the longitudinal reinforcement of a column or pedestal shall be transferred to its supporting pedestal or footing either by extending the longitudinal bars into the supporting member, or by dowels.

(a) In case the transfer of stress in the reinforcement is accomplished by extension of the longitudinal bars, they shall extend into the supporting member the distance required to transfer to the concrete, by allowable bond stress, their full working value.

(b) In cases where dowels are used, their total sectional area shall be not less than the sectional area of the longitudinal reinforcement in the member from which the stress is being transferred. In no case shall the number of dowels per member be less than 4 and the diameter of the dowels shall not exceed the diameter of the column bars by more than ⅛ inch.

(c) Dowels shall extend up into the column or pedestal a distance at least equal to that required for lap of longitudinal column bars and down into the supporting pedestal or footing the distance required to transfer to the concrete, by allowable bond stress, the full working value of the dowel.

(d) The compressive stress in the concrete at the base of a column or pedestal shall be considered as being transferred by bearing to the top of the supporting pedestal or footing. The unit compressive stress on the loaded area shall not exceed the bearing stress allowable for the quality of concrete in the supporting member as limited by the ratio of the loaded area to the supporting area.

(e) In sloped or stepped footings, the supporting area for bearing may be taken as the top horizontal surface of the footing, or assumed as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base the area actually loaded, and having side slopes of one vertical to 2 horizontal.

(5) PEDESTALS AND FOOTINGS (PLAIN CONCRETE). The allowable compressive unit stress on the gross area of a concentrically loaded pedestal shall not exceed 0.25 f'_c. Where this stress is exceeded, reinforcement shall be provided and the member designed as a reinforced concrete column.

(a) The depth and width of a pedestal or footing of plain concrete shall be such that the tension in the concrete shall not exceed .03 f'_c and the average shearing stress shall not exceed .02 f'_c taken on sections as prescribed heretofore for reinforced concrete footings.

(6) FOOTINGS SUPPORTING ROUND COLUMNS. In computing the stresses in footings which support a round or octagonal concrete column or pedestal, the "face" of the column or pedestal shall be taken as the side of a square having an area equal to the area enclosed within the perimeter of the column or pedestal.

(7) MINIMUM EDGE-THICKNESS. In reinforced concrete footings, the thickness above the reinforcement at the edge shall be not less than 6 inches for footings on soil, nor less than 12 inches for footings on piles.

(a) In plain concrete footings, the thickness at the edge shall be not less than 8 inches for footings on soil, nor less than 14 inches above the tops of the piles for footings on piles.

Ind 53.22 Allowable working stresses. (1) CONCRETE STRENGTH. The strength of concrete is fixed by the water content as described in Wis. Adm. Code subsection Ind 53.15 (3). Reinforced concrete used under this code shall have a compressive strength of at least 2000# per sq. in. and no credit shall be given for strengths in excess of 3000# per sq. in. unless approved in writing by the industrial commission.

(2) MODULAR RATIO. The modular ratio, n, shall be assumed equal to $n = \frac{30,000}{f'_c}$.

(3) ALLOWABLE UNIT STRESSES IN CONCRETE.

Description		Allowable unit stresses: For any strength of concrete in accordance with Section Ind 53.15(2) $n = \frac{30,000}{f'_c}$	Maximum value psi	For strength of concrete shown below: $f'_c=2000$ psi $n=15$	$f'_c=2500$ psi $n=12$	$f'_c=3000$ psi $n=10$
Flexure: f_c						
Extreme fiber stress in compression	f_c	$0.45f'_c$	-------	900	1125	1350
Extreme fiber stress in tension in plain concrete footings	f_c	$0.03f'_c$	-------	60	75	90
Shear: v (as a measure of diagonal tension)						
Beams with no web reinforcement	v_c	$0.03f'_c$	-------	60	75	90
Beams with properly designed web reinforcement	v	$0.12f'_c$	-------	240	300	360
Flat slabs at distance d from edge of column capital or drop panel	v_c	$0.03f'_c$	-------	60	75	90
Footings	v_c	$0.03f'_c$	75	60	75	75
Bond: u						
Deformed bars						
Top bars	------	$0.07f'_c$	245	140	175	210
In 2-way footings (except top bars)	------	$0.08f'_c$	280	160	200	240
All others	------	$0.10f'_c$	350	200	250	300
Plain bars (must be hooked)						
Top bars	------	$0.03f'_c$	105	60	75	90
In 2-way footings (except top bars)	------	$0.036f'_c$	126	72	90	108
All others	------	$0.045f'_c$	158	90	113	135
Bearing: f_c						
Walls, Piers, Pilasters and Pedestals						
On full area	f_c	$0.25f'_c$	-------	500	625	750
On ⅓ area or less	f_c	$0.375f'_c$	-------	750	938	1125
Columns: See section Ind 53.19						

(4) ALLOWABLE UNIT STRESSES IN REINFORCEMENT. (a) *Tension in longitudinal steel and web reinforcement:*

1. Structural grade steel rods ---------------------- $f_s = 18,000$
2. Intermediate grade and hard steel rods (Billet steel, rail steel or axle steel) -------------- $f_s = 20,000$

(b) *Compression in column verticals:*

1. Intermediate grade steel rods ------------------- $f_s = 16,000$
2. Hard grade steel rods (Billet steel, rail steel or axle steel) ---------------------------------- $f_s = 20,000$
3. The symbols and notation used in the above formulas are defined as follows:

   f'_c—ultimate compressive strength of concrete at age of 28 days.

   f_c—compressive unit stress in extreme fibre of concrete in flexure or axial compression in concrete in columns.

   v_c—unit shearing stress in concrete.

   u—bond stress per unit area of surface of bar.

   f_s—tensile unit stress in reinforcement.

(5) ULTIMATE STRENGTH METHOD OF DESIGN. (a) The ultimate strength method of design for reinforced concrete may be used under the following conditions if approved in writing by the industrial commission.

1. Where the ultimate strength method of design is used, all other features of the design shall conform to the requirements of the building code.

2. Positive control shall be provided for the concrete mix. This includes periodic tests of regular concrete cylinders to determine the strength of the concrete.

3. Supervision shall be provided by the supervising architect or engineer during mixing and pouring operations where this method of design is involved.

History: 1–2–56; cr. (5), Register, September, 1959, No. 45, eff. 10–1–59.

Ind 53.23 Reinforced gypsum concrete. (1) MATERIALS. (a) The term "gypsum" as used in this chapter shall mean calcined gypsum manufactured from gypsum meeting the requirements of the American Society for Testing Materials' Standard Specifications for Gypsum C22–25, (American Standard A49.1–1933).

(b) Gypsum concrete shall consist of a mixture of gypsum and water, with or without wood chips, fiber or other approved aggregate.

(c) Precast gypsum concrete shall contain not more than 3% and cast-in-place gypsum concrete not more than 12½% of wood chips, shavings, or fiber measured as a percentage by weight of the dry mix.

(d) Wood chips, shavings, or fiber used in gypsum concrete shall be dry, soft wood, uniform and clean in appearance. They shall pass a 1-inch screen and shall be not more than 1/16 inch in thickness.

(e) Steel bar and wire reinforcing shall meet the requirements of Wis. Adm. Code subsection Ind 53.14 (5).

(2) MINIMUM THICKNESS. (a) The minimum thickness of gypsum concrete in floors and roofs shall be 2 inches except the suspension system, which shall be not less than 3 inches thick. Hollow precast gypsum concrete units for roof construction shall be not less than 3 inches thick and the shell not less than ½ inch thick.

(b) Precast gypsum concrete units for floor and roof construction shall be reinforced and unless the shape or marking of the unit is such as to insure its being placed right side up, the reinforcing shall be symmetrical so that the unit can support its load either side up.

(3) DESIGN. (a) Reinforced gypsum concrete shall be designed by methods admitting of rational analysis according to established principles of mechanics, to support the loads and withstand the forces to which it is subject without exceeding the stresses allowed in this chapter for the materials thereof except as hereinafter provided. The general assumptions and principles established for reinforced concrete shall also apply to reinforced gypsum concrete insofar as they are pertinent.

(b) For precast gypsum structural units which can not be analyzed in accordance with established principles of mechanics, the safe uniformly distributed carrying capacity shall be taken as ⅙ of the total load causing failure in a full size test panel with the load applied along 2 lines each distant ¼ of the clear span from the support.

(c) Reinforced gypsum concrete shall not be used where exposed directly to the weather or where subjected to frequent or continuous wetting.

(4) STRENGTH. (a) Gypsum concrete shall be classified according to mixture, and concrete of each class shall have a minimum strength in compression as follows:

1. Class 1	Neat (Containing gypsum and water only)	1800 lbs. per sq. in.
2. Class 2	Containing not more than 3% by weight of wood chips or fiber	1000 lbs. per sq. in.
3. Class 3	Containing not more than 12½% by weight of wood chips or fiber	500 lbs. per sq. in.

(b) The strength of gypsum concrete shall be determined by compressive tests of 5 cylinders, 6 inches in diameter and 12 inches in length, from each 25 tons or fraction thereof. The test specimens shall be dried at a temperature of not less than 70 degrees Fahrenheit nor more than 100 degrees Fahrenheit in an atmosphere of not more than 50% relative humidity. The specimens shall be weighed at 1-day intervals until constant weight is attained. The method of testing and application of load shall be in accordance with the requirements specified in sections 19 and 20 of Standard Methods of Making Compression Tests of Concrete, A.S.T.M. C39–39. The average of the 5 specimens shall not fall below the specified minimum and in no case shall any specimen show a strength of less than 80% of the specified minimum.

(5) MODULUS OF ELASTICITY. (a) In the design of structural members of reinforced gypsum concrete the following values shall be used for the modulus of elasticity:

1. Class 1	Neat	1,000,000 lbs. per sq. in.
2. Class 2	Containing not more than 3% by weight of wood chips or fiber	600,000 lbs. per sq. in.
3. Class 3	Containing not more than 12½% by weight of wood chips or fiber	200,000 lbs. per sq. in.

(6) ALLOWABLE STRESSES. (a) In the design of structural members of reinforced gypsum concrete the stresses in the concrete shall not exceed the following allowable values:

1. Compressive stress in bending	$0.25f_g$
2. Axial compressive or bearing stress	$0.20f_g$
3. Bond stress (reinforcement anchored)	$0.02f_g$
4. Shearing stress (reinforcement anchored)	$0.02f_g$

5. In this table (f_g) indicates the compressive strength of the gypsum concrete as specified in subsection (4) (a).

(b) The tensile stresses in reinforcing steel shall be as specified for reinforced concrete made with Portland cement.

(7) SUSPENSION SYSTEM. In the construction of floors or other slabs the reinforcing shall consist of wires with continuity through multiple spans and anchored at the ends. The wires shall be supported in the top of the slab by the roof or floor beams and shall be tightly drawn down as nearly to the bottom of the slab at mid-span as fire protection requirements will allow. Provision shall be made in the framing of the end bays of this system for resisting the forces due to end anchorage of the wires. The wires shall be designed for a tension in pounds per foot width of slab equal to:

$$\frac{wL^2}{8d}$$

in which

w is the total load in lbs. per sq. ft.
L is the clear span in feet
d is the sag of the wires in feet

Ind 53.24 Structural steel. (1) MATERIAL. (a) *Minimum yield point.* The minimum yield point in pounds per square inch for structural steel used in buildings and structures under this code shall be as follows:

Steel for bridges and buildings, Designation A-7	33,000
Structural steel for welding, Designation A–373	32,000
Structural steel, Designation A-36	36,000
High-strength structural steel, Designation A–440	42,000—50,000
High-strength low-alloy structural manganese vanadium steel, Designation A–441	42,000—50,000
High-strength low-alloy structural steel, Designation A–242	42,000—50,000

1. Certified test reports shall be submitted as evidence of conformity with the specifications when requested by the industrial commission.

2. Unidentified steel, if free from surface imperfections, may be used for parts of minor importance, or for unimportant details, where the precise physical properties of the steel and its weldability would not affect the strength of the structure.

(b) *Other metals.* Cast steel shall conform to one of the following specifications:

Mild-to-medium-strength carbon-steel castings for general application, Designation A-27, Grade 65–35.

High-strength steel castings for structural purposes, Designation A–148, Grade 80–50.

1. Certified test reports shall be submitted as evidence of conformity with the specifications when requested by the industrial commission.

2. Steel forgings shall conform to one of the following specifications:

a. Carbon steel forgings for general industrial use, Designation A-235, Class C1, F and G. (Class C1 forgings that are to be welded shall be ordered in accordance with supplemental requirements S5 of A-235.)

b. Alloy steel forgings for general industrial use, Designation A-237, Class A.

3. Certified test reports shall be submitted as evidence of conformity with the specifications when requested by the industrial commission.

(c) *Rivet steel.* Rivet steel shall conform to one of the following specifications:

Structural rivet steel, Designation A–141.
High-strength structural rivet steel, Designation A–195.
High-strength structural alloy rivet steel, Designation A–406.

1. Certified test reports shall be submitted as evidence of conformity with the specifications when requested by the industrial commission.

(d) *Bolts.* High-strength steel bolts shall conform to one of the following specifications:

High-strength steel bolts for structural joints, Designation A-325.

Quenched and tempered alloy steel bolts and studs with suitable nuts, Designation A-354, Grade BC.

1. Other bolts shall conform to the specification for low-carbon steel externally and internally threaded standard fasteners, Designation A-307, hereinafter designated as A-307 bolts.

2. Manufacturer's certification shall be submitted as evidence of conformity with the specifications when requested by the industrial commission.

(e) *Filler metal for welding.* Welding electrodes for manual shielded metal arc welding shall conform to the E60 or E70 series of the specification for mild steel arc welding electrodes, Designation A-233.

1. Bare electrodes and granular fusible flux used in combinations for submerged arc welding shall be capable of producing weld metal having the following tensile properties when deposited in a multiple pass weld:

a. Grade SA-1	
Tensile strength	62,000 to 80,000 psi
Yield point, min.	45,000 psi
Elongation in 2 in., min.	25%
Reduction in area, min.	40%
b. Grade SA-2	
Tensile strength	70,000 to 90,000 psi
Yield point, min.	50,000 psi
Elongation in 2 in., min.	22%
Reduction in area, min.	40%

2. Manufacturer's certification shall be submitted as evidence of conformity with the specifications when requested by the industrial commission.

(2) ALLOWABLE UNIT STRESSES. All components of the structure shall be so proportioned that the unit stresses in pounds per square inch shall not exceed the following values except as specified in Wis. Adm. Code section Ind 53.01.

(a) *Structural steel.* 1. Tension. a. On the net section, except as pin holes

$$F_t = 0.60F_y$$

b. On the net section at pin holes in eyebars, pin-connected plates or built-up members

$$F_t = 0.45\ F_y$$

Note: F_t = Allowable tensile stress
F_y = Minimum yield point of type of steel used

2. Shear. On the gross section of beam and plate girder webs

$$F_v = 0.40 F_y$$

3. Compression. a. On the gross section of axially loaded compression members when $\frac{1}{r}$, the largest slenderness ratio of any unbraced segment is less than C_c

(FORMULA 1)

$$F_a = \frac{\left[1 - \frac{\left(\frac{1}{r}\right)^2}{2C_c^2}\right] F_y}{F.\ S.}$$

Where

$$F.\ S. = \text{factor of safety} = \frac{5}{3} + \frac{3\left(\frac{1}{r}\right)}{8C_c} - \frac{\left(\frac{1}{r}\right)^3}{8C_c}$$

and

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$$

b. On the gross section of axially loaded columns when $\frac{1}{r}$ exceeds C_c

(FORMULA 2)

$$F_a = \frac{149{,}000{,}000}{\left(\frac{1}{r}\right)^2}$$

c. On the gross section of axially loaded bracing and secondary members, when $\frac{1}{r}$ exceeds 120

(FORMULA 3)

$$F_{as} = \frac{F_a\ \text{(by Formula 1 or 2)}}{1.6 - \frac{1}{200r}}$$

d. On the gross area of plate girder stiffeners

$$F_a = 0.60\ F_y$$

e. On the web of rolled shapes at the toe of the fillet.

$$F_a = 0.75\ F_y$$

4. Bending. a. Tension and compression on extreme fibers of rolled shapes and built-up members having an axis of symmetry in the plane

of loading and proportions meeting the requirements of compact sections, when the member is supported laterally at intervals no greater than 13 times its compression flange width

$$F_b = 0.66\ F_y$$

b. Beams and girders which meet the requirements of the preceding paragraph and are continuous over supports or are rigidly framed to columns by means of rivets, high-strength bolts or welds, may be proportioned for 9/10 of the negative moments produced by gravity loading which are maximum at points of support provided that, for such members, the maximum positive moment shall be increased by 1/10 of the average negative moments. This reduction shall not apply to moments produced by loading on cantilevers. If the negative moment is resisted by a column rigidly framed to the beam or girder, the 1/10 reduction may be used in proportioning the column for the combined axial and bending loading, provided that the unit stress, due to any concurrent axial load on the member, does not exceed $0.15F_y$.

c. Tension and compression on extreme fibers of unsymmetrical members supported in the region of compression stress as specified in section 4. a.

$$F_b = 0.60F_y$$

d. Tension and compression on extreme fibers of box-type members whose proportions do not meet the provisions of compact sections, but do conform to the provisions of section 5—Width-Thickness Ratio.

$$F_b = 0.60F_y$$

e. Tension on extreme fibers of other rolled shapes, built-up members, and plate girders.

$$F_b = 0.60F_y$$

f. Compression on extreme fibers of rolled shapes, plate girders, and built-up members having an axis of symmetry in the plane of their web (other than box-type beams and girders), the larger value computed by formulas (4) and (5), but not more than $0.60F_y$

(FORMULA 4)

$$F_b = \left[1.0 - \frac{\left(\frac{1}{r}\right)^2}{2C_c^2\ C_b} \right] 0.60F_y$$

(FORMULA 5)

$$F_b = \frac{12,000,000}{\frac{1d}{A_f}}$$

where 1 is the unbraced length of the compression flange; r is the radius of gyration of a tee section comprising the compression flange plus 1/6 of the web area, about an axis in the plane of the web; A_f is the area of the compression flange; C_c is defined in section 3. a. and C_b, which can conservatively be taken as unity, is equal to

$$C_b = 1.75 - 1.05 \left(\frac{M_1}{M_2}\right) + 0.3 \left(\frac{M_1}{M_2}\right)^2, \text{ but not more than } 2.3$$

where M_1 is the smaller and M_2 the larger bending moment at the ends of the unbraced length, taken about the strong axis of the member, and where $\frac{M_1}{M_2}$, the ratio of end moments, is positive when M_1 and M_2 have the same sign (single curvature bending) and negative when they are of opposite signs (reverse curvature bending). When the bending moment at any point within an unbraced length is larger than that at both ends of this length the ratio $\frac{M_1}{M_2}$ shall be taken as unity.

g. Compression on extreme fibers of channels, the value computed by formula (5), but not more than

$$F_b = 0.60F_y$$

h. Tension and compression on extreme fibers of large pins.

$$F_b = 0.90F_y$$

i. Tension and compression on extreme fibers of rectangular bearing plates.

$$F_b = 0.75F_y$$

5. Bearing (on contact area). a. Milled surfaces and pins in reamed, drilled or bored holes, pounds per square inch

b. Finished stiffeners pounds per square inch

$$F_p = 0.80\ F_y$$

$$F_p = 0.90F_y$$

c. Expansion rollers and rockers, pounds per linear inch

$$F_p = \left(\frac{F_y - 13{,}000}{20{,}000}\right) 660d$$

where d is the diameter of roller rocker in inches

d. Rivets and bolts. Allowable unit tension and shear stresses on rivets, bolts and threaded parts (pounds per square inch of area of rivets before driving or unthreaded body area of bolts and threaded parts) shall be as given in table 1.

TABLE 1

Description of Fastener	Tension (F_t)	Shear (F_v) Friction-type Connections	Shear (F_v) Bearing-type Connections
A141 hot-driven rivets	20,000	--------------	15,000
A195 and A406 hot-driven rivets	27,000	--------------	20,000
A307 bolts and threaded parts of A7 and A373 steel	14,000	--------------	10,000
Threaded parts of other steels	$0.40F_y$	--------------	$0.30F_y$
A325 bolts when threading is *not* excluded from shear planes	40,000	15,000	15,000
A325 bolts when threading is excluded from shear planes	40,000	15,000	22,000
A354, Grade BC, bolts when threading is *not* excluded from shear planes	50,000	20,000	20,000
A354, Grade BC, when threading is excluded from shear planes	50,000	20,000	24,000

Allowable bearing stress on projected area of bolts in bearing-type connections and on rivets.

$$F_p = 1.35F_y$$

(Bearing stress not restricted in friction-type connections assembled with A325 and A354, Grade BC, bolts).

Welds (stress in pounds per square inch throat area).

Fillet, plug, slot and partial penetration groove welds.

Fillet, plug, slot and partial penetration groove welds made with A233 Class E60 series electrodes and fillet welds made by submerged arc welding Grade SA-1—13,600.

Fillet, plug, slot and partial penetration groove welds made with A233 Class E70 series electrodes and fillet welds made by submerged arc welding Grade SA-2—15,800.

Complete penetration groove welds.

On complete penetration groove welds the allowable tension, compression, bending, shear and bearing stresses shall be the same as those allowed by section (2) in the connected material.

e. Cast steel and steel forgings.

1. Tension (on net section) F_t $0.60F_y$
2. Shear (on gross section) F_v $0.40F_y$
3. Compression—same as provided under section (2) (a) 3. a.
4. Bending (on extreme fibers) F_b $0.60F_y$
5. Bearing—same as provided under section (2) (a) 5.

f. Wind stresses. (See Wis. Adm. Code section Ind 53.01)

(3) COMBINED STRESSES. (a) *Axial compression and bending.* Members subject to both axial compression and bending stresses shall be proportioned to meet the requirements of both Formula (6) and Formula (7).

FORMULA (6)

$$\frac{f_a}{F_a} + \frac{C_m f_b}{\left(1 - \frac{f_a}{F^1_e}\right) F_b} \leqq 1.0$$

FORMULA (7)

$$\frac{f_a}{0.6F_y} + \frac{f_b}{F_b} \leqq 1.0 \text{ (applicable only at braced points)}$$

where

F_a = axial stress that would be permitted if axial stress alone existed

F_b = bending stress that would be permitted if bending stress alone existed

$F^1_e = \frac{149,000,000}{\left(\frac{1}{r_b}\right)^2}$ (May be increased ⅓ in accordance with Wis. Adm. Code section Ind 53.01)

l = actual unbraced length in the plane of bending

r_b = radius of gyration about axis of bending

f_a = computed axial stress

f_b = computed bending stress at the point under consideration
C_m = 0.85, except as follows:

1. When $\frac{f_a}{F_a} \leq 0.15$. (For this case the member selected shall meet the limitation that

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1.0$$

2. For restrained compression members in frames braced against joint translation but not subject to transverse loading between their supports in the plane of loading, C_m may be taken as 0.6 plus 0.4 $\left(\frac{M_1}{M_2}\right)$, where $\frac{M_1}{M_2}$ is the ratio of smaller to larger moments at the ends of the critical unbraced length of the member. $\frac{M_1}{M_2}$ is positive when the unbraced length is bent in single curvature and negative when it is bent in reverse curvature.
3. For restrained compression members in frames braced against joint translation in the plane of loading and subject to transverse loading between their supports (joints) in the plane of loading, a value of C_m may be determined by rational analysis.

(b) *Shear and tension.* Rivets and bolts subject to combined shear and tension due to force applied to the connected parts, shall be so proportioned that the tension stress produced by the force shall not exceed the following:

For A141 rivets	$F_t = 28{,}000 - 1.6f_v \leq 20{,}000$
For A195 and A406 rivets	$F_t = 38{,}000 - 1.6f_v \leq 27{,}000$
For A307 bolts	$F_t = 20{,}000 - 1.6f_v \leq 14{,}000$
For A325 bolts in bearing-type joints	$F_t = 50{,}000 - 1.6f_v \leq 40{,}000$
For A354, Grade BC, bolts in bearing-type joints	$F_t = 60{,}000 - 1.6f_v \leq 50{,}000$

where f_v, the shear stress produced by the same force, shall not exceed the value for shear given in section (2) 5. (d).

For bolts used in friction-type joints, the shear stress allowed in section (2) 5. (d) shall be reduced as follows:

For A 325 bolts ---------- $F_v \leq 15{,}000 \left(1 - \frac{f_t A_b}{T_b}\right)$

For A 354, Grade BC, bolts ---------- $F_v \leq 20{,}000 \left(1 - \frac{f_t A_b}{T_b}\right)$

where f_t is the tensile stress due to applied load and T_b is the proof load of the bolt.

(4) SLENDERNESS RATIOS. (a) *Definition.* In determining the slenderness ratio of an axially loaded compression member, l shall be taken as its effective length and r the corresponding radius of gyration.

(b) *Sidesway prevented.* The effective length of compression members in trusses, and in frames where lateral stability is provided by diagonal bracing, shear walls, attachment to an adjacent structure having adequate lateral stability, or by floor slabs or roof decks secured horizontally by walls or bracing systems parallel to the plane of the frame, shall be taken as the actual unbraced length, unless analysis shows that a shorter length may be used.

(c) *Sidesway not prevented.* The effective length of compression members in a frame which depends upon its own bending stiffness for lateral stability, shall be determined by a rational method and shall not be less than the actual unbraced length.

(d) *Maximum ratios.* The slenderness ratio of compression members shall not exceed 200. The slenderness ratio of tension members, other than rods, preferably should not exceed:

For main members	240
For bracing and other secondary members	300

(5) WIDTH-THICKNESS RATIOS. (a) *Projecting elements under compression.* 1. Projecting elements of members subjected to axial compression or compression due to bending shall have ratios of width-to-thickness not greater than the following:

Single-angle struts; double-angle struts with separators	$\frac{2{,}400}{\sqrt{F_y}}$
Struts comprising double angles in contact; angles or plates projecting from girders, columns or other compression members; compression flanges of beams; stiffeners on plate girders	$\frac{3{,}000}{\sqrt{F_y}}$
Stems of tees	$\frac{4{,}000}{\sqrt{F_y}}$

2. The width of plates shall be taken from the free edge to the first row of rivets, bolts, or welds; the width of legs of angles, channels and zees, and of the stems of tees, shall be taken as the full nominal dimension; the width of flanges of beams and tees shall be taken as ½ the full nominal width. The thickness of a sloping flange shall be measured halfway between a free edge and the corresponding face of the web.

3. When a projecting element exceeds the width-to-thickness ratio prescribed in the preceding paragraph, but would conform to same and would satisfy the stress requirements with a portion of its width considered as removed, the member will be acceptable.

(b) *Compression elements supported along 2 edges.* 1. In compression members the unsupported width of web, cover or diaphragm plates, between the nearest lines of fasteners or welds, or between the roots of the flanges in case of rolled sections, shall not exceed $\frac{8{,}000}{\sqrt{F_y}}$ times its thickness.

2. When the unsupported width exceeds this limit, but a portion of its width no greater than $\frac{8{,}000}{\sqrt{F_y}}$ times the thickness would satisfy the stress requirements, the member will be considered acceptable.

3. The unsupported width of cover plates perforated with a succession of access holes, may exceed $\frac{8,000}{\sqrt{F_y}}$, but shall not exceed $\frac{10,000}{\sqrt{F_y}}$, times the thickness. The gross width of the plate less the width of the widest access hole shall be assumed available to resist compression.

(6) SIMPLE AND CONTINUOUS SPANS. (a) *Simple spans.* Beams, girders and trusses shall ordinarily be designed on the basis of simple spans whose effective length is equal to the distance between centers of gravity of the members to which they deliver their end reactions.

(b) *End restraint.* When designed on the assumption of full or partial end restraint, due to continuous, semi-continuous or cantilever action, the beams, girders and trusses, as well as the sections of the members to which they connect, shall be designed to carry the shears and moments so introduced, as well as all other forces, without exceeding at any point the unit stresses prescribed in section (2) (a); except that some non-elastic but self-limiting deformation of a part of the connection may be permitted when this is essential to the avoidance of overstressing of fasteners.

(7) DEFLECTIONS. (a) Beams and girders supporting floors and roofs shall be proportioned with due regard to the deflection produced by the design loads.

(b) Beams and girders supporting plastered ceilings shall be so proportioned that the maximum live load deflection will not exceed 1/360 of the span.

(c) The depth of beams and girders supporting flat roofs shall be not less than $\frac{F_y}{1,000,000}$ times their span length whether designed as simple or continuous spans.

(8) CONNECTIONS. (a) *Minimum connections.* Connections carrying calculated stresses, except for lacing, sag bars, and girts, shall be designed to support not less than 6,000 pounds.

(b) *Eccentric connections.* Axially stressed members meeting at a point shall have their gravity axes intersect at a point if practicable; if not, provision shall be made for bending stresses due to the eccentricity.

(c) *Placement of rivets, bolts and welds.* Except as hereinafter provided, the rivets, bolts or welds at the ends of any member transmitting axial stress into that member shall have their centers of gravity on the gravity axis of the member unless provision is made for the effect of the resulting eccentricity. Except in members subject to repeated variation in stress, disposition of fillet welds to balance the forces about the neutral axis or axes for end connections of single angle, double angle, and similar type members is not required. Eccentricity between the gravity axes of such members and the gauge lines for their riveted or bolted end connections may be neglected.

(d) *Unrestrained members.* Except as otherwise indicated by the designer, connections of beams, girders or trusses shall be designed as flexible, and may ordinarily be proportioned for the reaction shears only. Flexible beam connections shall permit the ends of the beam to rotate sufficiently to accommodate its deflection by providing for a horizontal displacement of the top flange determined as follows:

$e = 0.007d$, when the beam is designed for full uniform load and for live load deflection not exceeding 1/360 of the span

$= \frac{f_b L}{3,600,000}$, when the beam is designed for full uniform load producing the unit stress f_b at mid-span

where

e = the horizontal displacement of the end of the top flange, in the direction of the span, in inches

f_b = the flexural unit stress in the beam at mid-span, in pounds per square inch

d = the depth of the beam, in inches

L = the span of the beam, in feet

(e) *Restrained members.* Fasteners or welds for end connections of beams, girders and trusses not conforming to the requirements of section (8) (d) shall be designed for the combined effect of end reaction shear and tensile or compressive stresses resulting from moment induced by the rigidity of the connection when the member is fully loaded.

(9) COLUMN BASES. (a) *Loads.* Proper provision shall be made to transfer the column loads and moments, if any, to the footings and foundations.

(b) *Alignment.* Column bases shall be set level and to correct elevation with full bearing on the masonry.

(c) *Finishing.* Column bases shall be finished in accordance with the following requirements:

1. Rolled steel bearing plates, 2 inches or less in thickness, may be used without planing, provided a satisfactory contact bearing is obtained; rolled steel bearing plates over 2 inches but not over 4 inches in thickness may be straightened by pressing; or, if presses are not available, by planing for all bearing surfaces (except as noted under requirement 3. of this section), to obtain a satisfactory contact bearing; rolled steel bearing plates over 4 inches in thickness shall be planed for all bearing surfaces (except as noted under requirement 3. of this section).

2. Column bases other than rolled steel bearing plates shall be planed for all bearing surfaces (except as noted under requirement 3. of this section).

3. The bottom surfaces of bearing plates and column bases which are grouted to insure full bearing contact on foundations need not be planed.

(10) SHOP PAINTING. (a) *General requirements.* Unless otherwise specified, steelwork which will be concealed by interior building finish need not be painted; steelwork to be encased in concrete shall not be painted. Unless specifically exempted, all other steelwork shall be given one coat of shop paint, applied thoroughly and evenly to dry surfaces which have been cleaned in accordance with the following paragraph, by brush, spray, roller coating, flow coating, or dipping, at the election of the fabricator.

(b) *Cleaning.* After inspection and approval and before leaving the shop, all steelwork specified to be painted shall be cleaned by hand-wire brushing, or by other methods elected by the fabricator, of loose mill scale, loose rust, weld slag or flux deposit, dirt and other foreign matter. Oil and grease deposits shall be removed by solvent. Steelwork specified to have no shop paint, after fabrication, shall be cleaned of oil or grease by solvent cleaners and shall be cleaned of dirt and other foreign material by thorough sweeping with a fiber brush.

(c) *Protection for short period of exposure.* The shop coat of paint is intended to protect the steel for only a short period of exposure, even if it is a primer for subsequent painting to be performed in the field by others.

(d) *Inaccessible surfaces.* Surfaces inaccessible after assembly shall be treated in accordance with section (10) (a) before assembly.

(e) *Contact surfaces.* Contact surfaces shall be cleaned in accordance with section (10) (a) before assembly but shall not be painted.

(f) *Finished surfaces.* Machine finished surfaces shall be protected against corrosion by a rust-inhibiting coating that can be easily removed prior to erection or which has characteristics that make removal unnecessary prior to erection.

(g) *Surfaces adjacent to field welds.* Unless otherwise provided, surfaces within 2 inches of any field weld location shall be free of materials that would prevent proper welding or produce objectionable fumes while welding is being done.

(11) ERECTION. (a) *Bracing.* The frame of steel skeleton buildings shall be carried up true and plumb, and temporary bracing shall be introduced whenever necessary to take care of all loads to which the structure may be subjected, including equipment and the operation of same. Such bracing shall be left in place as long as may be required for safety.

(b) *Carrying.* Wherever piles of material, erection equipment or other loads are carried during erection, proper provision shall be made to take care of stresses resulting from such loads.

(c) *Adequacy of temporary connections.* As erection progresses, the work shall be securely bolted, or welded, to take care of all dead load, wind and erection stresses.

(d) *Alignment.* No riveting, permanent bolting or welding shall be done until as much of the structure as will be stiffened thereby has been properly aligned.

(e) *Field welding.* Any shop paint on surfaces adjacent to joints to be field welded shall be wire brushed to reduce the paint film to a minimum.

(f) *Field painting.* Responsibility for touch-up painting and cleaning, as well as for general painting shall be allocated in accordance with accepted local practices and this allocation shall be set forth explicitly in the contract.

(12) PLASTIC DESIGN AND FABRICATION. (a) The design, fabrication and erection of structural steel for buildings and structures by the plastic design method shall conform with recognized good engineering practice as approved by the industrial commission.

Note: It will be the policy of the industrial commission to accept methods of plastic design which conform with the rules for plastic design and fabrication of structural steel issued by the American Institute of Steel Construction.

(13) WELDS. (a) *Type of welds.* Butt, fillet, plug or slot welds, or a combination of these types, may be used in making joints and joining component parts.

(b) *Qualification of weld details.* The details of all joints (including for butt welds, the groove form, root face, root spacing, etc.) to be employed under this rule without qualification shall comply with all of the requirements for joints which are accepted without qualification test by the industrial commission. No joint form not included in the foregoing shall be employed until it shall have been qualified to the satisfaction of the industrial commission.

Note: It will be the policy of the industrial commission to approve of weld details, processes and methods conforming to the requirements of the standard code for arc and gas welding in building construction of the American Welding Society.

(c) *Operator qualifications.* All welding shall be done by skilled workmen who shall give satisfactory proof of their skill and ability with process to be used on the proposed work.

(d) *Qualifications and inspection requirements for welding operations and operators.* 1. The state building code provides that the industrial commission shall determine necessary data, tests and other evidence required to prove the merits of materials, methods of construction and devices used in the construction, alteration and equipment of buildings or structures, and further, in connection with welding, requires such work to be done by skilled welders who must give satisfactory proof of their skill and ability.

2. In conformance with these provisions, the following regulations are adopted and promulgated to apply to all welding operations on buildings and structures coming within the scope of the state building code.

3. All welding operators employed as such in executive work covered by the Wisconsin state building code shall be previously qualified by tests as prescribed herein. These qualification tests shall be performed under the supervision of an approved testing laboratory or commercial testing engineer who will certify to the industrial commission that the operator has passed the prescribed qualification tests.

4. The industrial commission shall issue, to any operator who has successfully passed the prescribed qualification tests, a certificate bearing the operator's name, address and signature, and the record of the extent of his successful qualification testing. This certificate shall remain in force for one year provided the operator is engaged in welding without an interruption of more than 3 consecutive months' duration, in which latter case the certificate shall automatically become void. The renewal of a certificate shall be granted only upon successful completion of new qualification tests.

5. The procedure for qualification of welding operators shall consist essentially of tests for the making of both groove and fillet welds in 4 positions each. One test is required for each position for fillet welds, and for groove welds one test for each position in material up to and including ¾ inch thick shall be made in material ⅜ inch thick, except that if the construction involves welding of material over ¾ inch thick, one test weld shall be made for each position in material of the maximum thickness to be used, but need not exceed one inch in thickness, if a test weld is made in the maximum or one inch thickness, no test weld is necessary in the ⅜ inch thickness.

6. All welding shall be subject to examination by a competent inspector approved by the industrial commission, who shall certify to the industrial commission that all welding has been completed in accordance with the approved plans and specifications and with the provisions of the Wisconsin state building code.

Note: The methods and procedures of such inspection shall be in accordance with the provisions of section 5 of the Code for Arc and Gas Welding in Building Construction, latest edition, as published by the American Welding Society.

7. The form SB–13A "Certificate of Competency—WELDER" is issued pursuant to Wis. Adm. Code Ind 53.24 (13) (c).

Note: Section Ind 53.24 is based on the American Institute of Steel Specification dated November 30, 1961. For members and connections subject to repeated variation of stress, plate girders, composite construction, fabrication, shop practice, and plastic design, see A.I.S.C. Specification.

(14) LIGHT GAUGE STEEL STRUCTURAL MEMBERS. (a) *Scope.* The requirements of this section shall apply to the design of structural members formed of sheet or strip steel less than 3/16 inch thick and used for load carrying purposes in buildings and structures within the scope of this code. All such structural members shall be capable of supporting all required loads without exceeding the allowable unit stresses specified in this section and shall be designed in accordance with recognized engineering practice.

(b) *Material.* 1. All steel used in the construction of buildings and structures shall be fabricated from materials of uniform quality and free from defects that would impair the strength or stability of the structure.

Note: It will be the policy of the industrial commission to approve, subject to the provisions of this section, steel that conforms to the following standard specifications of the American Society for Testing Materials:

a. Flat-rolled carbon steel sheets of structural quality.
Designation A245
b. Hot rolled carbon strip of structural quality.
Designation A303
c. High-strength low-alloy cold rolled steel sheets and strip.
Designation A374
d. High-strength low-alloy hot rolled steel sheets and strip.
Designation A375

2. Steel of higher strength than is covered by the above mentioned specifications may be used at the unit stresses herein specified for "other grades" of steel provided the design is based upon the minimum properties of those grades of steel as guaranteed by the manufacturer. When requested by the industrial commission, the manufacturer shall furnish certified data showing the properties of such grades of steel.

(c) *Basic design stress. Allowable working stresses.* 1. Tension on the net section of tension members, and tension and compression f_b on extreme fiber of flexural members shall not exceed the values specified in the following table, except as otherwise provided in this section:

Grade of Steel	Minimum Yield Point Pounds per Sq. In.	Allowable Working Stress Pounds per Sq. In.
C	33,000	20,000
B	30,000	18,000
A	25,000	15,000
Other Grades	Minimum Yield Point Divided by 1.65	

2. Compression on unstiffened elements. Compression f_c in pounds per square inch on flat unstiffened elements shall not exceed the values in accordance with the following formula:

a. For $\frac{w}{t}$ not greater than 10, $f_c = f_b$ except that when f_b exceeds 30,000 psi, the maximum $\frac{w}{t}$ ratio for which f_c may be taken equal to f_c shall not exceed $\frac{300,000}{f_b}$

b. For $\frac{w}{t}$ greater than 10 but not greater than 25 $f_c = (1.667 f_b - 8640) - (1/15) \quad (f_b - 12950) \frac{w}{t}$

For steels with a yield point in excess of 50,000 psi, the value of f_b to be used in the determination of f_c when $\frac{w}{t}$ exceeds 10 shall be 30,000 psi.

c. For $\frac{w}{t}$ from 25 to 60

For angle struts $f_c = \dfrac{8,090,000}{\left(\frac{w}{t}\right)^2}$

For all other sections $f_c = 20,000 - 282 \left(\frac{w}{t}\right)$

In the above formula $\frac{w}{t}$ = ratio of flat width to thickness of an element.

3. Allowable web shear. a. The maximum average web shear stress, v, in pounds per square inch on the gross area of a flat web shall not exceed the values in accordance with the following formula:

$$v = \frac{64,000,000}{\left(\frac{h}{t}\right)^2} \text{ with a maximum of } 2/3\ f_b.$$

In the above formula

t = web thickness

h = clear distance between flanges

f_b = allowable working stress as specified in (c).

b. Where the web consists of 2 or more sheets, each sheet shall be considered as a separate member carrying its share of the shear.

c. Maximum slenderness ratio.

1. The maximum allowable ratio $\frac{L}{r}$ of unsupported length L to radius of gyration r, of compression members shall not exceed 200.

History: 1-2-56; cr. (9) (d) 7. Register, October, 1957, No. 22, eff. 11-1-57; cr. (15), Register, September, 1959, No. 45, eff. 10-1-59; am. Register, December, 1962, No. 84, eff. 1-1-63.

Ind 53.25 Steel joist construction. (1) DEFINITION. Steel joist construction shall consist of decks or top slabs defined in Wis. Adm. Code subsection Ind 53.25 (7), supported by separate steel members referred to as steel joists. Any steel member suitable for supporting floors and roofs between the main supporting girders, trusses, beams, or walls when used as hereinafter stipulated shall be known as a "steel joist". Such steel joists may be made of hot or cold formed sections, strip or sheet steel, riveted or welded together, or by expanding.

(2) LIMIT OF SPAN AND SPACING. The clear span of steel joist shall not exceed 24 times the depth of the steel portion of the steel joist.

(a) The spacing of steel joist for floors shall not exceed the safe span for the top slab or flooring. Where the joist spacing for floors exceeds 24 inches on centers, the bridging shall be adequate to distribute concentrated loads between joist. The spacing of steel joist for roofs shall not exceed the safe span of the top slab or roof deck.

(b) Where these spans or spacings are exceeded, the requirements for steel joist construction shall not apply, but the steel members shall be designed in accordance with the requirements of Wis. Adm. Code section Ind 53.24.

(3) MATERIALS. All steel joist used in the construction of buildings and structures shall be fabricated from materials of uniform quality and free from defects that would impair the strength or stability of the structure. The steel used shall conform to the following specifications:

Structural steel for bridges and buildings: Designation A-7; Minimum yield point, 33,000
Structural steel: Designation A-36; Minimum yield point, 36,000
Flat rolled carbon steel sheets of structural quality: Designation A-245; Minimum yield point, 33,000
Hot rolled carbon steel strip of structural quality: Designation A–303; Minimum yield point, 33,000
High strength low alloy manganese, Vanadium steel; Designation A-441; Minimum yield point, 42,000—50,000
High strength structural steel: Designation A–440; Minimum yield point, 42,000—50,000

(a) All steel joist shall receive one coat of asphalt base paint or an equivalent protective covering before leaving the fabricating shop.

(4) DESIGN OF STEEL JOIST. An open web steel joist shall be built up of bars or other sections, or one fabricated by expanding a rolled section shall be designed as a truss. The compressive stress in chord members and diagnonals of the joist shall not exceed those given in Wis. Adm. Code section Ind 53.24 for main members. The tensile stress shall not exceed 0.60 of the yield point of the grade of steel used in any member. The minimum shear to be used in designing the web members shall not be less than 20% of the rated end reaction at mid-span and shall be increased lineally to 30% of the rated end reaction at a distance 0.35 from the end supports.

(a) A solid web steel joist shall be designed as a beam in accordance with the requirements of Wis. Adm. Code section Ind 53.24.

(b) In the completed structure, the top chord of open web steel joist or the top flanges of solid web steel joist may be considered as being stayed laterally when the deck or top slab over the steel joist complies with the provisions of Wis. Adm. Code subsection Ind 53.25 (7).

(c) All joints and connections of an open web steel joist shall be capable of withstanding a load at least 3 times the designed load and shall be sufficiently rugged to resist the stresses incident to transportation and erection when handled in a reasonable manner.

(d) All elements of an open web joist shall have their lines of center of gravity meet at a point if practicable; if not, stresses arising from eccentricity shall be included with other stresses in designing these elements.

(e) Ends of steel joist shall be designed to resist the bending produced by the eccentricity of the reaction at the support.

(5) ERECTION. The ends of steel joist shall extend a distance of at least 4 inches on to masonry or reinforced concrete supports and at least 2½ inches on steel supports. In floor construction every third steel joist and in roof construction every steel joist supported on concrete or masonry supports shall be anchored thereto with an anchor equivalent to a ⅜ inch round bar. All steel joist supported on steel beams shall be secured thereto by welding or with an anchor made of not less than 3/16 inch bar fastened over the flanges of the supporting beams.

(a) The ends of long span steel joist shall extend a distance of not less than 6 inches on masonry or reinforced concrete supports and at least 4 inches on steel supports.

(b) During the construction period, care shall be exercised to prevent excessive concentrated or moving loads. The construction contractor shall provide for adequate distribution of such loads so that the carrying capacity of any steel joist is not exceeded during that period. When erected and bridged, the total concentrated load on any one steel joist shall not exceed 800 pounds and in the case of open web steel joist, such concentrated load shall not be imposed between panel points.

(6) BRIDGING. As soon as steel joist are erected, bridging shall be installed between the joist before the application of construction loads. This bridging shall be adequate to support the top chords or flanges against lateral movement during the construction period and shall hold the steel joist in a vertical plane passing through the bearings.

(a) Horizontal bridging shall consist of two continuous horizontal steel members, one of which is attached to the top chord and the other attached to the bottom chord. Attachment to the joist shall be made by welding or by mechanical means, and the attachments shall be capable of resisting a horizontal force of not less than 500 pounds.

The ratio of unbraced length to the least radius of gyration $\left(\frac{L}{r}\right)$ of the bridging member shall not exceed 300. Where a round bar is used for bridging the diameter shall be at least ½ inch.

(b) Diagonal cross bridging may be used for joist spacing up to 30 inches. The ratio of unbraced length to the least radius of gyration $\left(\frac{L}{r}\right)$ shall not exceed 200. Connections to the top and bottom chords of the joist shall be made by positive mechanical means or by welding.

(c) In roof construction, where the slope is perpendicular to the longitudinal axis of the joist, sag rods may be used in lieu of bridging. The rods shall not be less than ½ inch in diameter and the number of lines shall be the same as specified for bridging.

(d) In no case shall the spacing of bridging be greater than specified in the following table:

Clear Span	*Number of Lines of Bridging*
Up to 14 feet	One row near center.
14 to 21 feet	Two rows placed at 1/3 point of span.
21 to 32 feet	Three rows placed at ¼ point of span.
32 to 40 feet	Four rows placed at 1/5 point of span.
40 to 48 feet	Five rows placed at 1/6 point of span.

(e) Bridging for long span joist shall consist of cross bracing with an $\frac{L}{r}$ ratio of not more than 200. The maximum spacing of lines of bridging for long span joist shall not exceed the following:

Joist Depth in Inches	*Maximum Spacing of Lines of Bridging*
18 to 24 inches, inclusive	10 feet
Over 24 to 36 inches, inclusive	12 feet
Over 36 inches	16 feet

(7) DECKS AND TOP SLABS. Decks or top slabs over steel joist may be of concrete or gypsum poured on metal lath centering attached to the top chords or flanges of steel joist as required elsewhere in this section or on removable centering provided the top chords or flanges of the steel joist are properly stayed by the concrete or gypsum slab. Other equally suitable permanent centering may be used, provided it is substantially attached to the top chords or flanges as required elsewhere in this section and provided these attachments (or the centering itself) are securely anchored into the concrete or gypsum slab. Precast concrete or precast gypsum slabs when securely attached to the top chords or flanges and anchored thereto and brought to a firm bearing, wood decks as stipulated below, and corrugated or other steel roof decks securely anchored to the top chords or flanges may be used over steel joist. Any attachment or pair of attachments when applied shall be capable of staying the top chord or flange laterally in both directions and in the case of open web steel joist, shall be spaced not farther apart then the panel point spacing. Decks or top slabs over steel joist shall not be assumed to carry any part of the compression stress in the steel joist.

(a) Flat wood decks of single thickness of one inch nominal material shall not have a span of more than 20 inches for floors, or 30 inches for roofs. All such decks shall be securely fastened to the joist.

(b) Poured structural slabs of concrete, gypsum or other similar material shall not be less than 2 inches thick. They shall be poured upon ⅜ inch ribbed metal lath weighing not less than 4 pounds per square yard for spans not exceeding 24 inches and upon ¾ inch rib lath weighing not less than 4.5 pounds per square yard for spans not exceeding 30 inches. Other material equally suitable as a form or centering for casting concrete or gypsum slabs may be used in place of rib lath. Rib lath or other centering which remains in place shall be substantially attached to the top chord or flange of each steel joist at intervals of not over 8 inches. Such slabs shall be reinforced with mesh or rods, in addition to the rib lath, except that when slabs are to be covered with a wood strip top floor, the rib lath or centering may, if adequate, serve also as the reinforcement.

(c) Any material used as centering for the top slab shall be installed so as not to exert an undue lateral pull on the top chords or flanges of the steel joist.

History: 1–2–56; r. and recr., Register, September, 1959, No. 45, eff. 10–1–59; am. Register, December, 1962, No. 84, eff. 1–1–63.

Ind 53.26 Wrought iron. (1) The requirements for design, fabrication and erection of steel for buildings and structures under Wis. Adm. Code section Ind 53.24 shall apply to wrought iron, except that the following stresses in pounds per square inch shall not be exceeded:

(a) Tension on net section 12,000

(b) Compression, on short lengths or where lateral deflection is prevented 10,000

on gross section of columns

$$12{,}000 - 60\frac{L}{r}$$

in which L = length in inches
r = radius of gyration in inches

(c) Bending. On extreme fibers if lateral deflection is prevented 12,000

(2) Wrought iron shall conform to the Standard Specifications for Refined Wrought Iron Plates, Serial Designation A42–18.

Ind 53.27 Cast iron. (1) The following unit stresses in pounds per square inch shall not be exceeded in cast iron:

(a) Tension on net section 0

(b) Compression, on short lengths or where lateral deflection is prevented 10,000

on gross section of columns

$$10{,}000 - 40\frac{L}{r}$$

in which L = length in inches
r = radius of gyration in inches

(c) Tension in the extreme fiber if lateral deflection is prevented 3,000

(2) The material and workmanship of cast iron members shall be equal in all respects to that described in the American Society for Testing Materials Specifications for Gray-Iron Castings, Serial Designation A48–29.

(3) All columns resting on, or supporting, other columns shall have their ends machine faced to a plane surface perpendicular to the axis.

Ind 53.28 Wood construction. (1) Quality of material. The quality and design of all wood used in the construction of all buildings and structures or parts thereof, shall conform to the minimum standards under this section.

(a) All members shall be so framed, anchored, tied and braced together as to develop the maximum strength and rigidity necessary for the purpose for which they are used. No member shall be stressed in excess of the strength of its details and connections.

(b) All wood structural members shall be of sufficient quality, size and strength, as to carry their imposed loads safely and without exceeding the allowable working stresses as specified in this section.

(c) The requirements stated are a minimum standard and apply primarily to conventional types of construction.

(d) The substitution of materials other than those called for in the code will be permitted when shown by an approved authority to be equal to or better than those specified.

(e) Workmanship in fabrication, preparation, installation, joining of wood members and the connectors and mechanical devices for the fastening thereof, shall conform throughout to good engineering practice.

(f) Where wood is used in parts of a building or structure habitually exposed to moisture, ample ventilation or sufficient preservative treatment, or both, shall be provided.

(2) Allowable working stresses. In the design of wood structural members and the construction of structures of wood, the following unit stresses in pounds per square inch shall not be exceeded.

(a) Stresses that exceed those given in the following table for the lowest grade of any species shall be used only when the higher grade of that species is identified by the grade mark or a certificate of inspection issued by a recognized lumber grading or inspection agency.