ICC SPRING INTERCHANGE

An Overview of Changes from ACI 318-14 to ACI 318-19

ICC INTERNATIONAL CODE COUNCIL®

Significant Changes in ACI 318-19

S. K. Ghosh
S. K. Ghosh Associates LLC
Palatine, IL

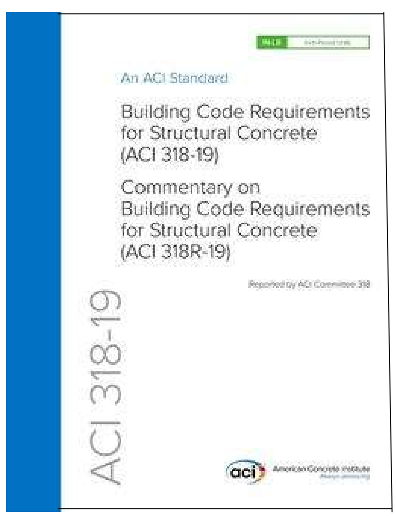
www.skghoshassociates.com

SKGA

- 1 -

1

ACI 318-19



SKGA

- 2 -

2

ACI 318-19

- A large number of substantive changes of far-reaching consequence
- Will require significant learning and adjustment on the part of the practitioner

ACI 318-19

ACI 318-19 is the referenced standard for concrete design and construction in

- The 2021 IBC
- ASCE 7-22

The 2021 IBC has been and is being adopted by major jurisdictions around the country.

Some Highlights

- Introduction of high-strength reinforcement
- Modification of straight bar development length provisions
- Modification of hooked/headed bar development length provisions
- Simplified shear provisions for nonprestressed beams and slabs
- Recognition of size effect on shear strength contributed by concrete

SKGA

- 5 -

5

Some Highlights

- Introduction of screw anchors and shear lugs
- Introduction of shotcrete provisions
- Shear strength equations for ordinary and special shear walls coordinated
- Extensive additions to the foundations chapter, which now covers deep foundations
- Highly important changes to the design of special shear walls (Not Discussed)
- Other important changes in seismic detailing requirements (Not Discussed)

SKGA

- 6 -

6

Chapter 1—General

7

1.7 Licensed Design Professional

[MODIFIED]

1.7.1 All references in this Code to the licensed design professional shall be understood to mean the ~~person who is licensed and responsible for, and in charge of, the structural design or inspection~~ engineer in either 1.7.1.1 or 1.7.1.2.

1.7.1.1 The licensed design professional responsible for, and in charge of, the structural design work.

8

1.7 Licensed Design Professional

1.7.1.2 A specialty engineer to whom a specific portion of the structural design work has been delegated subject to the condition of (a) and (b)

(a) The authority of the specialty engineer shall be explicitly limited to the delegated design work.

(b) The portion of design work delegated shall be well defined such that responsibilities and obligations of the parties are apparent.

SKGA

- 9 -

9

Chapter 2—Notation and Terminology

SKGA

- 10 -

10

Chapter 3—Referenced Standards

Chapter 4—Structural System Requirements

4.2 Materials – Shotcrete

- **4.2.1.1** Design properties of shotcrete shall conform to the requirements for concrete except as modified by provisions of the Code.
- Sections with shotcrete provisions added to ACI 318-19.

SKGA

- 13 -

13

4.4.6 Seismic-Force-Resisting System

- Authority having jurisdiction replaced with Building official.
- **4.4.6.7** Design verification of earthquake-resistant concrete structures using nonlinear response history analysis shall be in accordance with Appendix A.

SKGA

- 14 -

14

Chapter 5—Loads

- 15 -

SKGA

15

Chapter 6—Structural Analysis

- 16 -

SKGA

16

6.2.4.1 Two-Way Slabs

6.2.4.1 Two-way slabs shall be permitted to be analyzed for gravity loads in accordance with (a) or (b):

(a) Direct design method <u>for nonprestressed slabs</u> ~~in 8.10~~

(b) Equivalent frame method <u>for nonprestressed and prestressed slabs</u> ~~in 8.11~~

SKGA

- 17 -

17

R6.2.4.1 Two-Way Slabs

<u>**R6.2.4.1** Code editions from 1971 to 2014 contained provisions for use of the direct design method and the equivalent frame method. These methods are well-established and are covered in available texts. These provisions for gravity load analysis of two-way slabs have been removed from the Code because they are considered to be only two of several analysis methods currently used for the design of two-way slabs. The direct design method and the equivalent frame method of the 2014 Code, however, may still be used for the analysis of two-way slabs for gravity loads.</u>

SKGA

- 18 -

18

6.7 Linear Elastic Second-Order Analysis

6.7 – Linear elastic second-order analysis

ACI 318-19 provides clarification on elastic vs inelastic analysis and first-order vs second-order analysis. It presents 4 methods:

- Linear elastic first-order analysis
- Linear elastic second-order analysis
- Inelastic first-order analysis
- Inelastic second-order analysis

SKGA

- 19 -

19

6.7 Linear Elastic Second-Order Analysis

- First-order analysis: initial undeformed shape of the structure is considered.
- Second-order analysis: actual deformed shape of the structure should be considered.

SKGA

- 20 -

20

Chapter 7—One-Way Slabs

SKGA

- 21 -

21

7.3.3 Reinforcement Strain Limit in Nonprestressed Slabs.

7.3.3.1 ~~For nonprestressed slabs, ε_t shall be at least 0.004~~ Nonprestressed slabs shall be tension-controlled in accordance with Table 21.2.2.

This applies to two-way slabs and beams as well.

Table 21.2.2 provides ε_t limits for tension-controlled sections : $\varepsilon_t \geq \varepsilon_{ty} + 0.003$

SKGA

- 22 -

22

Compression Controlled Strain Limit, ε_{ty}

21.2.2.1 For deformed reinforcement, ε_{ty} shall be f_y/E_s. For Grade 60 deformed reinforcement, it shall be permitted to take ε_{ty} equal to 0.002.

21.2.2.2 For all prestressed reinforcement, ε_{ty} shall be taken as 0.002.

SKGA

- 23 -

23

7.6 Reinforcement Limits

7.6.1.1 Minimum area of flexural reinforcement, $A_{s,min}$, <u>of 0.0018A_g</u> shall be provided ~~in accordance with Table 7.6.1.1~~.

Table 7.6.1.1—$A_{s,min}$ for nonprestressed one-way slabs

Reinforcement type	f_y, psi	$A_{s,min}$	
Deformed bars	< 60,000	$0.0020A_g$	
Deformed bars or welded wire reinforcement	≥ 60,000	Greater of:	$\frac{0.0018\times 60,000}{f_y}A_g$
			$0.0014A_g$

SKGA

- 24 -

24

24.4 Shrinkage and Temperature Reinforcement

R24.4.3.2 Previous editions of the Code permitted a reduction in shrinkage and temperature reinforcement for reinforcement with yield strength greater than 60,000 psi. However, the mechanics of cracking suggest that increased yield strength provides no benefit for the control of cracking.

SKGA

- 25 -

25

7.7.7 Structural Integrity Reinforcement in Cast-in-Place One-Way Slabs [NEW]

Reason: To make structural integrity requirements for one-way cast-in-place slabs consistent with those for beams.

7.7.7 Structural integrity reinforcement in cast-in-place one-way slabs

7.7.7.1 Longitudinal structural integrity reinforcement consisting of at least one-quarter of the maximum positive moment reinforcement shall be continuous.

SKGA

- 26 -

26

7.7.7 Structural Integrity Reinforcement in Cast-in-Place One-Way Slabs [NEW]

7.7.7.2 Longitudinal structural integrity reinforcement at noncontinuous supports shall be anchored to develop f_y at the face of the support.

7.7.7.3 If splices are necessary in continuous structural integrity reinforcement, the reinforcement shall be spliced near supports. Splices shall be mechanical or welded in accordance with 25.5.7 or Class B tension lap splices in accordance with 25.5.2.

- 27 -

27

Chapter 8—Two-Way Slabs

- 28 -

28

Table 8.3.1.1 Minimum Thickness

- The table for minimum thickness of nonprestressed two-way slabs without interior beams has changed.
- Values for f_y=75,000 psi are replaced by values for f_y=80,000 psi.
- For f_y exceeding 80,000 psi, the calculated deflection limits in 8.3.2 [Table 24.2.2] shall be satisfied assuming a reduced modulus of rupture $f_r=5\sqrt{f_c'}$.

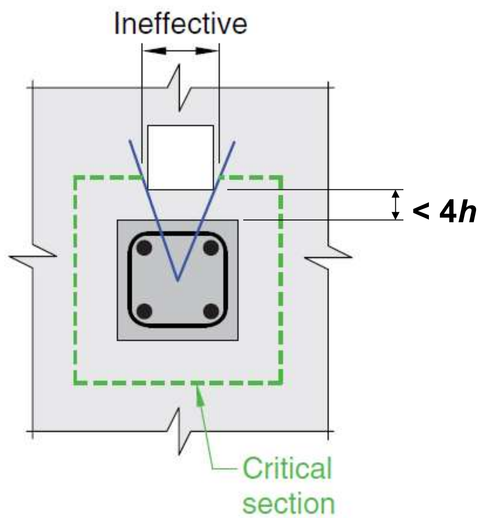
8.5.4.2 Openings

8.5.4.2 (d) has been modified to reduce the distance at which there is an effect of openings on shear strength from *10h* to *4h*.

(d) If an opening is located ~~within a column strip~~ or closer than *4h* ~~*10h*~~ from the periphery of a column, concentrated load, or reaction area, 22.6.4.3 ~~for slabs without shearheads or 22.6.9.9 for slabs with shearheads~~ shall be satisfied.

Critical Section for Two-Way Shear Strength

22.6.4.3



- 31 -

31

8.6.1 Minimum Flexural Reinforcement in Nonprestressed Slabs

- **Table 8.6.1.1** removed and replaced with requirement that minimum area of flexural reinforcement $A_{s,min}$ be $0.0018A_g$ or as calculated by 8.6.1.2.
- New: **8.6.1.2** If $v_{uv} > \phi 2\lambda_s \lambda \sqrt{f_c'}$ on the critical section for two-way shear surrounding a column, concentrated load, or reaction area, $A_{s,min}$, provided over the width b_{slab}, shall satisfy Eq. (8.6.1.2)

- 32 -

32

8.6.1 Minimum Flexural Reinforcement in Nonprestressed Slabs

Eq. 8.6.1.2

$$A_{s,min} = \frac{5 v_{uv} b_{slab} b_o}{\phi \alpha_s f_y}$$

α_s is 40 for interior columns, 30 for edge columns, and 20 for corner columns.

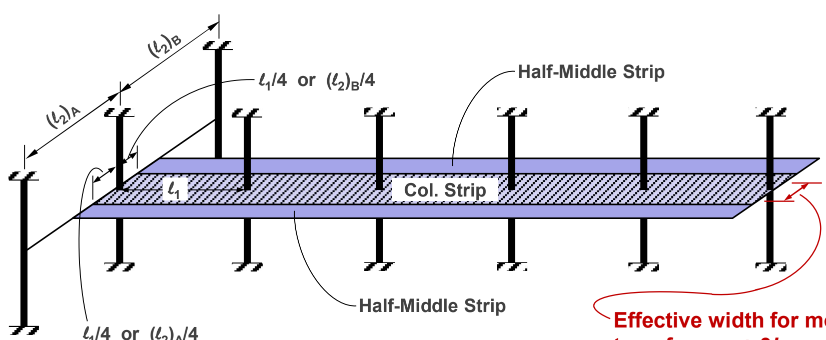
- Commentary with explanation and background added.

SKGA

- 33 -

33

Unbalanced Moment Transferred by Flexure



Effective width for moment transfer = $c_2 + 3h$

where,
c_2 = column depth
h = slab thickness

SKGA

- 34 -

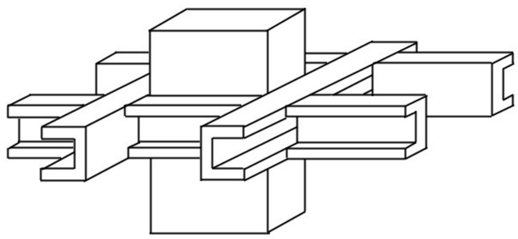
34

Shearheads

All references to shearheads are removed from Chapter 8 because

22.6.9 *Design provisions for two-way members with shearheads*

is removed from ACI 318-19.



- 35 -

35

Chapter 9—Beams

- 36 -

36

R9.7.6.2.1 Hanger Reinforcement

R9.7.6.2.1 If a reinforced concrete beam is cast monolithically with a supporting beam and intersects one or both side faces of a supporting beam, the soffit of the supporting beam may be subject to premature failure unless additional transverse reinforcement, commonly referred to as hanger reinforcement, is provided (Mattock and Shen 1992). The hanger reinforcement (Figure R9.7.6), placed in addition to other transverse reinforcement, is provided to transfer shear from the end of the supported beam.

SKGA

- 37 -

37

R9.7.6.2.1 Hanger Reinforcement

R9.7.6.2.1 (Contd.) Research indicates that if the bottom of the supported beam is at or above middepth of the supporting beam or if the factored shear transferred from the supported beam is less than $3\sqrt{f'_c} b_w d$, hanger reinforcement is not required.

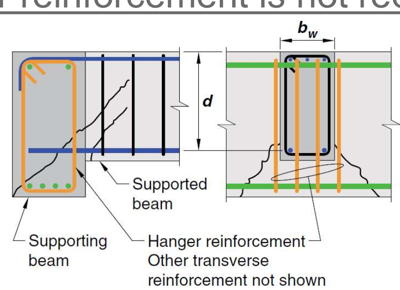


Fig. R9.7.6.2.1—Hanger reinforcement for shear transfer.

SKGA

- 38 -

38

9.7.6 Transverse Reinforcement

9.7.6.2.2 Maximum spacing for shear reinforcement across the beam width for wide beams added to improve shear behavior of wide beams and one-way slabs.

Table 9.7.6.2.2 Maximum spacing of ~~-~~legs of shear reinforcement

Required V_s ~~$V_{s,required}$~~		Maximum s, in.			
		Nonprestressed beam		Prestressed beam	
		Along length	Across width	Along length	Across width
$\leq 4\sqrt{f'_c}b_w d$	Lesser of:	$d/2$	d	$3h/4$	$3h/2$
		24 in.			
$> 4\sqrt{f'_c}b_w d$	Lesser of:	$d/4$	$d/2$	$3h/8$	$3h/4$
		12 in.			

SKGA

- 39 -

39

Chapter 10—Columns

SKGA

- 40 -

40

Composite Column Requirements Removed

- Removed composite column requirements from:

  10.1.1, 10.2.1.2, 10.2.2, 10.3.1.6, R10.3.1.6, 10.5.2.2, R10.5.2.2, 10.6.1.2, R10.6.1.2, 10.7.3.2, 10.7.5.3.2, R10.7.5.3.2, 10.7.6.1.4, R10.7.6.1.4
- Reason: ACI 318-14 had minimal composite column provisions that are outdated and incomplete.
- Refers users to AISC 360

SKGA

- 41 -

41

R10.1—Scope

R10.1.1 Composite structural steel-concrete columns are not covered in this chapter. Composite columns include both structural steel sections encased in reinforced concrete and hollow structural steel sections filled with concrete. Design provisions for such composite columns are covered in AISC 360**.**

SKGA

- 42 -

42

Chapter 11—Walls

SKGA
- 43 -

43

11.1 – Scope

- **11.1.4** Design of cantilever retaining walls shall be in accordance with ~~22.2 through 22.4, with minimum horizontal reinforcement in accordance with 11.6~~ Chapter 13.
- **11.1.6** Cast-in-place walls with insulating forms shall be permitted by this Code for use in one- or two-story buildings.

SKGA
- 44 -

44

11.2.4 – Intersecting Elements

- **11.2.4.2** For cast-in-place walls having $P_u > 0.2f_c'A_g$, the portion of the wall within the thickness of the floor system shall have specified compressive strength at least $0.8f_c'$ of the wall.
- Reason: To include the effect of floor system concrete strength on wall axial strength.
- **R11.2.4.2** The 0.8 factor reflects reduced confinement in floor-wall joints compared with floor-column joints under gravity loads.

- 45 -

45

11.5.4 In-Plane Shear: Coordination of Shear Strength Equations

11.5.4.~~3~~ 2 V_n at any horizontal section shall not exceed ~~$10\sqrt{f_c'}hd$~~ $8\sqrt{f_c'}A_{cv}$.

11.5.4.4 3 V_n shall be calculated by:

~~$V_n = V_c + V_s$~~ ~~(11.5.4.4)~~

$$V_n = (\alpha_c\lambda\sqrt{f_c'} + \rho_t f_{yt})A_{cv} \qquad (11.5.4.3)$$

where:

$\alpha_c = 3$ for $h_w/\ell_w \leq 1.5$

$\alpha_c = 2$ for $h_w/\ell_w \geq 2.0$

α_c varies linearly between 3 and 2 for $1.5 < h_w/\ell_w < 2.0$

- 46 -

46

11.5.4 In-Plane Shear: Coordination of Shear Strength Equations

11.5.4.5 4 ~~Unless a more detailed calculation is made in accordance with 11.5.4.6, V_c shall not exceed $2\sqrt{f_c'}hd$ for walls subject to axial compression or exceed the value given in 22.5.7 f~~For walls subject to a net axial tension, α_c in Eq. (11.5.4.3) shall be taken as:

$$\alpha_c = 2\left(1+\frac{N_u}{500A_g}\right) \geq 0.0 \qquad (11.5.4.4)$$

where N_u is negative for tension.

SKGA

- 47 -

47

Chapter 12—Diaphragms

SKGA

- 48 -

48

Chapter 13—Foundations

13.1 Scope

- Two items added in the scope for this chapter
  - Cantilever retaining walls
  - Counterfort and buttressed cantilever retaining walls
- Reason: To clarify design of the reinforced concrete components of retaining walls.

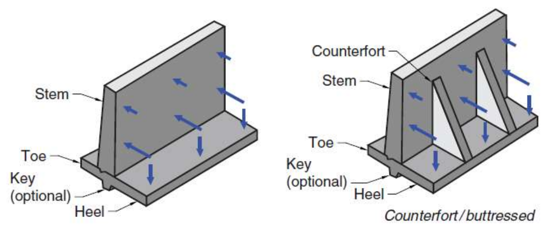


Fig. R13.1.1—Types of foundations.

13.2.6 Design Criteria

13.2.6.1 – ~~Foundations shall be proportioned to resist factored loads and induced reactions.~~ Foundations shall be proportioned for bearing effects, stability against overturning and sliding at the soil-foundation interface in accordance with the general building code.

13.2.6.2 – For one-way shallow foundations, two-way isolated footings, or two-way combined footings and mat foundations, it is permissible to neglect the size effect factor specified in 22.5 for one-way shear strength and 22.6 for two-way shear strength.

- 51 -

51

13.2.6 Design Criteria

13.2.6.3 – Foundation members shall be designed to resist factored loads and corresponding induced reactions except as permitted by 13.4.2 (allowable axial strength for deep foundations.)

- 52 -

52

13.4 Deep Foundations

R13.4.1.1

…

The 2019 edition of the Code contains provisions for the design of deep foundations. These provisions are based in part on similar provisions that were previously included in ASCE 7 and the IBC.

- 53 -

53

Chapter 14—Plain Concrete

- 54 -

54

Chapter 15—Beam-Column and Slab-Column Joints

- 55 -

55

15.2 General

15.2.1 Beam-column joints shall satisfy the detailing provisions of 15.3 and strength requirements of 15.4.

.

- 56 -

56

Chapter 16—Connection between Members

- 57 -

57

Required Strength for Bearing Connections

- ACI 318-14 provisions for restraint forces at bearing connections were given only for corbels and brackets.
- ACI 318-19 added 16.2.2.3 and 16.2.2.4 to include consideration of restraint forces at all bearing connections.

- 58 -

58

Chapter 17—Anchoring to Concrete

SKGA

- 59 -

59

ACI 318-19

- Chapter 17 reorganized into member-based format
- Anchor inspection provisions transferred from Chapter 17 to Chapter 26
- New provisions for screw anchors
- New provisions for shear lugs

SKGA

- 60 -

60

Reusing Post-Installed Mechanical Anchors Adhesive Anchors

17.1.3 The removal and resetting of post-installed mechanical anchors is prohibited.

17.2.2 Adhesive anchors shall be installed in concrete having a minimum age of 21 days at time of anchor installation.

- 61 -

61

Other Changes Reinforcement Used for Anchorage

17.1.6 Reinforcement used as part of an embedment shall have development length established in accordance with other parts of this Code. If reinforcement is used as anchorage, concrete breakout failure shall be considered. Alternatively, anchor reinforcement in accordance with 17.5.2.1 shall be provided.

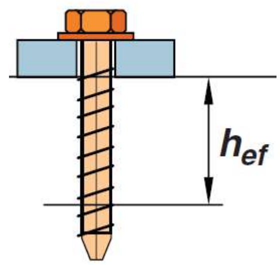
[This is extremely important and is attracting a lot of attention within ACI Committee 318 lately. See Commentary on next two slides.]

- 62 -

62

Screw Anchors

- Design procedure is exactly the same as that for post-installed expansion or undercut anchors
- Separate values for various design parameters are provided.



- 63 -

63

Screw Anchors

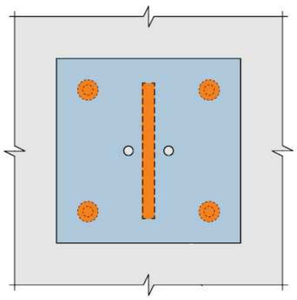
17.3.4 For screw anchors with embedment depths $5d_a \le h_{ef} \le 10d_a$, and $h_{ef} \ge 1.5$ in., concrete breakout strength requirements shall be considered satisfied by the design procedure of 17.6.2 [concrete breakout strength of anchors in tension] and 17.7.2 [concrete breakout strength of anchors in shear].

- 64 -

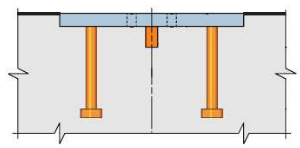
64

Shear Lugs

17.5.2.6 Attachments with shear lugs used to transfer structural loads shall satisfy the requirements of 17.11.



Plan



Elevation

- 65 -

65

Shear Lugs

- Steel plates welded to an attachment base plate
- Shear is transferred through direct bearing or concrete breakout
- Tension is transferred through separate anchor bolts/studs (minimum four anchors)

- 66 -

66

Chapter 18—Earthquake-Resistant Structures

NOT DISCUSSED

- 67 -

67

Chapter 19—Concrete: Design and Durability Requirements

- 68 -

68

19.2.1 Specified Compressive Strength

Table 19.2.1.1 is updated to add minimum specified concrete strength, f_c', for:

- Foundations (adopted from 2018 IBC Table 1808.8.1)
- Special structural walls with Grade 100 reinforcement
- Precast piles (adopted from 2018 IBC Table 1808.8.1)

- 69 -

69

19.2.1 Specified Compressive Strength

Minimum specified concrete strength, f_c', for foundations (adopted from 2018 IBC Table 1808.8.1)

Application	Minimum f_c', psi
Foundations for structures assigned to SDC A, B, or C	2500
Foundations for Residential and Utility use and occupancy classifications with stud bearing wall construction two stories or less assigned to SDC D, E, or F	2500
Foundations for structures assigned to SDC D, E, or F other than Residential and Utility use and occupancy classifications with stud bearing wall construction two stories or less	3000

- 70 -

70

19.2.1 Specified Compressive Strength

Minimum specified concrete strength, f_c', for special moment frames and special structural walls

Application	Minimum f_c', psi
Special moment frames Special structural walls with Grade 60 or 80 reinforcement	3000
Special structural walls with Grade 100 reinforcement	5000

- 71 -

71

19.2.1 Specified Compressive Strength

Minimum specified concrete strength, f_c', for precast piles (adopted from 2018 IBC Table 1808.8.1)

Application	Minimum f_c', psi
Precast-nonprestressed driven piles Drilled shafts	4000
Precast-prestressed driven piles	5000

- 72 -

72

19.2.2.2 Specification of E_c Based on Testing

19.2.2.2 It shall be permitted to specify E_c based upon testing of concrete mixtures to be used in the Work in accordance with (a) through (c):

(a) Specified E_c shall be used for proportioning concrete mixtures in accordance with 26.4.3.

(b) Testing to verify that the specified E_c has been achieved shall be conducted, and results shall be provided with the mixture submittal.

(c) Test age of measurement of E_c shall be 28 days or as indicated in the construction documents.

SKGA

- 73 -

73

19.2.4.1 Determination of λ for Lightweight Concrete

New simplified option to determine λ based on equilibrium density of concrete.

Table 19.2.4.1(a)—Values of λ for lightweight concrete based on equilibrium density

w_c, lb/ft^3	λ	
≤ 100	0.75	(a)
$100 < w_c \leq 135$	$0.0075 w_c \leq 1.0$	(b)
> 135	1.0	(c)

SKGA

- 74 -

74

19.3 Concrete Durability Requirements: Exposure to Water

Exposure Class W0 is split into W0 and W1, and the old W1 is renamed W2

ACI 318-14 Table 19.3.1.1

In contact with water (W)	W0	Concrete dry in service Concrete in contact with water and low permeability is not required
	W1	Concrete in contact with water and low permeability is required

New W1

Renamed W2

SKGA

- 75 -

75

19.3 Concrete Durability Requirements: Exposure to Water

Requirements for Exposure Category W are updated in Table 19.3.2.1

ACI 318-19 Table 19.3.2.1

Exposure Class	Maximum w/cm	Minimum f_c', psi	Additional requirements	
			Air content	Limits on cementitious materials
W0	N/A	2500	None	
W1	N/A	2500	26.4.2.2(d)	
~~W1~~ W2	0.50	4000	~~None~~ 26.4.2.2(d)	

- 76 -

76

19.3 Concrete Durability Requirements: Exposure to Water

26.4.2.2(d) For concrete identified as being exposed to water in service, evidence shall be submitted that the concrete mixture complies with (1) and (2).

1) Aggregates are not alkali-silica reactive or measures to mitigate alkali-silica reactivity have been established.
2) Aggregates are not alkali-carbonate reactive.

- 77 -

77

19.3 Concrete Durability Requirements: Exposure to Sulfate

An Option 2 is added in the requirements for Exposure Class S3 in Table 19.3.2.1

- Maximum w/cm reduced to 0.40 from 0.45
- Minimum f_c' increased to 5000 psi from 4500 psi
- Allows use of Type V cements without pozzolans or slag cement
- Allows use of C595 HS and C1157 HS blended cements without additional pozzolans or slag cement

- 78 -

78

19.3 Concrete Durability Requirements: Provisions for Shotcrete

- Provisions for shotcrete are added throughout ACI 318-19 for the first time.
- Even though shotcrete has already been recognized by ACI 318, there were no provisions covering the material or process.
- New provisions are adapted from those first included in the 2000 IBC.

SKGA

- 79 -

79

Chapter 20—Steel Reinforcement Properties, Durability, and Embedments

SKGA

- 80 -

80

20.2.1.3 Exclusion of No. 20 Bars

20.2.1.3 Deformed bars shall conform to (a), (b), (c), (d), or (e), except bar sizes larger than No. 18 shall not be permitted

- ASTM A615-18$^{\varepsilon 1}$ referenced in ACI 318-19 includes No. 20 bars
- There is a lack of information on the performance of these large bars including bar bending and development lengths

SKGA

- 81 -

81

20.2.1.3 Additional Requirements for ASTM A615 and ASTM A706 bars

- Requirements additional to those included in the ASTM specifications are added for ASTM A615 (Gr. 40, 60, 80, 100) and ASTM A706 (Gr. 60, 80) bars
- The added requirements
  - Provide for harmonization of minimum tensile strength requirements between those two materials,
  - Add new ductility requirements to both materials,
  - Introduce Grade 100 reinforcement into ASTM A706.

SKGA

- 82 -

82

20.2.1.3 Additional Requirements for ASTM A615 and ASTM A706 bars

Added Requirements for ASTM A615

(a) ASTM A615 – carbon steel, including requirements specified in Table 20.2.1.3(a)

Table 20.2.1.3(a)—Modified tensile strength and additional tensile property requirements for ASTM A615 reinforcement

	Grade 40	Grade 60	Grade 80	Grade 100
Tensile strength, minimum, psi	60,000	80,000	100,000	115,000
Ratio of actual tensile strength to actual yield strength, minimum	1.10	1.10	1.10	1.10

SKGA

- 83 -

83

20.2.1.3 Additional Requirements for ASTM A615 and ASTM A706 bars

Added Requirements for ASTM A706

(b) ASTM A706 – low-alloy steel, including requirements specified in (i), (ii), and (iii):

(i) Tensile property requirements for ASTM A706 Grade 100 reinforcement shall be as specified in Table 20.2.1.3(b), and bend test requirements for ASTM A706 Grade 100 reinforcement shall be the same as the bend test requirements for ASTM A706 Grade 80 reinforcement.

SKGA

- 84 -

84

20.2.1.3 Additional Requirements for ASTM A615 and ASTM A706 bars

Added Requirements for ASTM A706

Table 20.2.1.3(b)—Tensile property requirements for ASTM A706 Grade 100 reinforcement

	Grade 100
Tensile strength, minimum, psi	117,000
Ratio of actual tensile strength to actual yield strength, minimum	1.17
Yield strength, minimum, psi	100,000
Yield strength, maximum, psi	118,000
Fracture elongation in 8 in., minimum, %	10

SKGA

- 85 -

85

20.2.1.3 Additional Requirements for ASTM A615 and ASTM A706 bars

Added Requirements for ASTM A706

(ii) Uniform elongation requirements for all grades of ASTM A706 reinforcement shall be as specified in Table 20.2.1.3(c), and uniform elongation shall be determined as the elongation at the maximum force sustained by the reinforcing bar test piece.

SKGA

- 86 -

86

20.2.1.3 Additional Requirements for ASTM A615 and ASTM A706 bars

Added Requirements for ASTM A706

Table 20.2.1.3(c)—Uniform elongation requirements for ASTM A706 reinforcement

	Grade 60	Grade 80	Grade 100
Uniform elongation, minimum, percent			
Bar designation No.			
3, 4, 5, 6, 7, 8, 9, 10	9	7	6
11, 14, 18	6	6	6

SKGA

- 87 -

87

20.2.2.4 Wider Acceptance of High-Strength Reinforcement

- Based on recent research demonstrating satisfactory performance, Grade 80 and 100 reinforcement are now permitted in more seismic and nonseismic applications.
- Table 20.2.2.4(a), *Nonprestressed deformed reinforcement*, is updated accordingly.

SKGA

- 88 -

88

20.2.2.4 Wider Acceptance of High-Strength Reinforcement

Table 20.2.2.4(a) (Partial)

Usage	Application		Maximum value of f_y or f_{yt} permitted for design calculations, psi	Applicable ASTM specification for deformed bars
Flexure; axial force; and shrinkage and temperature	Special seismic system	Special moment frames	~~60,000~~ 80,000	A706[2]
		Special structural walls	~~60,000~~ 100,000	
	Other		~~80,000~~ 100,000	A615, A706, A955, A996, A1035

[2]ASTM A615 Grade 60 shall be permitted if requirements of 20.2.2.5(b) are satisfied.

- 89 -

89

20.2.2.4 Wider Acceptance of High-Strength Reinforcement

Table 20.2.2.4(a) (Partial)

Usage	Application		Maximum value of f_y or f_{yt} permitted for design calculations, psi	Applicable ASTM specification for deformed bars
Shear	Special seismic system	Special moment frames	~~60,000~~ 80,000	A615, A706, A955, A996
		Special structural walls	~~60,000~~ 100,000	

- 90 -

90

20.2.2.5 Reinforcement Properties for Seismic Applications

- Minimum elongation requirements revised for ASTM A615 Gr. 60 bars to be used as longitudinal reinforcement in high seismic applications
- Revisions make the elongation requirements the same as the revised requirements for ASTM A706 Gr. 60 bars.
- ASTM A615 Gr. 80 and 100 bars are still not permitted in high seismic applications.

SKGA

- 91 -

91

20.5.1.3.4 Reinforcement Cover for Deep Foundation Members

- Cover requirement for deep foundation members are added in new Table 20.5.1.3.4
- Adopted from 2018 IBC Table 1808.8.2 and ACI 543R-12 Table 4.5.3.6
- This should allow IBC to omit the cover requirements in future editions

SKGA

- 92 -

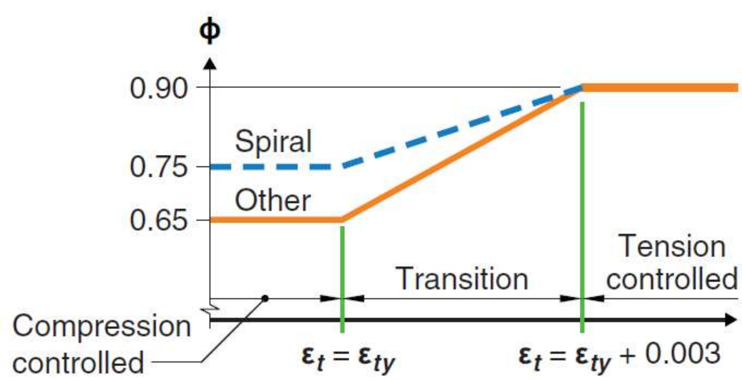
92

Chapter 21—Strength Reduction Factors

- 93 -

93

21.2.2 ϕ for Flexure, Axial Force, or Combination



- 94 -

94

21.2.4.3 ϕ for Shear for Foundation Elements

21.2.4.3 For foundation elements supporting the primary seismic force-resisting system, ϕ for shear shall not exceed the least value of ϕ for shear used for the vertical components of the primary seismic force-resisting system.

R21.2.4.3 This provision is intended to provide consistent reliability for shear in foundation elements that support shear-controlled walls designed with a strength reduction factor of 0.6.

- 95 -

95

Chapter 22—Sectional Strength

- 96 -

96

ACI 318-19

- One-way shear equations changed for nonprestressed members with the primary objectives of including size effect and longitudinal reinforcement ratio on shear strength.

SKGA

- 97 -

97

Updated Calculation of V_c

Accounting for Size Effect

V_c does not change in direct proportion to member depth as suggested by conventional expressions such as:

$$V_c = 2\lambda\sqrt{f_c'}b_w d$$

Doubling the member depth does not lead to twice the concrete contribution toward resisting shear.

SKGA

- 98 -

98

Size Effect – Experimental Evidence

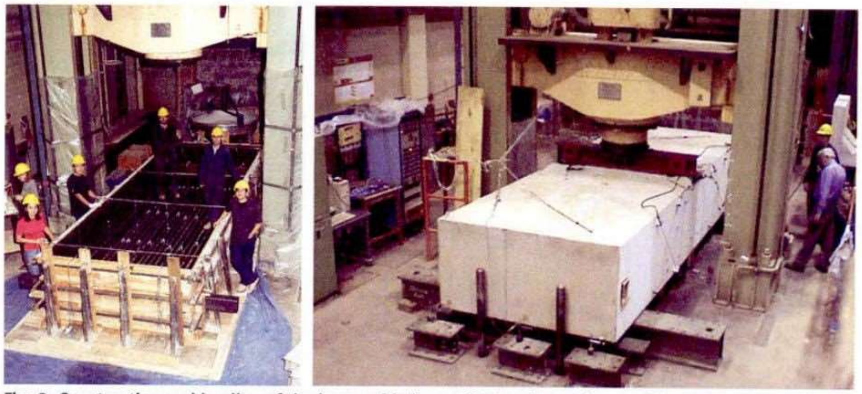


Fig. 8: Construction and loading of the large, wide beam, AT-1 under testing machine at the University of Toronto

Lubell, A., Sherwood, T., Bentz, E., Collins, M. P. (2004). Safe Shear Design of Large, Wide Beams. Concrete International. 26. 66-78.

SKGA

- 99 -

99

Size Effect – Experimental Evidence

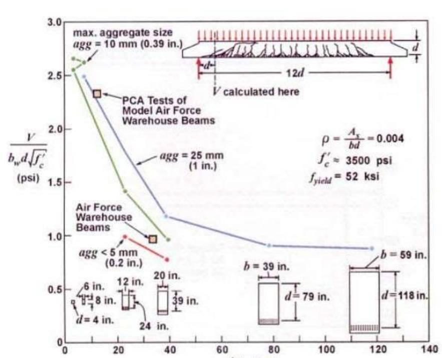


Fig. 5: Influence of member depth and maximum aggregate size on shear stress at failure (tests by Shioya et al.[9] and Shioya[10]) (1 in. = 25.4 mm; 1 ksi = 6.89 MPa; 1 psi = 6.89 kPa)

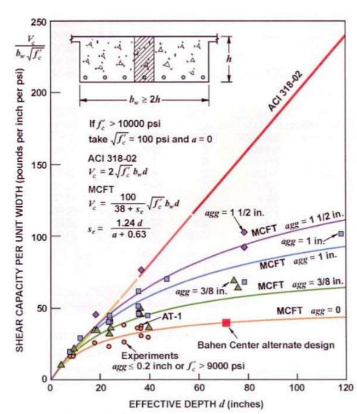


Fig. 13: Safety of ACI shear design procedure for large, wide beams (1 in. = 25.4 mm; 1 lb/in./psi = 0.025 kN/m/kPa; and 1 psi = 6.89 kPa)

Lubell, A., Sherwood, T., Bentz, E., Collins, M. P. (2004). Safe Shear Design of Large, Wide Beams. Concrete International. 26. 66-78.

SKGA

- 100 -

100

Updated Calculation of V_c

Accounting for Size Effect

New size effect modification factor, λ_s, has been introduced to modify the expressions to calculate V_c for

- beams without shear reinforcement
- two-way slabs with or without shear reinforcement

$$\lambda_s = \sqrt{\frac{2}{1+\frac{d}{10}}} \leq 1 \qquad (22.5.5.1.3)$$

SKGA

- 101 -

101

Updated Calculation of V_c

Simplification in Calculation of V_c for beams

- 8 expressions in ACI 318-14 reduced to 3
- New expressions work well for varying amounts of shear reinforcement provided (A_v)
- New expressions work well with varying axial compressive stresses applied.
- Accounts for longitudinal reinforcement ratios in members without shear reinforcement

SKGA

- 102 -

102

Updated Calculation of V_c

Simplification in Calculation of V_c for beams

ACI 318-19 expressions for V_c for nonprestressed members

Table 22.5.5.1—V_c for nonprestressed members

Criteria	V_c		
$A_v \geq A_{v,min}$	Either of:	$\left[2\lambda\sqrt{f_c'} + \frac{N_u}{6A_g}\right]b_w d$	(a)
		$\left[8\lambda(\rho_w)^{1/3}\sqrt{f_c'} + \frac{N_u}{6A_g}\right]b_w d$	(b)
$A_v < A_{v,min}$	$\left[8\lambda_s\lambda(\rho_w)^{1/3}\sqrt{f_c'} + \frac{N_u}{6A_g}\right]b_w d$		(c)

Size Effect Factor

Notes:
1. Axial load, N_u, is positive for compression and negative for tension.
2. V_c shall not be taken less than zero.

SKGA

- 103 -

103

Updated Calculation of V_c

Simplification in Calculation of V_c for beams

ACI 318-19 expressions for V_c for nonprestressed members

22.5.5.1.1 V_c shall not be taken greater than $5\lambda\sqrt{f_c'}\,b_w d$.

22.5.5.1.2 In Table 22.5.5.1, the value of $N_u/6A_g$ shall not be taken greater than $0.05f_c'$.

SKGA

- 104 -

104

Updated Calculation of V_c

Simplification in Calculation of V_c for beams

- New expressions still unconservative for concrete with strength higher then 10,000 psi.
  - ACI 318-19 Section 22.5.3.1 still limits concrete strength at 10,000 psi for the purpose of calculating concrete shear strength unless enhanced minimum transverse reinforcement is provided

SKGA

- 105 -

105

Updated Calculation of V_c:Two-Way Slabs without Shear Reinforcement

Table 22.6.5.2—v_c for two-way members without shear reinforcement

v_c		
Least of (a), (b), and (c):	$4\lambda_s\lambda\sqrt{f'_c}$	(a)
	$\left(2+\frac{4}{\beta}\right)\lambda_s\lambda\sqrt{f'_c}$	(b)
	$\left(2+\frac{\alpha_s d}{b_o}\right)\lambda_s\lambda\sqrt{f'_c}$	(c)

- 106 -

106

Updated Calculation of V_c:Two-Way Slabs without Shear Reinforcement

Table 22.6.6.1—v_c for two-way members with shear reinforcement

Type of shear reinforcement	Critical sections	v_c		
Stirrups	All		$2\lambda_s\lambda\sqrt{f_c'}$	(a)
Headed shear stud reinforcement	According to 22.6.4.1	Least of (b), (c), and (d):	$3\lambda_s\lambda\sqrt{f_c'}$	(b)
			$\left(2+\frac{4}{\beta}\right)\lambda_s\lambda\sqrt{f_c'}$	(c)
			$\left(2+\frac{\alpha_s d}{b_o}\right)\lambda_s\lambda\sqrt{f_c'}$	(d)
	According to 22.6.4.2		$2\lambda_s\lambda\sqrt{f_c'}$	(e)

22.6.4.2 – Critical section beyond where punching shear reinforcement ends

SKGA

- 107 -

107

Other Changes
Correction: Torsional Strength T_n

22.7.6.1 For nonprestressed and prestressed member, T_n shall be the lesser of (a) and (b):

(a) ……

(b) $T_n = \dfrac{2A_oA_\ell f_y}{p_h}$ ~~$\cot\theta$~~ $\tan\theta$

SKGA

- 108 -

108

Chapter 23—Strut and Tie Models

- 109 -

109

Major Changes

- Revisions in how to incorporate prestressing forces
- New factor β_c for struts and nodal zones to account for concrete confinement
- Revisions in strut coefficient β_s
- Revised provisions for controlling diagonal cracking in struts
- New provisions for curved-bar nodes
- New provisions for seismic design

- 110 -

110

Chapter 24—Serviceability Requirements

R24.1—Scope

R24.1 … This chapter has no specific requirements for vibrations.

Cast-in-place floor systems designed in accordance with the minimum thickness and deflection requirements of 7.3, 8.3, 9.3, and 24.2 have generally been found, through experience, to provide vibration performance suitable for human comfort under typical service conditions. However, there may be situations where serviceability conditions are not satisfied, for example:

R24.1—Scope

R24.1(Contd.)

- Long spans and open floor plans,
- Floors with strict vibration performance requirements such as precision manufacturing and laboratory spaces,
- Facilities subject to rhythmic loadings or vibrating mechanical equipment.

- 113 -

113

Chapter 25—Reinforcement Details

- 114 -

114

ACI 318-19

- Straight bar development length unchanged, except for introduction of reinforcement grade factor
- Hooked bar development length changed: diameter to the power 1.5, correction factor for f_c' below 6000 psi, limit of 100 psi on square root of f_c' retained

- 115 -

115

25.4.2 – Development of Deformed Bars and Deformed Wires in Tension

Table 25.4.2.3 – Development length for deformed bars and deformed wires in tension

Spacing and cover	No. 6 and smaller bars and deformed wires	No. 7 and larger bars
Clear spacing of bars or wires being developed or lap spliced not less than d_b, clear cover at least d_b, and stirrups or ties throughout ℓ_d not less than the Code minimum or Clear spacing of bars or wires being developed or lap spliced at least 2db and clear cover at least d_b	$\left(\frac{f_y\psi_t\psi_e\psi_g}{25\lambda\sqrt{f_c'}}\right)d_b$	$\left(\frac{f_y\psi_t\psi_e\psi_g}{20\lambda\sqrt{f_c'}}\right)d_b$
Other Cases	$\left(\frac{3f_y\psi_t\psi_e\psi_g}{50\lambda\sqrt{f_c'}}\right)d_b$	$\left(\frac{3f_y\psi_t\psi_e\psi_g}{40\lambda\sqrt{f_c'}}\right)d_b$

- 116 -

116

25.4.2 – Development of Deformed Bars and Deformed Wires in Tension

- Equation 25.4.2.3a has been modified

$$l_d = \left(\frac{3}{40}\frac{f_y}{\lambda\sqrt{f_c'}}\frac{\Psi_t\Psi_e\Psi_s\Psi_g}{\left(\frac{c_b+K_{tr}}{d_b}\right)}\right)d_b$$

- The values of Ψ_g are included in Table 25.4.2.5.

Reinforcement grade ψ_g	Grade 40 or Grade 60	1.0
	Grade 80	1.15
	Grade 100	1.3

SKGA

- 117 -

117

ACI 318-14 Section 25.4.3.1

25.4.3.1 Development length l_{dh} for deformed bars in tension terminating in a standard hook shall be the greater of (a) through (c):

(a) $\left(\frac{f_y\psi_e\psi_c\psi_r}{50\lambda\sqrt{f_c'}}\right)d_b$ with ψ_e, ψ_c, ψ_r, and λ given in 25.4.3.

(b) $8d_b$

(c) 6 in.

e for epoxy-coating, c for cover, r for confining reinf.

SKGA

- 118 -

118

25.4.3 – Development of Standard Hooks in Tension

Equation provided in Section 25.4.3.1 (a) modified to include Ψ_o, the location factor.

$$\left(\frac{f_y \Psi_e \Psi_r \Psi_o \Psi_c}{55\lambda\sqrt{f_c'}}\right) d_b^{1.5}$$

Ψ_o is the factor used to modify development length based on bar placement within member (controlled by side cover and location inside or outside a confined column core

Ψ_r, still confining reinf. factor, is modified; Ψ_c is now concrete strength factor

- 119 -

119

25.4.4 – Development of Headed Deformed Bars in Tension

25.4.4.1 Use of a head~~s~~ to develop a deformed bar~~s~~ in tension shall be permitted if conditions (a) through (~~g~~f) are satisfied:

~~(b) Bar f_y shall not exceed 60,000 psi~~

(~~g~~f) Center-to-center ~~Clear~~ spacing between bars shall be at least ~~4~~3d_b

- 120 -

120

25.4.4 – Development of Headed Deformed Bars in Tension

- Equation for ℓ_{dt} in 25.4.4.2 (a) is modified as shown below:

$$\sout{\left(\frac{0.016 f_y \Psi_e}{\sqrt{f_c'}}\right) d_b} \left(\frac{f_y \Psi_e \Psi_p \Psi_o \Psi_c}{75\sqrt{f_c'}}\right) d_b^{1.5}$$

- Table 25.4.4.3 provides the values for Ψ_e, Ψ_p, Ψ_o, and Ψ_c

- 121 -

121

25.4.10 – Reduction of Development Length for Excess Reinforcement

25.4.10.1, 25.4.10.2 no longer permit the use of the $(A_{s,required})/(A_{s,provided})$ term to reduce the development length of hooked, headed, and mechanically anchored deformed reinforcement.

- 122 -

122

R25.4.10.2 – Reduction of Development Length for Excess Reinforcement

R25.4.10.2 The excess reinforcement factor ($A_{s,required}/A_{s,provided}$), applicable to straight reinforcement is not applicable for hooked or headed bars where force is transferred through a combination of bearing at the hook or head and bond along the bar. Concrete breakout due to bearing at a hook or head was considered in developing the provisions of 25.4.3 and 25.4.4. Because the anchorage strength, and in particular the concrete breakout strength of a hooked or headed bar is a function of the embedment depth to a power slightly more than 1.0, a reduction in development length with the application of the excess reinforcement factor could result in a potential concrete breakout failure.

SKGA

- 123 -

123

25.4.10 – Reduction of Development Length for Excess Reinforcement

25.4.10.2 presents cases where reduction of development length is not permitted.

(d) For hooked, headed, and mechanically anchored deformed reinforcement

(e) In seismic force-resisting systems in structures assigned to Seismic Design Categories C, D, E, or F.

(f) Anchorage of concrete piles to pile caps in structures assigned to Seismic Design Categories C, D, E, or F.

SKGA

- 124 -

124

25.5 – Splices

- Requirements for transverse reinforcement for bars with $f_y \geq 80{,}000$ psi (Grade 100 reinforcement) are provided in 25.5.1.5.
- Lap splice length of deformed bars in compression is adjusted for Gr. 80 and Gr. 100 reinforcement.

SKGA

- 125 -

125

Chapter 26—Construction Documents and Inspection

SKGA

- 126 -

126

26.2 – Design Criteria

26.2.2 Compliance Requirements [New]

(a) Design work delegated to the contractor shall be performed by a specialty engineer.

(b) The contractor's specialty engineer, relying on the documents identifying the portion of design work assigned, shall produce design work that is compatible with the construction documents and the design criteria provided by the licensed design professional in charge of the design work.

- 127 -

127

26.2 – Design Criteria

26.2.2 (Contd.)

(c) The contractor shall submit necessary information to the licensed design professional to confirm that the specialty engineer complied with the documents identifying the portion of the design work assigned.

- 128 -

128

Changes Due to Addition of Shotcrete to ACI 318-19

26.12—Evaluation and Acceptance of Hardened Concrete

Added shotcrete evaluation and acceptance criteria. Acceptance criteria are in a new Section 26.12.4.

SKGA

- 129 -

129

26.4 Concrete Materials and Mixture

26.4.1 *Concrete materials*

26.4.1.1 *Cementitious materials*

26.4.1.1.1 Compliance Requirements

(b) Alternative cements shall be permitted if approved by the licensed design professional and the building official. Approval shall be based upon test data documenting that the proposed concrete mixture made with the alternative cement meets the performance requirements for the application including structural, fire, and durability.

SKGA

- 130 -

130

26.4 Concrete Materials and Mixture

26.4.1.2 *Aggregates*

26.4.1.2.1 Compliance Requirements

(a) Aggregates shall conform to (1), ~~or~~ (2), or (3):

(3) Mineral fillers: ASTM C1797.

(c) Crushed hydraulic-cement concrete or recycled aggregate shall be permitted if approved by the licensed design professional and the building official based on documentation that demonstrates compliance with (1) and (2).

SKGA

- 131 -

131

26.4 Concrete Materials and Mixture

26.4.1.2.1 Compliance Requirements

(c) (Contd.)

(1) Concrete incorporating the specific aggregate proposed for the Work has been demonstrated to provide the mechanical properties and durability required in structural design.

(2) A testing program to verify aggregate consistency and a quality control program to achieve consistency of properties of the concrete are conducted throughout the duration of the project.

SKGA

- 132 -

132

26.13.1 – Inspection, General

A number of subsections have been modified.

26.13.1.1 Concrete construction shall be inspected as required by the general building code, and as a minimum, the inspection shall comply with the requirements provided in 26.13. In the absence of a general building code, concrete construction shall be inspected in accordance with the provisions of this Code.

- 133 -

133

Chapter 27—Strength Evaluation of Existing Structures

- 134 -

134

Reorganization

- Section 27.5 modified and New Section 27.6 added.
  - 27.5–Monotonic load test procedure
  - 27.6–Cyclic load test procedure

- 135 -

135

27.2 General

3118-14 27.5.1 is now 27.2.5

27.2.5 If the structure under investigation does not satisfy conditions or criteria of 27.3 [Analytical Strength Evaluation] ~~or 27.4.5~~, 27.5, or 27.6, the structure shall be permitted for use at a lower load rating, based on the results of the load test or analysis, and if approved by the building official.

- 136 -

136

27.3 Analytical Strength Evaluation

27.3.1.1 As-built dDimensions of members shall be established field-verified at critical sections.

27.3.1.3 If required, an estimated equivalent f_c' shall be based on analysis of results of cylinder tests from the original constructions or, tests of cores removed from the part of the structure, where strength is in question or both sets of data. Original cylinder data and core test data shall be representative of the area of concern.

- 137 -

137

27.4.6 – Test Load Arrangement and Load Factors

(a) T_t = 1.0D_w + 1.1D_s + 1.6L + 0.5(L_r or S or R)

(b) T_t = 1.0D_w + 1.1D_s + 1.0*L + 1.6(L_r or S or R)

(c) T_t = 1.3(D_w + D_s)

*Permitted to be reduced to 0.5

Reason: To be consistent with the requirements of ACI 437.2

- 138 -

138

27.5 – Monotonic Load Test Procedure

~~**27.4.5.5**~~ **27.5.3.5** Measured deflections shall satisfy ~~(a) or (b)~~:

~~(a)~~ ~~$\Delta_1 \le \frac{l_t^2}{20{,}000h}$~~ ~~(27.4.5.5a)~~

~~(b)~~ $\Delta_r \le \frac{\Delta_1}{4}$ (~~27.4.5.5b~~27.5.3.5)

27.5.3.6 If the maximum deflection measured during the test, Δ_1, does not exceed the larger of 0.05 in. or $\ell_t/2000$, the residual deflection requirements in 27.5.3.5 shall be permitted to be waived.

SKGA

- 139 -

139

27.6 – Cyclic Load Test Procedure [New]

27.6.1 A cyclic load test in accordance with ACI 437.2 shall be permitted to be used to evaluate the strength of an existing structure.

27.6.2 Acceptance criteria for cyclic load test results shall be in accordance with ACI 437.2.

SKGA

- 140 -

140

Appendix A—Design Verification Using Nonlinear Response History Analysis

- 141 -

141

New! Appendix A

- Provides a set of requirements for nonlinear response history analysis
- Supplemental to those in ASCE 7 Chapter 16
- The provisions of Appendix A are in addition those of Chapters 1 through 26
- Requires a licensed design professional to implement this appendix
- Requires an independent design review

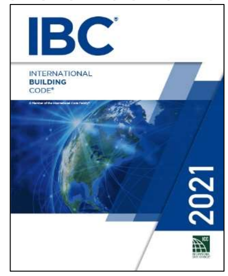
- 142 -

142

ACI 318-19

ACI 318-19 is or will be the referenced standard for concrete design and construction in

- The 2021 IBC
- ASCE 7-22



The 2021 IBC has been and is being adopted by major jurisdictions around the country.

SKGA

- 143 -

143

Thank You!!

For more information…

www.skghoshassociates.com

Phone: (847) 991-2700

Email: kbhaumik@skghoshassociates.com

Follow us on:

SKGA

- 144 -

144


ICC SPRING
INTERCHANGE
Thank you for Attending
Visit learn.iccsafe.org for more training opportunities
ICC INTERNATIONAL CODE COUNCIL®

1


ICC SPRING
INTERCHANGE
www.iccsafe.org/spring
#ICCSpringInterchange
ICC INTERNATIONAL CODE COUNCIL®

2