ACI Building Code: Operations and Discussion of Recent & Coming Changes

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ACI 318: Philosophy for Committee Operation

- Consensus Document Based on Practical Engineering Principles
- Membership: 53% Practicing Engineers, 33% Academics, and 14% Trade or Gov't. Associations
- Goal is for continuous improvement in safety and usability of the code, not just simplification
- New items for the code need a reason statement to justify the proposed change and must contain example(s) to show the impact on current design practice

ACI 318 Code Committee

- Code organization:
  - 22 Chapters
  - 4 Appendices
- Committee organization:
  - 8 Subcommittees
- Technical change proposals are developed by subcommittees and approved by main committee.
- Each chapter/appendix is the responsibility of a different subcommittee.

What's new in 318-05

- Consistent notation
- Alternative torsion design procedure
- Use of spiral reinforcement with f_y of 100 ksi for confinement
- Limits on reinforcement spacing for crack control and skin reinforcement
- Need for shear reinforcement at slab-column connections of structures in high seismic performance categories

ACI 318-02 – Notation Issues

α Angle of inclination of inclined stirrups (shear - chapter 11)

α Modification factor for top bars (anchorage – chapter 12)

α Ratio of flexural stiffness of beam to flexural stiffness of slab (two-way slabs – chapter 13)

ACI 318-02 – Notation Issues

ρ_n Reinforcement ratio for vertical web reinforcement in walls (ordinary systems) – Chapter 14

ρ_n Reinforcement ratio for horizontal web reinforcement in walls (special systems)- Chapter 21

Notation and Terminology Task Group

- Task group formed to reduce the number of conflicts and duplicate definitions in 318-05.
- Task group recommendations were sent directly to the main committee and were not balloted by any of the eight subcommittees.
- Task group generated more than half of the changes to 318-02 that were released for public comment.

Approach Taken

- Each term used in the code should have a unique definition.
- Consolidate similar terms where possible.
- Add or revise subscripts to distinguish among terms and give meaning to them.
- Existing terms were not modified unless changes were required to avoid duplication of notation.

Consolidation of Terms

- 318-02
  - f_y – yield strength (most chapters and appendices)
  - f_{yh} – yield strength (11, circular hoop)
  - f_{yh} – yield strength (21, all transverse reinf.)
  - $f_{y\ell}$ – yield strength (11, longitudinal steel)
  - f_{yv} – yield strength (11, transverse steel)
  - f_{yt} – yield strength (12, transverse steel)

Consolidation of Terms

- 318-05
  - f_y – specified yield strength of reinforcement
  - f_{ya} – specified yield strength of anchor steel
  - f_{yt} – specified yield strength of transverse reinforcement

ACI 318-02 **ACI 318-05**

$$\rho_s = 0.45\left(\frac{A_g}{A_c} - 1\right)\frac{f'_c}{f_y} \quad \Rightarrow \quad \rho_s = 0.45\left(\frac{A_g}{A_{ch}} - 1\right)\frac{f'_c}{f_{yt}}$$

$$V_s = \frac{A_v f_y d}{s} \quad \Rightarrow \quad V_s = \frac{A_v f_{yt} d}{s}$$

Development Length

- 318-02
  - α – reinforcement location factor (12)
  - β – coating factor (12)
  - γ – reinforcement size factor (12)
  - λ – lightweight aggregate concrete factor (12)

$$\ell_d = \left(\frac{3}{40} \frac{f_y}{f'_c} \frac{\alpha\beta\gamma\lambda}{\left(\frac{c + K_{tr}}{d_b} \right)} \right) d_b$$

Development Length

- 318-05: factor used to modify development length based on
  - ψ_t – reinforcement location
  - ψ_e – reinforcement coating
  - ψ_s – reinforcement size

$$\ell_d = \left(\frac{3}{40} \frac{f_y}{f'_c} \frac{\psi_t \psi_e \psi_s \lambda}{\left(\frac{c + K_{tr}}{d_b} \right)} \right) d_b$$

Text Versus Notation

The possibility of using only notation within the Code text was discussed.

- **11.1.3** — Computation of maximum *factored shear force* $\boldsymbol{V_u}$ at supports ...
- **11.1.3** — Computation of maximum $\boldsymbol{V_u}$ at supports ...

Defining of Terms in Code

- A limited number of common terms are not defined each time they are used:

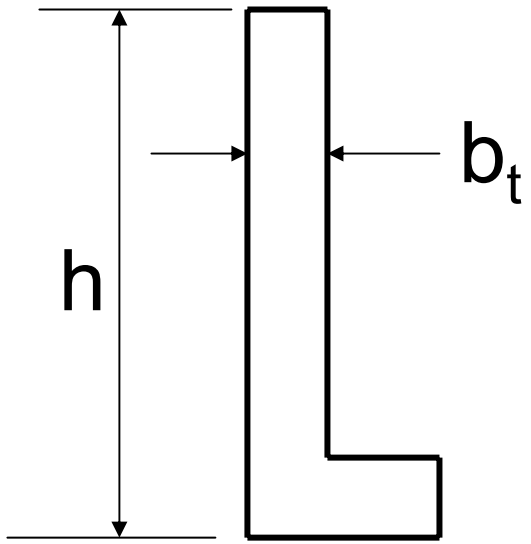
f_y f'_c d b b_w h

ℓ_n M_n M_u V_n V_u ϕ

- Terms are defined the first time that they are used in a section, and only the notation is used subsequently.

Alternate Design Procedure in Torsion

- Section 10.6.7 permits an alternate torsion design procedure for deep thin members where the equivalent tube analogy leads to very unconservative designs



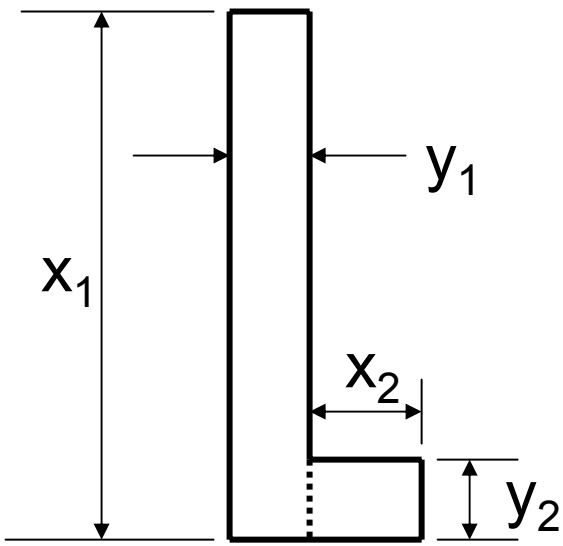
$h/b_t \geq 3$

Alternate Design Procedure in Torsion

- Permitted to use method given in PCI Handbook and/or method given in paper by Zia and Hsu, PCI Journal, May-June 2004. T_n is taken equal to T_c plus T_s and for the concrete contribution in torsion they use:

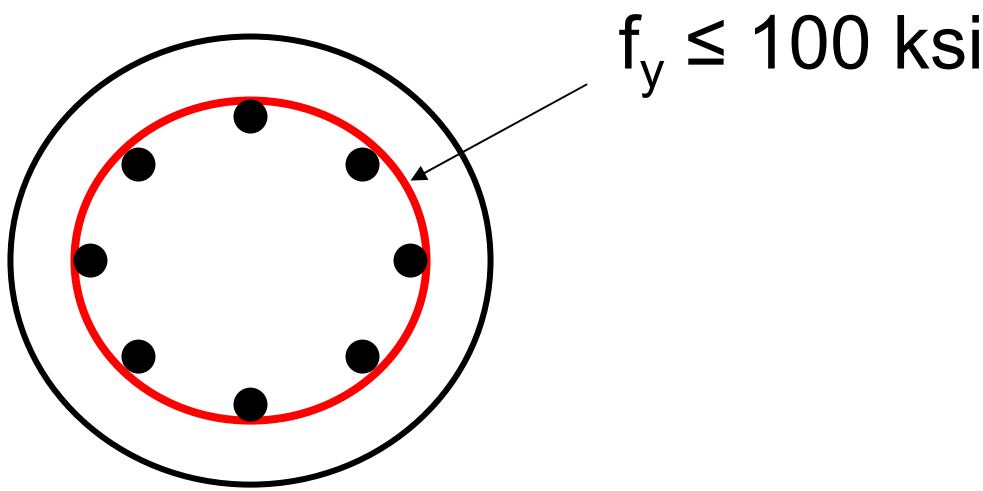
$$T_c = 0.8\sqrt{f_c'}\sum x^2 y\left(2.5\gamma - 1.5\right)$$

$$\gamma = \sqrt{1 + \frac{10P_e}{A_g f_c'}}$$



Use of High-Strength Steel for Spiral Reinforcement

- Section 10.9.3 permits the use of steel with a yield strength, f_y, up to 100 ksi (690 MPa) for spiral reinforcement.

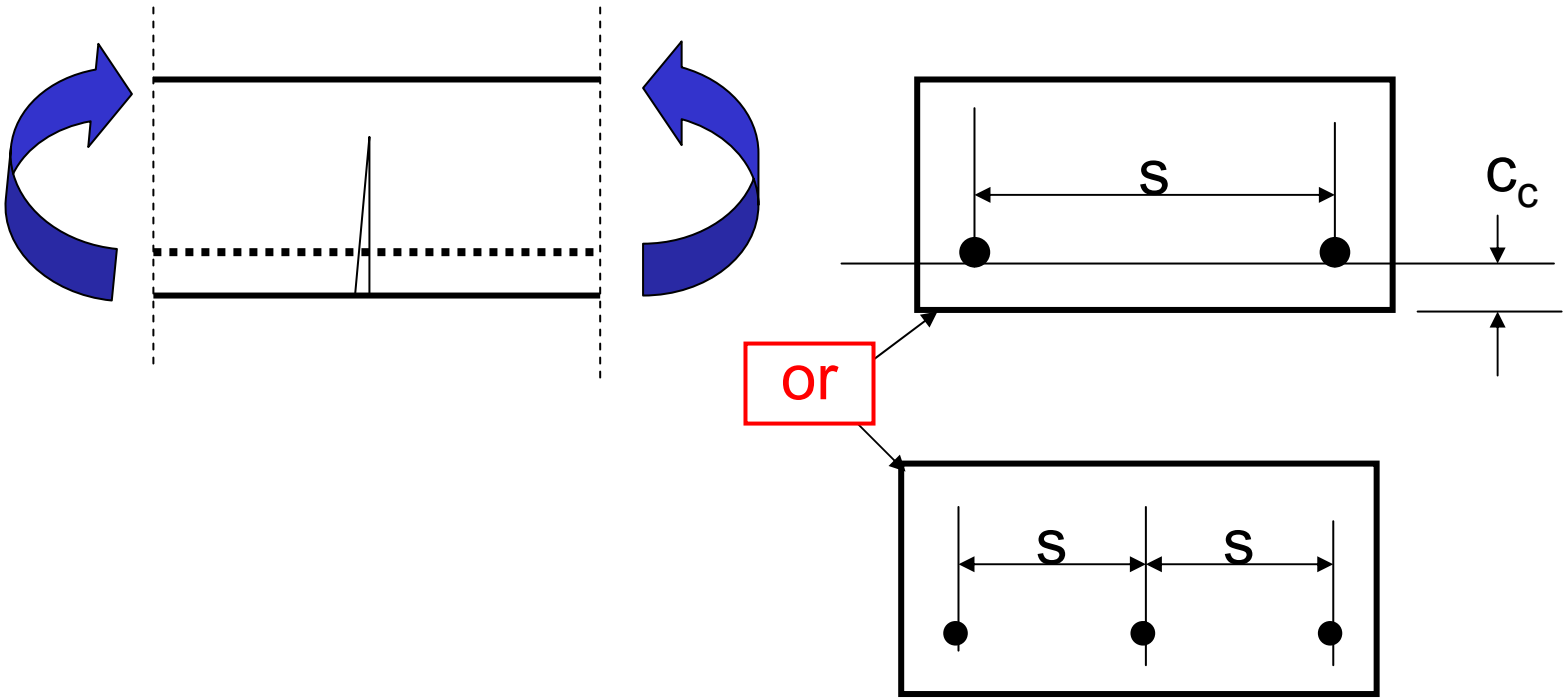


Use of High-Strength Steel for Spiral Reinforcement

- In Chapter 21 (earthquake-resistant design), the value of f_y permitted for design is limited to 60 ksi (21.11.5). Note: this limit is to be enforced when checking the shear strength of spiral columns, but the higher yield strength (≤100 ksi) is permitted when designing spiral as confinement reinforcement.

Limits on Bar Spacing for Crack Width Control

- Section 10.6.4 – Applies to reinforcement nearest to the extreme tension fiber.



Limits on Bar Spacing for Crack Width Control

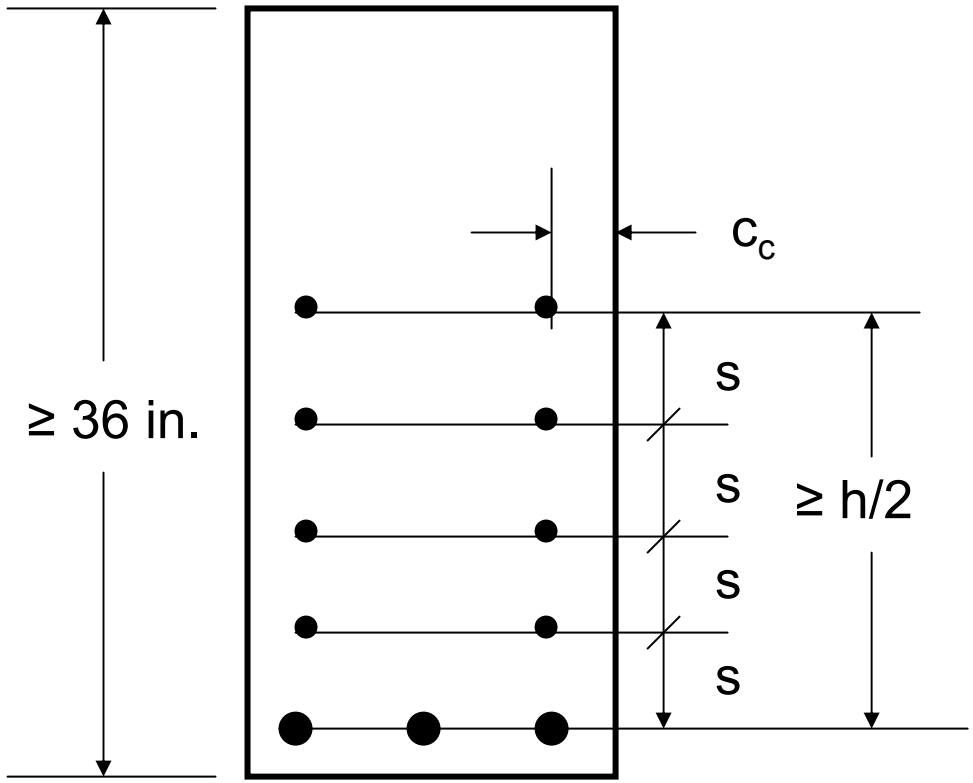
- Limiting equation was changed to reflect potentially higher working stresses resulting from changes in load factors and phi factors.

$$s \le 15\left(\frac{40,000}{f_s}\right) - 2.5c_c$$

$$s \le 12\left(\frac{40,000}{f_s}\right)$$

Spacing Limit for Skin Reinforcement in Deep Beams

- In 2002 Code, the limit was based on d, not h.
- Also, the spacing limit was given as a function of the size of the bar.



Spacing Limit for Skin Reinforcement in Deep Beams

- Research has shown that the size of the bar is not important, so the code was simplified and the spacing limit is the same as that for crack-control reinforcement.

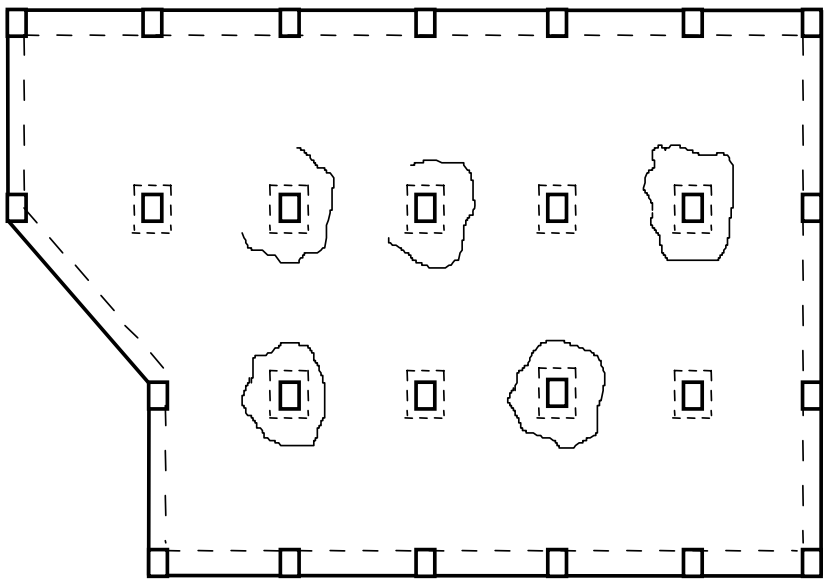
$$s \le 15\left(\frac{40,000}{f_s}\right) - 2.5c_c$$

$$s \le 12\left(\frac{40,000}{f_s}\right)$$

Need for Shear Reinforcement at Slab-Column Connections

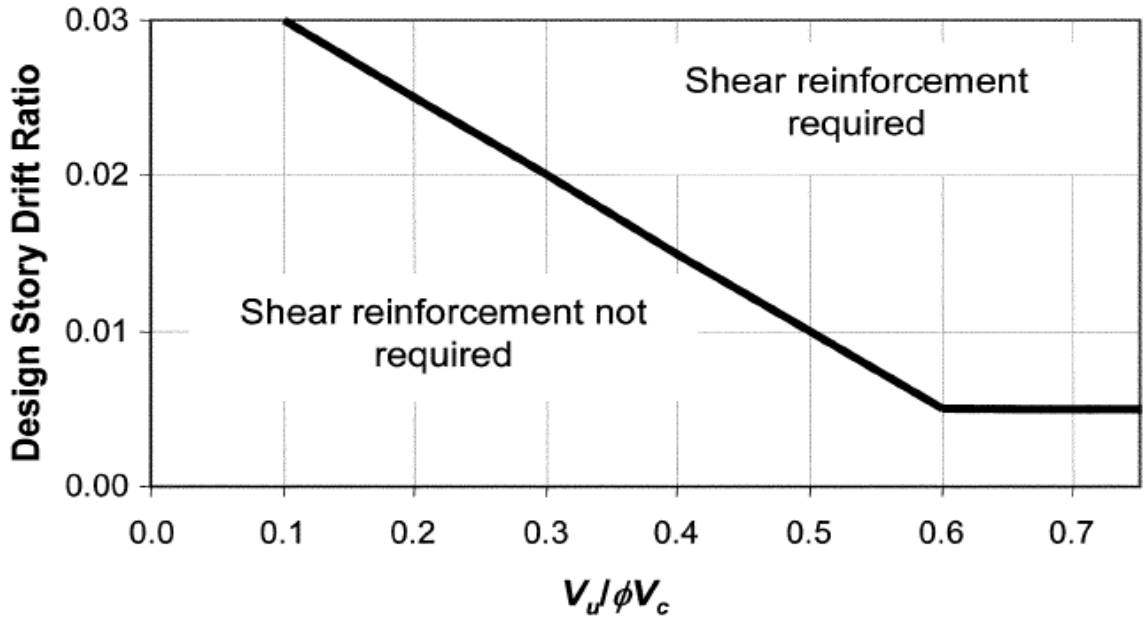
- Although not designed as part of the system for resisting lateral loads, transfer moments can be developed at these connections due to lateral drift of the building during an earthquake.
- If connection area is already subjected to high shear stresses for resisting gravity loads, displacement-induced transfer moments can cause a punching shear failure.

Need for Shear Reinforcement at Slab-Column Connections



Need for Shear Reinforcement at Slab-Column Connections

- Section 21.11.5 requires a minimum amount of shear reinforcement as a function of gravity induced shear and expected story drift.



Potential Changes for ACI 318-08

- Modification (modernization) of analysis portions of the code.
- Include in-plane design of structural walls in Chapter 14.
- Use of steel studs as shear reinforcement at slab-column connections.
- Include adhesive and grouted anchors in Appendix D.
- Simplify the analysis and design procedures for slender columns.

Potential Changes for ACI 318-08

- Modification of the “stress block” for use with high-strength concrete.
- Include the “size effect” for shear strength contributed by concrete in deep beams.
- Include “seismic design categories” within Chapter 21.
- Seismic design requirements for foundations, including concrete piles.
- General reorganization and reduction of “textbook” material included in the Code.

Summary for ACI 318-05

- Primary change was to achieve consistent notation throughout the code.
- Limited number of technical changes.
- Expect more technical changes in 2008 edition of the Code.