Guide to the Use of Grade 80 Reinforcing Bars in ACI 318-19

Introduction

Grade 60 reinforcing steel, with a yield strength of 60,000 psi, is the most commonly used grade in North America. Recent advances, including substantial new research, have enabled reinforcing steels of higher strengths to be a viable option in a variety of applications in reinforced concrete structures.

Permissible applications of high-strength steel reinforcement (that is, reinforcement with a yield strength of 80,000 or 100,000 psi) were significantly expanded in the 2019 edition of Building Code Requirements for Structural Concrete and Commentary (ACI 2019). The purpose of this Technical Note is to summarize the requirements in ACI 318-19 related to Grade 80 reinforcing bars. Industry professionals should find the information useful when designing, detailing, and specifying Grade 80 reinforcing bars in building projects. Benefits related to the use of Grade 80 reinforcing bars are also included.

Information on the design and detailing of cast-in-place reinforced concrete buildings with high-strength steel reinforcement, including worked-out design examples, can be found in Design Guide on the ACI 318 Building Code Requirements for Structural Concrete – ACI 318-19 (CRSI 2020).

Types of Nonprestressed Grade 80 Reinforcing Bars

Grade 80 deformed reinforcing bars must conform to the following specifications (ACI 20.2.1.3):  

- ASTM A615 (ASTM 2018a) – carbon steel, including the requirements in ACI Table 20.2.1.3(a)  
- ASTM A706 (ASTM 2016a) – low-alloy steel, including the requirements in ACI 20.2.1.3(c)  
- ASTM A955 (ASTM 2018b) – stainless steel

Similarly, Grade 80 plain reinforcing bars for spiral reinforcement must conform to the following specifications (ACI 20.2.1.4):

- ASTM A615 (ASTM 2018a)  
- ASTM A706 (ASTM 2016a)  
- ASTM A955 (ASTM 2018b)

Bar sizes larger than #18 are given in current editions of ASTM A615 and ASTM A1035. Due to the lack of information on their performance (including bar bends and the determination of development lengths), bar sizes larger than #18 are not permitted by ACI 318-19 (ACI R20.2.1.3).

New property requirements are given in ACI Table 20.2.1.3(a) for ASTM A615 Grade 80 deformed reinforcing bars and in ACI Table 20.2.1.3(c) for ASTM A706 Grade 80 deformed reinforcing bars (see Tables 1 and 2, respectively). These requirements are not included in the 2018 edition of ASTM A615 and the 2016 edition of ASTM A706, which are the referenced specifications in ACI 318-19 (see ACI 3.2.4).

Bend test requirements for ASTM A706 Grade 80 reinforcement are given in the latest version of that specification (ASTM 2016a). [Note: Due to potential safety concerns with shop fabrication, CRSI does not recommend bending reinforcing bars larger than #14 with a grade designation of Grade 75 or higher.]

The following new requirement was introduced for all grades of ASTM A706 deformed reinforcing bars (ACI 20.2.1.3(b) (iii)): The radius on newly-machined rolls used to manufacture reinforcing bars must be at least 1.5 times the height of the deformation, \( h \) (see Figure 1). This requirement applies to all deformations, including transverse lugs, longitudinal ribs, grade ribs, grade marks, and intersections between deformations. Conformation is assessed by measurements taken on newly-machined rolls used to manufacture...
reinforcing bars, instead of measurements taken on bar samples. The ratio \((r/h)\) affects the magnitude of the strain localization occurring at the juncture between the deformation and the barrel of the bar. Increased strain localization has a negative effect on inelastic fatigue and tensile fracture (ductility) performance. The reason for this limitation is to ensure that inelastic fatigue cracks do not develop at the root of the deformation (which is a critical issue in seismic design).

When specifying ASTM A615 and ASTM A706 Grade 80 reinforcing bars for a project, it is important to include these new property requirements in the project specifications along with the corresponding ASTM requirements.

### Applications Where Grade 80 Reinforcing Bars are Permitted

Types of deformed reinforcing bars permitted for particular structural applications are given in ACI Table 20.2.2.4(a). Grade 80 reinforcement is now permitted to resist the following:

- Flexure, axial forces, and shear forces due to gravity and earthquake loads in special moment frames, which are required in buildings assigned to Seismic Design Category (SDC) D, E, and F (previously, the maximum permitted value of the yield strength in such applications was 60,000 psi).
- Flexure, axial forces, and shear forces due to gravity and earthquake loads in special structural walls, which are required in buildings assigned to Seismic Design Category (SDC) D, E, and F (previously, the maximum permitted yield strength in such applications was 60,000 psi).

Permitted usages and applications of Grade 80 reinforcement are given in Table 3. [Note: maximum values of \(f_y\) and \(f_{ypt}\) are given in Table 3 in accordance with ACI Table 20.2.2.4(a); therefore, ASTM 1035 Grade 100 bars and ASTM A996 bars with a maximum yield strength of 60,000 psi are included in the table even though these two types of deformed bars are not available with a yield strength of 80,000 psi.] The numbers in parentheses below the tabulated values of \(f_y\) and \(f_{ypt}\) are the maximum permitted yield strengths in ACI 318-14. Permitted values of \(f_y\) and \(f_{ypt}\) for lateral support of longitudinal bars and concrete confinement are the same as those in ACI 318-14.

According to Footnote [2] in ACI Table 20.2.2.4(a), ASTM A615 Grade 60 reinforcement is permitted to be used in lieu of ASTM A706 Grade 80 reinforcement in special structural walls provided the requirements in ACI 20.2.2.5(b) are satisfied (the requirements in ACI 20.2.2.5(b) have been revised in ACI 318-19). ASTM A615 Grade 80 reinforcement is not permitted to resist earthquake-induced moments, axial forces, or both in special seismic systems [that is, in special moment frames\(^6\) and special structural walls; see ACI 20.2.2.5(b)] and anchor reinforcement in Seismic Design Categories C, D, E, and F.

In ACI 318-19, Grade 80 plain spiral reinforcement (ASTM A615, ASTM A706, and ASTM A955) is permit-

### Table 1 – Modified Tensile Strength and Additional Tensile Property Requirements for ASTM A615 Grade 80 Reinforcement

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum tensile strength (psi)</td>
<td>100,000</td>
</tr>
<tr>
<td>Minimum ratio of actual tensile strength to actual yield strength(^3)</td>
<td>1.10</td>
</tr>
</tbody>
</table>

### Table 2 – Uniform Elongation Requirements for ASTM A706 Grade 80 Reinforcement

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum uniform elongation for #3 through #10 bars (%)</td>
<td>7</td>
</tr>
<tr>
<td>Minimum uniform elongation for #11, #14, and #18 bars (%)</td>
<td>6</td>
</tr>
</tbody>
</table>

\(^3\) The yield strength of high-strength nonprestressed reinforcing bars without sharp-kneed or well-defined yield points is determined by the offset method (ASTM 2018c) [ACI 20.2.1.2].

\(^4\) Uniform elongation is the strain occurring at the tensile strength and is determined in accordance with ASTM E8 (ASTM 2016d).

\(^5\) Design and detailing requirements for special structural walls are given in ACI 18.10; these requirements have also undergone significant revisions in ACI 318-19 (see CRSI 2020).

\(^6\) Design and detailing requirements for special moment frames are given in ACI 18.6 through 18.8; these requirements have undergone significant revisions in ACI 318-19 (see CRSI 2020).
ted to be used as lateral support of longitudinal bars or as concrete confinement for members in special seismic systems and in all other systems [ACI Table 20.2.2.4(b)]. This requirement is the same as that in ACI 318-14.

### Development and Splice Lengths

#### Development of Deformed Bars in Tension

Revised equations for the development length, $\ell_d$, of deformed bars in tension in accordance with ACI 25.4.2.3 are given in Table 4. ACI Eq. (25.4.2.4a) in ACI 25.4.2.4 has also been revised:

$$\ell_d = \frac{3 \cdot f_y}{40 \cdot \sqrt{\frac{f_y}{f_y \cdot c_y + K_d}} \cdot d_b}$$

The modification factors in these equations are given in ACI Table 25.4.2.5.

The reinforcement grade factor, $\psi$, was introduced into ACI 318-19 to account for the effect of reinforcement yield strength on the required tension development length of deformed bars. According to recent research studies, the required tension development length increases disproportionately with increases in yield strength. Values of $\psi$ for Grades 40, 60, 80, and 100 reinforcement are given in Table 5 (ACI Table 25.4.2.5).

As in previous editions of ACI 318, $\ell_d$ must be greater than the calculated value and 12 in. (ACI 25.4.2.1).

The new requirement in ACI 25.4.2.2 must be satisfied regardless of the method used to determine $\ell_d$. For longitudinal bars with $f_y \geq 80,000$ psi and a center-to-center spacing less than 6 in., transverse reinforcement must be provided such that the transverse reinforcement index $K_{tr} = 40A_{tr}/s n \geq 0.5d_b$ [see ACI Eq. (25.4.2.4b)]. The term $A_{tr}$ is the total cross-sectional area of transverse reinforcement within the spacing.
crossing the potential plane of splitting through the reinforcement being developed and \( n \) is the number of reinforcing bars developed or lap spliced along the plane of splitting (see Figure 2 for the case of a rectangular column). Thus, for a given area of transverse reinforcement, the maximum permitted spacing is \( s \leq 80A_{tr} / nd_b \). The purpose of this requirement is to ensure that closely-spaced Grade 80 (and Grade 100) reinforcing bars are adequately confined so that splitting failures do not occur due to relatively large axial forces in the bars.

<table>
<thead>
<tr>
<th>Spacing and Cover</th>
<th>#6 and Smaller Bars</th>
<th>#7 and Larger Bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Clear spacing of bars being developed or lap spliced ( \geq d_b )</td>
<td>( f_y \psi \psi \psi / 25\sqrt{f'_c} ) ( d_b )</td>
<td>( f_y \psi \psi \psi / 20\sqrt{f'_c} ) ( d_b )</td>
</tr>
<tr>
<td>• Clear cover ( \geq d_b )</td>
<td>( 3f_y \psi \psi \psi / 50\sqrt{f'_c} ) ( d_b )</td>
<td>( 3f_y \psi \psi \psi / 40\sqrt{f'_c} ) ( d_b )</td>
</tr>
</tbody>
</table>

Other cases

<table>
<thead>
<tr>
<th>Grade</th>
<th>( \psi_g )</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 or 60</td>
<td>1.0</td>
</tr>
<tr>
<td>80</td>
<td>1.15</td>
</tr>
<tr>
<td>100</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Development of Standard Hooks in Tension

The equation to determine the development length, \( \ell_{dh} \), for deformed bars in tension terminating in a standard hook has been revised based on recent test results, and accounts for the effects of bar yield strength, spacing, and confinement by ties or stirrups (ACI 25.4.3.1):

\[
\ell_{dh} = \left( \frac{f_y \psi \psi \psi \psi \psi}{55\sqrt{f'_c}} \right) d_b^{1.5}
\]

This equation is applicable to any \( f_y \) and the modification factors are given in revised ACI Table 25.4.3.2. As in previous editions of ACI 318, \( \ell_{dh} \) must be the greater of that calculated by the above equation, \( 8d_b \), and 6 in. (ACI 25.4.3.1).

**Development of Headed Deformed Bars in Tension**

Like hooked bars, the equation to determine the development length, \( \ell_{dt} \), for headed deformed bars conforming to ACI 25.4.4.1 in tension has been revised based on recent test results (ACI 25.4.4.2):

\[
\ell_{dt} = \left( \frac{f_y \psi \psi \psi \psi \psi}{75\sqrt{f'_c}} \right) d_b^{1.5}
\]
This equation is applicable to any $f_y$ (prior to ACI 318-19, there was an upper limit of 60,000 psi on $f_y$). The modification factors are given in revised ACI Table 25.4.4.3. Also, $d_b$ must be the greater of that calculated by the above equation, $8d_b$, and 6 in. (ACI 25.4.4.2).

Lap Splice Lengths

The new requirement in ACI 25.5.1.5 pertaining to confinement of lap splices is the same requirement in ACI 25.4.2.2 for confinement of deformed bars in tension:

For lap-spliced bars with $f_y \geq 80,000$ psi and a center-to-center spacing less than 6 in., transverse reinforcement must be provided along the entire lap splice length such that $K_{tr} \geq 0.5d_b$. A minimum amount of transverse reinforcement is required to confine Grade 80 and Grade 100 bars to prevent splitting failures due to relatively large axial forces in the bars.

Requirements for compression lap splice lengths have been modified to account for higher strength reinforcement. For Grade 80 reinforcement, the compression lap splice length, $l_{sc}$, is equal to the following (ACI 25.5.5.1):

$$l_{sc} = \text{longer of} \left\{ \begin{array}{l} (0.0009f_y - 24)d_b \\ 12 \text{ in.} \end{array} \right.$$  

Tests have shown that splice strengths in compression depend mostly on end bearing and do not increase proportionally in strength when the lap splice length is doubled.

Structural Members

Two-way Slabs Designed in Accordance with ACI Chapter 8

Minimum thicknesses of nonprestressed two-way slabs without interior beams have been added to ACI Table 8.3.1.1 for Grade 80 reinforcement (see Table 6). In Table 6, $l_n$ is the longest clear span in the floor system in inches. The minimum thicknesses for Grade 75 reinforcement that were given in this table in ACI 318-14 have been removed.

Beams Designed in Accordance with ACI Chapter 9

The equations in ACI 9.6.1.2 to determine minimum area of flexural reinforcement, $A_{s,min}$, in nonprestressed beams are the same as in previous editions of ACI 318, except an upper limit of 80,000 psi on $f_y$ is imposed in ACI 318-19.

The new confinement requirements in ACI 9.7.1.4 for development lengths and lap splice lengths of Grade 80 (and Grade 100) longitudinal bars in beams are basically the same as those in ACI 25.4.2.2 and ACI 25.5.1.5 discussed previously; the only difference is the center-to-center spacing limitation in those sections is not specified in ACI 9.7.1.4. Therefore, transverse reinforcement in beams must be provided such that $K_{tr} \geq 0.5d_b$ for Grade 80 (and Grade 100) longitudinal bars regardless of the bar spacing.

Columns Designed in Accordance with ACI Chapter 10

The new confinement requirements in ACI 10.7.1.3 for development lengths and lap splice lengths of Grade 80 (and Grade 100) longitudinal bars in columns designed in accordance with ACI Chapter 10 are the same as those for beams designed in accordance with ACI Chapter 9: Transverse reinforcement must be provided along development and lap splice lengths such that $K_{tr} \geq 0.5d_b$.

Intermediate Moment Frames

New hoop spacing requirements at the ends of columns that are part of intermediate moment frames in buildings assigned to SDC C are given in ACI 18.4.3.3. For columns with Grade 80 longitudinal bars, the maximum hoop spacing, $s_h$, over the length $l_n$ is equal to the smaller of $6d_b$ of the smallest longitudinal bar enclosed, 6 in., and one-half of the smallest cross-sectional dimension of the column (see Figure 3 and CRSI 2020).

The hoop spacing requirements in ACI 18.4.3.3 are also applicable to columns supporting reactions from discontinuous stiff members (ACI 18.4.3.6) and to spacing

| Table 6 Minimum Thickness of Nonprestressed Two-way Slabs Without Interior Beams for Grade 80 Reinforcement(1) |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | Without Drop Panels(2) |                 | Without Drop Panels(2) |                 |
|                | Exterior Panels         | Interior Panels | Exterior Panels         | Interior Panels |
| Without Edge Beams | $l_n / 27$          | $l_n / 30$      | Without Edge Beams | $l_n / 30$      |
| With Edge Beams   | $l_n / 30$          | $l_n / 30$      | With Edge Beams   | $l_n / 30$      |
| (2) Drop panels are defined in ACI 8.2.4. |
| (3) Exterior panels are considered to be without edge beams where $\alpha_f < 0.8$. The term $\alpha_f$ is the ratio of the flexural stiffness of a beam section to the flexural stiffness of a width of slab bounded laterally by centerlines of adjacent panels, if any, on each side the beam ($\alpha_f = E_0A_0 / E_sI_s$). |

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Special Moment Frames

Based on new test data, Grade 80 reinforcement is now permitted to resist flexure, axial forces, and shear in special moment frames, which are required in buildings assigned to SDC D, E, or F (ACI Table 20.2.2.4(a)).

Requirements for beams and columns with Grade 80 reinforcement in special moment frames are given in Table 7 and Table 8, respectively.

Joints of Special Moment Frames

Where Grade 80 longitudinal beam reinforcement in a special moment frame extends through a beam-column joint, the depth, $h$, of the joint parallel to the beam longitudinal reinforcement must be greater than or equal to the following (ACI 18.8.2.3; see Figure 4):

$$h \geq \text{greatest of}$$

- $26d_b$ of the largest Grade 80 longitudinal bar
- $h / 2$ of any beam framing into the joint generating joint shear in the direction of analysis

Joint transverse reinforcement must satisfy the requirements in ACI 18.8.3.

Normalweight concrete must be used in beam-column joints with Grade 80 longitudinal reinforcement in beams (ACI 18.8.2.3.1); test data are not available for joints with lightweight concrete and Grade 80 longitudinal reinforcement.

The tension development length requirements in ACI 18.8.5.2 for headed bars in joints of special moment frames, which are applicable to any $f_y'$, are not correct because the development lengths calculated in accordance with that section are
### Table 7 Requirements for Beams with Grade 80 Reinforcement in Special Moment Frames

<table>
<thead>
<tr>
<th>Requirement</th>
<th>ACI Section No.</th>
<th>Figure No.(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum longitudinal reinforcement ratio: $\rho = 0.02$</td>
<td>18.6.3.1</td>
<td>4</td>
</tr>
<tr>
<td>Spacing, $s$, of hoops within a length equal to at least $2h$ from each end of the beam or on both sides of a section where flexural yielding is likely to occur:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$s \leq \text{least of}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\frac{d}{4}$</td>
<td>18.6.4.4</td>
<td>5</td>
</tr>
<tr>
<td>6 in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$5d_b$ of the smallest primary flexural reinforcing bar(2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beams with factored axial force $P_x &gt; A_f f'_c / 10$:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hoops satisfying ACI 18.7.5.2 through 18.7.5.4 must be provided along lengths given in ACI 18.6.4.1.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spacing, $s$, of hoops within a length equal to at least $2h$ from each end of the beam or on both sides of a section where flexural yielding is likely to occur:</td>
<td>18.6.4.7</td>
<td>—</td>
</tr>
<tr>
<td>$s \leq \text{least of}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$6$ in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$5d_b$ of the smallest enclosed longitudinal beam bar</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) See CRSI 2020 for in-depth design and detailing requirements for beams in special moment frames.
(2) Excludes longitudinal skin reinforcement required by ACI 9.7.2.3.

### Table 8 Requirements for Columns with Grade 80 Reinforcement in Special Moment Frames

<table>
<thead>
<tr>
<th>Requirement</th>
<th>ACI Section No.</th>
<th>Figure No.(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing, $s$, of transverse reinforcement within a length equal to at least $\ell_g$ from each end of the column or on both sides of a section where flexural yielding is likely to occur:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$s \leq \text{least of}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One-fourth the minimum column dimension</td>
<td>18.75.3</td>
<td>6</td>
</tr>
<tr>
<td>$5d_b$ of the smallest longitudinal bar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$4$ in. $\leq s_o = 4 + \left[ \frac{14 - h_s}{3} \right] \leq 6$ in.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beyond the length $\ell_g$, spacing, $s$, of transverse reinforcement(2):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$s \leq \text{least of}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$6$ in.</td>
<td>18.75.5</td>
<td>6</td>
</tr>
<tr>
<td>$5d_b$ of the smallest longitudinal column bar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For columns supporting reactions from discontinued stiff members, transverse reinforcement in accordance with ACI 18.7.5.2 through 18.7.5.4 must be provided over the full height of the columns and must be developed into the discontinued member and into the supporting member.</td>
<td>18.75.6</td>
<td>7</td>
</tr>
</tbody>
</table>

(1) See CRSI 2020 for in-depth design and detailing requirements for columns in special moment frames.
(2) Unless a greater amount of transverse reinforcement is required by ACI 18.7.4.4 or 18.7.6.
greater than the development lengths for hooked bars calculated in accordance with ACI 18.8.5.1. At the time of publishing this Technical Note, ACI Committee 318 is working to correct this issue.

**Special Structural Walls**

New maximum vertical spacing limits of transverse reinforcement at the boundaries of special structural walls, which are required in building frame systems and dual systems in buildings assigned to SDC D, E, or F, are given in ACI 18.10.6.5 (ACI 18.10.6.1). These spacing limits are intended to prevent bar buckling at the ends of a wall. For a given longitudinal bar size, the maximum spacing of transverse reinforcement in a wall with Grade 80 longitudinal reinforcement is smaller than that in a wall with Grade 60 reinforcement; the purpose of the smaller spacing is to attain performance capability similar to that of walls with Grade 60 longitudinal reinforcement.

The following vertical spacing limits are given in ACI Table 18.10.6.5(b) for special structural walls with Grade 80 longitudinal reinforcement:

- Within the greater of \( \ell^w \) and \( M_u / 4V_u \) above and below critical sections\(^7\) maximum spacing is equal to the lesser of \( 5d_b \) and 6 in.
- At other locations, maximum spacing is equal to the lesser of \( 6d_b \) and 6 in.

The term \( \ell^w \) is the length of the wall, \( M_u \) and \( V_u \) are the factored bending moment and shear force, respectively, at the critical section, and \( d_b \) is the diameter of the smallest longitudinal bar in the wall.

Significant revisions other than the one noted above related to Grade 80 reinforcement were made to the design and detailing requirements for special structural walls in ACI 18.10 (see CRSI 2020).

**Diaphragms in Buildings Assigned to SDC D, E, or F**

A new requirement is given in ACI 18.12.7.4 pertaining to mechanical splices used to transfer forces between a diaphragm and the vertical elements of the seismic-force-resisting system (SFRRS): Grade 80 (and Grade 100) reinforcing bars are not permitted to be mechanically spliced for this application.

**Limits on Concrete Compressive Strength**

Limits on \( f'_c \) are given in revised ACI Table 19.2.1.1, which are applicable to both normalweight and lightweight concrete. For special moment frames and special structural walls with Grade 80 longitudinal reinforcement, minimum \( f'_c \) is equal to 3,000 psi (test data are not available for such members with Grade 80 reinforcement and concrete compressive strengths less than 3,000 psi).

**Strength Reduction Factors**

A new tension-controlled limit is defined in ACI 21.2.2, which accounts for high-strength reinforcement:

Reinforced concrete sections are defined as tension-controlled where the net tensile strain in the extreme layer of longitudinal tension reinforcement at nominal strength, \( \varepsilon_{ty} \), is greater than or equal to \( \varepsilon_{ty} + 0.003 \). The term \( \varepsilon_{ty} \) is the net tensile strain in the extreme layer of longitudinal tension reinforcement used to define a compression-controlled section and is equal

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\( ^7 \) Critical sections are defined as locations where yielding of longitudinal reinforcement is likely to occur as a result of lateral displacements.
to \( \varepsilon_f / E_s \) where \( E_s \) is the modulus of elasticity of the reinforcing steel, which is equal to 29,000,000 psi for all grades of reinforcement (ACI 20.2.2.2). The maximum strain at the extreme concrete compression fiber is taken as 0.003 (ACI 22.2.2.1).

For sections with Grade 80 reinforcement, the tension-controlled limit is equal to the following:

\[
\varepsilon_t = (80,000 / 29,000,000) + 0.003 = 0.0028 + 0.003 = 0.0058
\]

The variation of the strength reduction factor, \( \phi \), based on revised ACI Table 21.2.2, is given in Figure 8.

**Strut-and-Tie Method**

For members subjected to earthquake loads designed by the strut-and-tie method, the maximum spacing of transverse reinforcement for struts with Grade 80 reinforcement is equal to the lesser of 6 in. and \( 5d_b \) where \( d_b \) is the diameter of the smallest longitudinal bar in the strut [ACI Table 23.11.3.2(b)].

**Nonlinear Response History Analysis**

New Appendix A in ACI 318-19 contains requirements specific to nonlinear response history analysis and the design of earthquake-resistant concrete structures. Expected materials strengths that are to be used in the analysis are given in ACI Table A.9.1. For ASTM A706 Grade 80 reinforcement, the expected yield strength is to be taken as 85,000 psi and the expected tensile strength is to be taken as 112,000 psi.

**Benefits of Grade 80 Reinforcement**

Utilizing Grade 80 reinforcement in concrete members may result in the following:

- Less congestion, especially at joints, because smaller bar sizes and/or a fewer number of Grade 80 bars may be needed compared to members reinforced with Grade 60 bars
- Improved concrete placement and consolidation because of less congestion
- Lower placement costs because of the fewer number of bars to be placed in the field
- Smaller member sizes
- More usable space because of smaller member sizes

The information in Figure 9 gives some insight into how smaller member sizes can be obtained with Grade 80 reinforcement. The curves in this figure give required gross areas, \( A_{p'} \), for uniaxially loaded reinforced concrete columns based on concrete compressive strength, area of longitudinal reinforcement, \( A_{l} \), and grade of reinforcement. As expected, for a given percentage of longitudinal reinforcement \( (A_{l} / A_{p'}) \), the required \( A_{p'} \) for a column with Grade 80 longitudinal bars is less than the required \( A_{p'} \) for a column with Grade 60 longitudinal bars. Combining Grade 80 reinforcement and high-strength concrete has the greatest impact on decreasing the required column area, which, in turn, increases the area of usable space.

Considering the aforementioned benefits and other factors, it is expected that Grade 80 reinforcement will be utilized as follows in buildings:

- As longitudinal reinforcement in columns designed in accordance with ACI Chapter 10, especially in the lower stories of mid- and high-rise buildings in combination with high-strength concrete
- As longitudinal and transverse reinforcement in special moment frames in SDC D, E, and F
• As longitudinal and transverse reinforcement in special structural walls
• As flexural reinforcement in mat foundations supporting buildings assigned to SDC D, E, or F
• As diagonal, longitudinal, and transverse reinforcement in coupling beams that are part of special structural walls
• As longitudinal reinforcement in collector elements in buildings assigned to SDC D, E, or F

Figure 7 Transverse reinforcement requirements for columns supporting reactions from discontinued stiff members in special moment frames with Grade 80 reinforcement.

Figure 8 Variation of strength reduction factor, $\phi$, with net tensile strain, $\varepsilon_t$. 
Figure 9  Required column area, $A_y'$, for reinforced concrete columns with Grade 60 and Grade 80 longitudinal reinforcement as a function of concrete compressive strength, $f'_c$. 
References


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Historical: None. New Technical Note.

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