## 5000. Concrete Structures and Construction

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## 5300. Reinforcing Bars, Reinforcing Details & Tolerances

### Objective and Scope
- Provide introductory level review of Reinforcing Bars, Reinforcing Details & Tolerances
- Present and discuss
  - Reinforcing Bar Specifications
  - Mechanical Splices
  - Specifications for Tolerances
Fabrication of Reinforcing Bars
Automatic Bender

Reinforcing Steel Specifications

- Bar Specifications
  - A615 – Plain carbon steel
  - A706 – Low alloy steel
  - A1035 – Low carbon/chromium steel

- Coated & Corrosion Resistant Steel
  - A775 – Epoxy coated rebar
  - A767 – Galvanized rebar
  - A1055 – Galvanized & Epoxy coated
  - A955 – Stainless steel

Reinforcing Steel Specifications
Bar Sizes

- Inch-pound bar size designations represent 1/8 inch fractions

<table>
<thead>
<tr>
<th>Inch-Pound Units</th>
<th>SI Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar Designation</td>
<td>Nominal Diameter</td>
</tr>
<tr>
<td>#3</td>
<td>3/8”</td>
</tr>
<tr>
<td>#4</td>
<td>4/8”</td>
</tr>
<tr>
<td>#5</td>
<td>5/8”</td>
</tr>
<tr>
<td>#6</td>
<td>6/8”</td>
</tr>
<tr>
<td>#7</td>
<td>7/8”</td>
</tr>
<tr>
<td>#8</td>
<td>8/8”</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A706</td>
<td>Grade 60</td>
<td>Grade 80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Grade 420)</td>
<td>(Grade 555)</td>
<td></td>
</tr>
<tr>
<td>Minimum Yield Strength, psi (MPa)</td>
<td>60,000 (420)</td>
<td>80,000 (555)</td>
<td></td>
</tr>
<tr>
<td>Maximum Yield Strength, psi (MPa)</td>
<td>78,000 (540)</td>
<td>100,000 (690)</td>
<td></td>
</tr>
<tr>
<td>Minimum Tensile Strength, psi (MPa)</td>
<td>80,000* (550)</td>
<td>105,000* (725)</td>
<td></td>
</tr>
<tr>
<td>* Tensile strength shall not be less than 1.25 times the actual yield strength</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bar Designation Minimum Percent Elongation in 8”

- #3, #4, #5, #6: 14%
- #7, #8, #9, #10, #11: 12%
- #14, #18: 10%
Reinforcing Steel Specifications

- Tensile Requirements
- Bending Requirements
  - Withstand bending without cracking
- Permissible Variation in Weight
  - At least 94% of nominal weight
- Deformations
  - Orientation, size, spacing, height
- Marking
  - Mill, bar size, type, grade

Reinforcing Steel Surface Conditions

CRSI Manual of Standard Practice - Section 8.3

- At the time of placement, all reinforcing bars shall be free of mud, oil, or other deleterious materials
- Reinforcing bars with rust, mill scale, or a combination of both should be considered as satisfactory, provided that the minimum dimensions, weight, and height of deformations of a hand-wire-brushed specimen are not less than the applicable ASTM specification requirements

Field Bending of Reinforcing Steel

- To correct bars partially embedded in concrete due to incorrect fabrication, incorrect placement, accidental misalignment or design change
- In-situ bending is prohibited unless shown on drawings or specifically authorized by the engineer
- Limited to bar size #11 and smaller
Field Bending of Reinforcing Steel

- Bend diameters must conform to ACI 318
- Bar sizes #3 through #5 and if were previously unbent, can be bent cold
- Bar sizes #3 through #5 and if were previously bent, must be heated prior to straightening and re-bending
- Bar sizes #6 through #11 must be heated prior to straightening and/or bending

Field Bending of Reinforcing Steel

<table>
<thead>
<tr>
<th>Bending Condition</th>
<th>Bar Size</th>
<th>Reduction in Yield Strength</th>
<th>Reduction in Ultimate Tensile Strength</th>
<th>Reduction in Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>#3 &amp; #4</td>
<td>-</td>
<td>-</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>#5</td>
<td>5%</td>
<td>-</td>
<td>30%</td>
</tr>
<tr>
<td>Hot</td>
<td>All Sizes</td>
<td>10%</td>
<td>10%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Field Cutting of Reinforcing Steel

- Bolt cutters for bar sizes #10 to #16
- Abrasive saw on any bar size
- Cutting torch on any bar size
  - Tests indicate no more than 3/8” from end of bar is effected by heat
- Flame cutting of epoxy-coated bars will damage the coating, proper repair is necessary
Epoxy Coated Reinforcing Bars

- Nylon slings or other padded material to lift bars
- Lift and set bars into place
  - Bars are not to be dragged into place
- Minimize walking on bars
  - Set up a walkway
- Bars to be visually inspected for damage after placement

5300. Reinforcing Bars, Reinforcing Details & Tolerances

- 5310 - Reinforcing Bars
- 5320 - Mechanical Splices
- 5330 - Tolerances & Construction Details

5320 - Mechanical Splices
Splicing Reinforcing Steel
Reinforcing Steel Splicing Options

• Lap Splices

• Welded Splices

• Mechanical Splices
  – Compression only splices
  – Tension-compression splices
  – Tension compression lap splices

Type 1 and Type 2 mechanical splices

• Type 1 splices are used in elements where there is little concern for inelastic deformations and elevated tensile stresses from seismic events
• Type 2 splices have proven, through accepted industry testing, the ability to develop the specified tensile strength of the spliced bars for resistance to elevated tensile stresses
• In ACI 318, Chapter 21, Type 2 mechanical splices are required to develop the specified tensile strength of the bars being spliced

Reinforcing Steel Splicing Options

• Compression-only mechanical splices
  – Engineer should confirm that the splice will not be subjected to stress reversal
  – Temporary stress reversals might be brought about by a dynamic condition
  – When loading is less certain, tension-compression splices are recommended

Reinforcing Steel Splicing Options

• Compression-only mechanical splices (Cont’d)
  – Except for a steel-filled coupling sleeve, ACI 318 requires that the ends of the bars be sawcut, or cut by some other means, within 1-1/2 degrees of square to the bar longitudinal axis. ACI 318 also requires that an end-bearing splice device be capable of holding the bars in concentric bearing contact
**Reinforcing Steel Splicing Options**

**Strap-type Steel Coupling Sleeve**

- Compression-only mechanical splice

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**Steel-filled Coupling Sleeve**

- By means of an exothermic process, molten filler solidifies around the deformations on the bar and internal grooves of the sleeve, creating a mechanical interlock; good also in tension

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**Reinforcing Steel Splicing Options**

**Tension-compression Mechanical Splice**

- Cold-swaged steel coupler with taper-threaded ends

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**Reinforcing Steel Splicing Options**

**Tension-compression Mechanical Splice**

- Bolted
Reinforcing Steel Splicing Options
Tension-compression Mechanical Splice

- Bolt heads shear off when proper values are reached

- Shear screw and wedge coupling sleeve

- Coupler for thread-like deformed reinforcing bars

- Transition cold-swaged coupler with taper-threaded ends
Reinforcing Steel Splicing Options
Tension-compression Mechanical Splice

- Grout-filled coupling sleeve

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Reinforcing Steel Splicing Options
Mechanical Lap Splice

- Shear screw and double-wedge coupling sleeve

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Reinforcing Steel Splicing Options
Mechanical Lap Splice

- Steel coupling sleeve with wedge

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Mechanical Splices - Summary

- It may be necessary to determine whether particular mechanical splices are acceptable to local code or building officials. The mechanical splice manufacturer should normally be the principal party to obtain the necessary recognition or approval of the splicing products it manufactures.

- The engineer should approve all splices on the project that are appropriate for certain conditions of inelastic behavior or repeated reverse loading, which should be considered in seismic design.
Mechanical Splices – Summary (Cont’d)

• Where no special requirements or job conditions exist that either favor or preclude the use of a particular mechanical splice, as in certain Type 1 splice applications, project specifications should be left open.

• Installation instructions and performance data should be secured directly from the manufacturers of the mechanical splices. Manufacturer’s requirements should be referenced in design drawings and specifications to provide greater assurance that the devices will be installed properly.

• Inspection or quality assurance is needed to ensure satisfactory performance. Splice manufacturers can provide installation acceptance criteria for field inspection.

• Testing can be performed to verify that a particular splice type will meet specified performance requirements, particularly in critical locations where Type 2 splices are used.

5300. Reinforcing Bars, Reinforcing Details & Tolerances

- 5310 - Reinforcing Bars

- 5320 - Mechanical Splices

- 5330 - Tolerances & Construction Details

5330 - Tolerances & Construction Details
Specifications for Tolerances - Examples
ACI 117

• Placement of nonprestressed reinforcement, measured from form surface:
  - When member depth (or thickness) is 4 in. or less.................................±1/4 in.
  - When member depth (or thickness) is over 4 in. and not over 12 in.........................±3/8 in.
  - When member depth (or thickness) is over 12 in........................................±1/2 in.
Specifications for Tolerances - Examples
ACI 117 (Cont’d)

- Concrete cover measured perpendicular to concrete surface
  - When member depth (or thickness) is 12 in. or less......................-3/48 in.
  - When member depth (or thickness) is over 12 in.............................-1/2 in.
  - Reduction in cover shall not exceed 1/3 the specified concrete cover

Placement of prestressing reinforcement or prestressing ducts

- Horizontal deviation
  - Element depth (or thickness) 24 in. or less.................... ±1/2 in
  - Element depth (or thickness) over 24 in............................... ±1 in.

- Vertical deviation
  - Element depth (or thickness) 8 in. or less...................... ±1/4 in
  - Element depth (or thickness) > 8 in. but ≤24 in........... ±3/8 in
  - Element depth (or thickness) over 24 in......................... ±1/2 in
Specifications for Tolerances - Examples
ACI 117 (Cont’d)

• Bearing plate for prestressing tendons

\[ (L / 48) \geq 1/8 \text{ in. (3 mm)} \]

Plan View
Or
Elevation View

Specifications for Tolerances - Examples
ACI 117 (Cont’d)

• Deviation from location - Foundations

Economical Concrete Construction

• Formwork
• Concrete
• Reinforcement
**Economical Concrete Construction**

- Keep Formwork
  - Simple
  - Repetitious
  - Standard
    - Form sizes
    - Lumber dimensions

**Economical Concrete Construction**

- Minimizing material quantities can lead to “inefficient” designs

**Typical Conventionally Reinforced Cast-In-Place Concrete Frame Costs**

- Formwork: 50%
- Concrete: 30%
- Reinforcing: 20%

**Material Quantity**

- Forming Cost
  - Optimum Design
Beam - Column Intersections

Floor Framing Systems

- Size beams and joists the same depth

Floor Framing Systems

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